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NATIONAL STANDARD OF THE PEOPLE'S REPUBLIC OF CHINA

中华人民共和国国家标准

Code for Investigation of Geotechnical Engineering

岩土工程勘察规范

（2009 Edition）

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Introduction

This version is one of China's engineering construction standards in English series, which, in compliance with the relevant procedures and stipulations, has been organized to translate by China Association for Engineering Construction Standardization (CECS) authorized by Ministry of Housing and Urban-Rural Development (MOHURD) of the People's Republic of China, On December 4, 2008, MOHURD published it by means of Announcement of No. 177.

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Many thanks should go to the organizations like Beijing Urban Construction Exploration & Surveying Design Research Institute CO., LTD. who have offered strong support during the course of translation and revision of this version, and also to staff from the relevant standard development organizations and groups who have provided practical assistance through their hard work.

For the sake of improving its quality, any kind of constructive criticism, comments and suggestions in association with this vesion is welcom. It would be grealy appreciated if they could be fed back to CECS.

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翻译出版说明

本译本为中华人民共和国住房和城乡建设部委托中国工程建设标准化协会按照有关程序和规定，统一组织翻译的中国工程建设标准英文版系列译本之一。2008 年 12 月 4 日，住房和城乡建设部以第 177 号公告予以公布。

本译本是根据中国建筑工业出版社出版的《岩土工程勘察规范》GB 50021－2001（2009 年版）翻译的，著作权归中华人民共和国住房和城乡建设部所有。在使用过程中，如出现异议，以中文版为准。

本译本在翻译和审核过程中，得到了北京城建勘察设计研究院等单位的大力支持，本规范编制单位及编制组有关成员给予了积极协助。

为不断提高本译本的质量，欢迎使用者提出意见和建议，并反馈给中国工程建设标准化协会。

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Announcement of Publishing the Partial Revision of National Standard of "Code for Investigation of Geotechnical Engineering

No. 314

"Code for Investigation of Geotechnical Engineering" has been approved as a national standard with a serial number of GB 50021—2001 and will be implemented on July 1, 2009. Therein, Clauses 1.0.3, 4.1.18 (1, 2, 3, and 4), 4.1.20 (1, 2, and 3), 4.8.5,5.7.2, and 7.2.2 are compulsory provisions and must be enforced strictly. The former clauses shall be abolished simultaneously.

Partial revision clauses and specific content will be published on the recent publications "Engineering Construction Standardization".

Ministry of Housing and Urban-Rural Development of the People's Republic of China

May 19, 2009

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Notice on Publishing the National Standard of "Code for Investigation of Geotechnical Engineering"

Jian Biao [2002] No. 7

In accordance with the requirements of "Notice on Printing the Development and Revision Plan of National Engineering Construction Standards in 1998"(No. Jian Biao [1998] No. 244), the "Code for Investigation of Geotechnical Engineering", revised jointly by the Ministry of Construction of P. R. C and other related department, has been reviewed and approved jointly as a national standard with a reference code of GB 50021—2001, and will be put into effect from March 1, 2002. In this code, the Articles 1.0.3, 4.1.11, 4.1.17, 4.1.18, 4.1.20, 4.8.5, 4.9.1, 5.1.1, 5.2.1, 5.3.1, 5.4.1, 5.7.2, 5.7.8, 5.7.10, 7.2.2 and 14.3.3 are compulsory articles and must be carried out strictly, correspondingly, the former "Code for Investigation of Geotechnical Engineering" GB 50021—94 will be abolished on December 31, 2002.

The Ministry of Construction, P. R. C shall be responsible for the interpretation of the compulsory articles in the code; Comprehensive Institute of Geotechnical Investigation & Surveying is in charge of the interpretation of the detailed technical content. Research Institute for Standards and Norms of the Ministry of Construction shall organize its publication by China Architecture & Building Press.

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Ministry of Construction of the People's Republic of China

January 10, 2002

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Foreword

This code is the revision of "Code for Investigation of Geotechnical Engineering" issued in 1994 according to the requirement of Jian Biao [1998] No. 224. In the course of revision, the chief editorial company, Comprehensive Institute of Geotechnical Investigation & Surveying, together with other investigation, design, scientific research and teaching units, formed adevelopment group, to inquire widely for comments in the whole nation. The group worked out some special reports on the key modification parts, by coordinating the code with the current national standards and those being amended. After lots of discussion and iterative revision, "Preliminary draft", "Inquired Comments draft" and "Final draft" were worked out successively and examined, the final version has been approved and developed finally.

This code maintains the scope of application, general frame and main content of "Code for Investigation of Geotechnical Engineering" issued in 1994 and adjusts partially. It includes 14 chapters: Chapter 1 General Provisions; Chapter 2 Terminology and symbols; Chapter 3 Grading of investigation and classification of rock & soil; Chapter 4 Basic requirements of the investigation for various engineering; Chapter 5 Adverse geological actions and geological disasters; Chapter 6 Special rock & soil; Chapter 7 Underground water, Chapter 8 Geological engineering mapping and survey; Chapter 9 Exploration and sampling; Chapter 10 In-situ tests; Chapter 11 Laboratory tests, Chapter 12 Appraisal of water and soil corrosivity; Chapter 13 In-situ inspection and monitoring; Chapter 14 Geotechnical Engineering Analysis and Assessment and Invesitigation Report.

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The main emendatory contents are as follows: 1. In the scope of application, the investigation of nuclear power plant is added; 2. The chapter "terminology and symbols" is added; 3. Classification of rock hardness and integrity and basic rock quality designation are added; 4. The investigation requirement of "buildings and structures" and "pile foundation" are modified; 5. The investigation specification of "underground cavity", "retaining and protecting for foundation excavation engineering", "foundation pit engineering", and "subsoil treatment" are modified; 6. The section "tailings dam and ash yard dam" is altered as the investigation for "waste disposal engineering"; 7. The chapter "stability of the site" is modified into "adverse geological actions and geological disasters"; 8. "Site and foundation of macro-seismic area" and "earthquake liquefaction" is combined into "earthquake effect of site and foundation"; 9. "Collapsible soil" and "red clay" in special soil is modified; 10. The investigation requirement of "underground wa-

ter" is strengthened; 11. "Deep static loading test" and "dilatometer test" are added. Meanwhile, In order to provide the executing criterion for the examination of engineering quality, the extent of the code is compressed and the compulsory technical criterions for investigation are emphasized.

The code may be modified partially in the future and the modification notice and the revised clauses will be published on the journal "Engineering Construction Standardization". The clauses in bold typeface are compulsory and must be implemented strictly.

In order to improve the quality of the code, all practitioners please pay more attention to generalizing your experience and accumulating data during the course of implementation of the code. Any comments can be fed back at any time to Comprehensive Institute of Geotechnical Investigation & Surveying (No. 177 Dongzhimennei Ave. Beijing, Post code: 100007).

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Comprehensive Institute of Geotechnical Investigation & Surveying

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Shanghai Geotechnical Engineering Investigation & Design Institute

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1 General Provisions

1.0.1 This code is formulated with a view to implement the technical and economic policy and in the geotechnical engineering investigation, to ensure use cost-effectiveness and investment efficienly, and engineering quality.

1.0.2 This code can be applied to the geotechnical engineering investigation for various engineering construction other than water conservancy, railway, road, bridge and tunnel.

1.0.3 Prior to the design and construction of the projects, the geotechnical investigation must be carried out according to the basic construction procedure.

1.0.3A The geotechnical investigation shall, according to the requirements of each investigation stages of the engineering construction, correctly reflect the engineering geological conditions, and ascertain the adverse geological actions and geological disaster. Through elaborate investigation and careful analysis, an investigation report presenting completed information and correct assessment shall be provided.

1.0.4 Geotechnical engineering investigation should be performed in accordance with not only the criteria of the code, but also that of other current related national standards and codes.

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2 Terms and symbols

2.1 Terms

2.1.1 Geotechnical investigation

The activity of ascertaining, analyzing and assessing the geological and environmental features, and geotechnical properties of the construction site according to the construction demand, and compiling investigation documents.

2.1.2 Engineering geological mapping

The activity of ascertaining the engineering geological feature and making corresponding engineering geological drawings by means of collecting data, reconnaissance, geological survey and remote sensing interpretation etc..

2.1.3 Geotechnical engineering exploration

The means of geotechnical engineering investigation, including drilling, welling, trenching, pitting, cave exploring, geophysical prospecting and penetration testing etc..

2.1.4 In-situ tests

The tests on rock & soil mass at its original location that could maintain its original structure, humidity and stress conditions largely.

2.1.5 Geotechnical engineering investigation report

A technical document, formed systematically to give construction proposals based on the raw data through collecting, statistics, generalization, analyzing and assessing.

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2.1.6 In-situ inspection

A checking activity in site, conducted by certain means to examine the investigation results or the effect of design and construction measures.

2.1.7 In-situ monitoring

The systematical monitoring and observation in site of the character of rock & soil mass, the change of underground water, the stress and displacement of rock & soil mass and structures.

2.1.8 Rock quality designation (RQD)

The percentage ratio of the total length of core greater than 10cm verse the total length of a turn. The rock core should be drilled with the diamond bit which diameter is 75mm and with double core barrel continuously.

2.1.9 Quality classification of soil samples

The classification of soil sample set out according to the degree of disturbance in

terms of quality.

2.1.10 Adverse geological actions

The geological actions may be harmful to the works, which is caused by internal or external forces of the ground.

2.1.11 Geological disasters

The incident caused by the adverse geological actions endangers the safety of lives, properties, engineering and environment.

2.1.12 Ground subsidence, land subsidence

The massive regional ground subsidence is generally the subsequence of the ground-water depression funnel as a result of over-pumping of the underground water. It also may be caused by the massive underground goaf and the self-weight collapse settlement of loess.

2.1.13 Standard value of a geotechnical parameter

The basic representative value of geotechnical parameter, which is generally 0.05 quantile of probability distribution.

2.2 Symbols

2.2.1 The physical properties and grain composition of rock & soil

e——Porosity ratio;

I_L——Liquidity index;

I_P——Plasticity index;

n——Porosity;

S_r——Saturation;

w——Water content, water content ratio;

w_L——Liquid limit;

w_P——Plastic limit;

W_u——Organic content;

γ——Gravity density (gd);

ρ——Mass density;

ρ_d——Dry density.

2.2.2 The deformation parameters of rock & soil

a——Coefficient of compressibility, compressibility coefficient;

C_c——Compression index;

C_e——Recompression index;

C_s——Rebound index;

C_h——Coefficient of horizontal consolidation;

C_v——Coefficient of vertical consolidation;

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E_0——Modulus of deformation, deformation modulus;

E_D——Modulus of side dilatancy;

E_m——Lateral pressure modulus;

E_s——Compression modulus;

G——Shear modulus;

p_c——Preconsolidation pressure.

2.2.3 The strength parameters of rock & soil

c——Cohesion;

p_0——Linear limit pressure in loading test, or initial pressure in pressuremeter test;

p_f——Critical plastic pressure in pressuremeter test;

p_L——Ultimate pressure in pressuremeter test;

p_u——Ultimate pressure in loading test;

q_u——Unconfined compression strength;

τ——Shear strength;

φ——Angle of internal friction.

2.2.4 Indices of penetration and standard penetration test

R_f——Ratio of skin friction to cone resistance of cone static penetration test;

f_s——Skin friction of cone static penetration test;

N——Blow number of standard penetration test;

N_{10}——Blow number of light dynamic penetration test;

$N_{63.5}$——Blow number of heavy dynamic penetration test;

N_{120}——Blow number of super heavy dynamic penetration test;

p_s——Specific penetration resistance of cone static penetration test;

q_c——Cone resistance of cone static penetration test.

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2.2.5 The hydrogeological parameters

B——Leakage factor;

k——Permeability coefficient, coefficient of permeability;

Q——Flow, yield;

R——Radius of influence;

S——Coefficient of storage, storage coefficient;

T——Coefficient of transmissibility, transmissibility coefficient;

u——Pore water pressure.

2.2.6 Others

F_s——Safety factor of side slope;

I_D——Soil dilatancy index;

K_D——Horizontal stress index of dilatometer test;

p_e——Expansive force;

U_D——Pore pressure index of dilatometer test;

ΔF_s——Additional collapsed settlement;

s——Settlement of foundation, settlement of the loading test;

S_t——Sensitivity;

α_w——Water content ratio of red clay;

v_p——Velocity of compressive wave, compressive wave velocity;

v_s——Velocity of shear wave, shear wave velocity;

δ——Coefficient of variation, variation coefficient;

Δ_S——Total collapsed settlement;

μ——Poisson ratio;

σ——Standard deviation.

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3 Grading of Investigation and Classification of Rock & Soil

3.1 Grading of Geotechnical Engineering Investigation

3.1.1 According to the scale and the feature of engineering, engineering destruction degree or the consequence of failure to normal use caused by the geotechnical engineering problem, the engineering can be divided into three grades in importance:

1 Grade Ⅰ: The key engineering, and the consequence of destruction or failure to normal use is very serious.

2 Grade Ⅱ: The common engineering, and the consequence of destruction or failure to normal use is serious.

3 Grade Ⅲ: The sub-ordinate engineering, and the consequence of destruction or failure to normal is not serious.

3.1.2 According to the complexity, the site can be divided into three grades:

1 It is designated as Grade Ⅰ site if its complexity accords with any of the following items (complex site):

1) The area is very dangerous in respect of anti-seismic of buildings;

2) The adverse geological action develops strongly;

3) The geologic environment has been destroyed or may be destroyed seriously;

4) The landform and the geomorphy is complex;

5) There is multi-layer underground water (groundwater or underground water) and karst fissure water which will affect the engineering, or the site where hydro-geological condition is complex and shall be studied specially.

2 It is designated as Grade Ⅱ site if its complexity accords with any of the following items (medium (moderately) complex site):

1) The site is adverse in respect of anti-seismic of buildings;

2) The adverse geological action develops moderately;

3) The geological environment has been destroyed or may be destroyed moderately;

4) The landform and the geomorphy is complex relatively;

5) There is no basement below the underground water level.

3 It is designated as Grade Ⅲ site if its complexity accords with any of the following items (simple site):

1) The seismic fortification intensity is less than grade 6 or the site is advantageous in respect of anti-seismic of buildings;

2) The adverse geological action does not develop;

3) The geological environment has not been destroyed yet;

4) The landform and geomorphy is simple;

5) There is no underground water affecting the engineering.

Note: 1 The engineering can be graded by identifying its conformance in the sequence of Grade Ⅰ, Ⅱ, Ⅲ, and the first conformed grade is preferred. For Article 3.1.3, the foundation grade can also be graded in this way.

2 The classification of advantageous section, disadvantageous section and dangerous section in terms of building seismic factor should accord with the current standard "Code for Anti-seismic Design of Buildings" GB 50011.

3.1.3 According to the complexity, the foundation can be divided into three grades:

1 It is designated as Grade Ⅰ foundation if its complexity accord with anyone of the following items (complex foundation):

1) Where there are many kinds of rock & soil, greatly inhomogeneous, the properties of rock & soil varies greatly and needs to be specially treated;

2) Where there are special rock & soil such as serious collapsible soil, expansive soil, salinized soil, and contaminated soil and others in complex condition that needs to be specially treated.

2 It is designated as Grade Ⅱ foundation if the complexity accords with any of the following items (medium or moderately complex foundation):

1) Where there are various rocks & soils, inhomogeneous, the properties of rock & soil varies moderately;

2) Where there are special rock & soil other than those in the above article 1.

3 It is designated as Grade Ⅲ foundation if the complexity accords with any of the following items (simple foundation):

1) Where there is few kinds of rocks & soils, homogeneous, the properties of the rock & soil does not vary seriously;

2) There is no special rock & soil.

3.1.4 According to the engineering importance, the complexity of the site and foundation, the grade of geotechnical engineering investigation can be divided as followings.

Grade A: At least one is in Grade I among grade of the engineering importance, grade of the site complexity and that of foundation.

Grade B: The grade of geotechnical engineering investigation is neither Grade A nor Grade C.

Grade C: The importance of engineering, the complexity of site and foundation are all in Grade Ⅲ.

Note: The grade of geotechnical engineering investigation may be designated as Grade B when Grade Ⅰ engineering in importance built on the rocky soil but both the grades of the complexity of site and foundation of Grade Ⅲ.

3.2 Classification and Identification of Rock

3.2.1 In the course of geotechnical engineering investigation, the geological name and

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the weathering degree of rock should be identified and the hardness, the degree of integrity and the rock quality designation shall be determined.

3.2.2 The hardness, the degree of integrity and the rock quality designation can be classified according to the criteria specified in the Table 3.2.2-1～Table 3.2.2-3.

Table 3.2.2-1 Classification of the Rock Hardness

Hardness	Hard rock	Secondly hard rock	Secondly soft rock	Soft rock	Extremely soft rock
Saturated uniaxial compressive strength (MPa)	$f_r>60$	$60\geqslant f_r>30$	$30\geqslant f_r>15$	$15\geqslant f_r>5$	$f_r\leqslant 5$

Note: 1 The saturated uniaxial compressive strength can be converted with the strength gotten from point loading test when it is not available. The conversion method should refer to the current national standard, "Standard for Engineering Rock Mass Grading" GB 50218.

2 Classification of hardness of rock can be neglected if the degree of integrity is extremely frangible.

Table 3.2.2-2 Classification of the Rock Integrity Degree

Degree of integrity	Integral	Secondly integral	Secondly frangible	Frangible	Extremely frangible
Integrity index	>0.75	0.75～0.55	0.55～0.35	0.35～0.15	<0.15

Note: Integrity index is the square of the ratio of the compressive wave velocity of rock verse that of rock mass. We should select the representative rock and rock mass when we measure the wave velocity.

Table 3.2.2-3 Classification of the Rock Quality Designation

Degree of / Integrity	Hardness	Integral	Secondly integral	Secondly frangible	Frangible
Hard rock	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ
Secondly hard rock	Ⅱ	Ⅲ	Ⅳ	Ⅳ	Ⅴ
Secondly soft rock	Ⅲ	Ⅳ	Ⅳ	Ⅴ	Ⅴ
Soft rock	Ⅳ	Ⅳ	Ⅴ	Ⅴ	Ⅴ
Extremely soft rock	Ⅴ	Ⅴ	Ⅴ	Ⅴ	Ⅴ

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3.2.3 If there is short of test data, we can make the classification of rock hardness and rock integrity degree according to Table A.0.1 and Table A.0.2 in Appendix A of this code. The degree of weathering can be classified according to Table A.0.3 in Appendix A.

3.2.4 The rock with the softening coefficient of less than 0.75 is designated softened rock; the rock with special component, special structure or special character should be defined as special rock, such as soluble rock, expansive rock, disintegrable rock, salinization rock and so on.

3.2.5 The description of rock includes geological age, geological name, degree of weathering, color, main minerals contained, structure, configuration and rock quality designation (RQD). The description of sedimentary rock should include grain size, shape, cement component and degree of cementation of the sediment. The description of magmatic rock and metamorphic rock should include the size of crystal and the degree of crystallinity.

According to the rock quality designation (RQD), the rock can be classified as excellent (RQD>90), better (RQD=75～90), bad (RQD=50～75), worse (RQD=25～50) and extremely worse (RQD<25).

3.2.6 The description of the rock mass should include structural plane, structural body, depth of stratum and structure type and accord with the followings:

1 The description of structural plane includes type, character, attitude, combinatorial pattern, development degree, ductility status, closure degree, roughness, filling status, character of filler and water containing etc..

2 The description of structural body includes type, shape, size and force-bearing condition in the surrounding rock etc.. The thickness of rock stratum should be classified according to Table 3.2.6.

Table 3.2.6 Classification of Thickness of Rock Stratum

Classification on thickness of rock stratum	Thickness of single stratum (m)	Classification of thickness of rock stratum	Thickness of single stratum (m)
Huge thick layer	$h>1.0$	Moderately thick layer	$0.5\geqslant h>0.1$
Thick layer	$1.0\geqslant h>0.5$	Thin layer	$h\leqslant 0.1$

3.2.7 For the underground cavity and side slope engineering, we should also ascertain the structure type of rock mass. The structure type of rock mass should be classified according to Table A.0.4 in Appendix A in this code.

3.2.8 For Grade Ⅳ and Grade Ⅴ rock mass, the rock quality designation should be classified according to not only the Articles 3.2.5～3.2.7 but also the following criteria:

1 For the soft rock and extremely soft rock, whether it has special properties of softenale, expansibility and salinizibility should be paid attention to.

2 For the extremely frangible rock mass, the cause of frangibility should be illustrated, eg: fault and fully weathered etc..

3 Whether there is further weathered possibility after the excavation.

3.3 Classification and Identification of Soil

3.3.1 The soil deposited in or before Epipleistocene Epoch should be viewed as aged sedimentary soil. The soil deposited in Holocene Epoch of Quaternary period should be viewed as newly sedimentary soil. According to the geologic origin, the soil can be classified into residual soil, slope deposit, diluvial deposit, silted deposit, glacial deposit and aeolian soil. Soil should be classificated according to Table A.0.5 in Appendix A.

3.3.2 If the mass of grain greater than 2mm is more than half of the total mass, the soil should be defined as gravelly soil and be further classified according to Table 3.3.2.

3.3.3 If the mass of grain greater than 2mm is less than half of the total mass or that

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greater than 0.075mm is more than half of the total mass, the soil should be defined as sandy soil and be further classified according to Table 3.3.3.

Table 3.3.2 Classification of Gravelly Soil

Name	Particle shape	Grain composition
Boulder	Dominatingly in rounded and sub-rounded	The mass of grain greater than 200mm accounts for more than half of the total mass
Chunk	Dominatingly in angular	
Pebble	Dominatingly in rounded and sub-rounded	The mass of grain greater than 20mm accounts for more than half of the total mass
Crushed stone	Dominatingly in angular	
Gravel	Dominatingly in rounded and sub-rounded	The mass of grain greater than 2mm accounts for more than half of the total mass
Angular gravel	Dominatingly in angular	

Note: Soil name should be defined from the big grain composition to the small one successively.

Table 3.3.3 Classification of Sandy Soil

Name	Grain composition
Gravely sand	The mass of grain larger than 2mm accounts for 25%～50% of the total mass
Coarse sand	The mass of grain larger than 0.5mm is more than 50% of the total mass
Medium sand	The mass of grain larger than 0.25mm is more than 50% of the total mass
Fine sand	The mass of grain greater than 0.075mm is more than 85% of the total mass
Silty sand	The mass of grain larger than 0.075mm is more than 50% of the total mass

Note: We should name the soil in the sequence from big to small of grain size.

3.3.4 The soil with mass of grain greater than 0.075mm less than 50% of the total mass and the plastic index not more than 10, should be nominated as silty soil.

3.3.5 The soil with the plastic index more than 10 should be nominated as cohesive soil.

The cohesive soil should be classified into silty clay and clay according to the plastic index; that with the plastic index more than 10 and not more than 17 should be nominated as silty clay, and that with the plastic index more than 17 should be nominated as clay.

Note: The above plastic index should be calculated according to the liquid limit measured with the 76g cone instrument submerging 10mm into the soil.

3.3.6 Nomination of soil not only depends on the grain grade and the plastic index, but also synthetical nomination should conform to the following criteria:

1 For the soil having special origin and age, we should take them into account when nominate it.

2 For the special soil, we should take the grain grade and the plastic index into account when nominate it.

3 For the compound soil, we should give it nomination with its main component.

4 For the rhythmic deposition in the same layer, if the ratio of the thickness of thick layer verse thin layer is more than 1/3, the soil should defined as "interbedding"; If the ratio of that is 1/10～1/3, it should be defined as "interlayer"; If the ratio is less

than 1/10 and appears frequently, it should be defined as "thin bed".

5 If the thickness of layer is more than 0.5mm, it should be delaminate separately.

3.3.7 Based on site description, soil identification shall be combined with laboratory description for samples and the result of laboratory test. Soil description should accord with following specifications:

1 For coarse-grained soil, grain size distribution, particle shape, grain grading, mother rock composition, degree of weathering, fillings character, filling degree and compactness should be described;

2 For sandy soil, color, mineral composition, grain grading , particle shape, clay content, moistness and compactness should be described;

3 For silty soil, color, contains moistness, compactness, dilatancy, glossy , dry strength, and toughness and so on should be described;

4 For cohesive soil, color, plasticity, contains, stratum structure and so on should be described;

5 Besides contents specified for above mentioned soil type shall be described ,for special Soil, its special component and special properties shall be described; for instance, the odor for muddy soil shall be described, and for filling soil, its component , accumulation age, compactness and uniformity shall be described;

6 For soils, featured in alternation of layers, interlayer, and thin layer, thickness of layer stratification characteristics shall be described;

7 When necessary, the soil glossy, dilatancy, dry strength and toughness may be described by the visual inspection, while the silty soil and cohesive soil is distingui-shed according to Table 3.3.7.

Table 3.3.7 Silty Soil and Cohesive Soil With Visual Inspection

Distinguish items	Dilatancy	Glossy	Dry strength	Toughness
Silty soil	Rapid and moderate	Without glossy	Low	Low
Cohesive soil	Without	With glossy and with little glossy	High and moderate	High and moderate

3.3.8 The degree of compaction of gravelly soil should be classified based on blows of heavy dynamic penetration test as per specifications in Table 3.3.8-1 or Table 3.3.8-2. The value of $N_{63.5}$ and N_{120} should be modified according to Appendix B. The qualitative description should be implemented according to Table A.0.6 in Appendix A.

Table 3.3.8-1 Classification of Degree of Compaction for Gravelly Soil in Terms of $N_{63.5}$

Blows of heavy dynamic penetration test $N_{63.5}$	Degree of compaction	Blows of heavy dynamic penetration test $N_{63.5}$	Degree of compaction
$N_{63.5} \leqslant 5$	Loose	$10 < N_{63.5} \leqslant 20$	Moderately dense
$5 < N_{63.5} \leqslant 10$	Slightly thick	$N_{63.5} > 20$	Dense

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Note: The above table is applicable to the gravelly soil with average grain size of not greater than 50mm and the maximum grain size of less than 100mm. For the gravelly soil aggregate with average grain size of more than 50mm and the maximum grain size of more than 100mm, identification should be based on super-heavy dynamic penetration test or field observation.

Table 3.3.8-2 Classification of Degree of Compaction of Gravelly Soil in Terms of N_{120}

Blows of super-heavy dynamic penetration test N_{120}	Degree of compaction	Blows of super-heavy dynamic penetration test N_{120}	Degree of compaction
$N_{120} \leqslant 3$	Loose	$11 < N_{120} \leqslant 14$	Dense
$3 < N_{120} \leqslant 6$	Slightly dense	$N_{120} > 14$	Very dense
$6 < N_{120} \leqslant 11$	Moderately dense		

3.3.9 The degree of compaction of sandy soil should be classified into dense, moderately dense, slightly dense and loose according to blows of standard penetration test N, meanwhile, which should conform to the criteria in Table 3.3.9. If the degree of compaction of sandy soil is classified based on cone resistance of static penetration test, local experience should be referred.

Table 3.3.9 Classification of the Degree of Compaction of Sandy Soil

Blows of standard penetration test N	Degree of compaction	Blows of standard penetration test N	Degree of compaction
$N \leqslant 10$	Loose	$15 < N \leqslant 30$	Moderately dense
$10 < N \leqslant 15$	Slightly dense	$N > 30$	Slightly dense

3.3.10 The degree of compaction of silty soil can be classified into dense, moderately dense, slightly dense according to the porosity ratio e. Its humidity should be classified into moisture, wet and very wet according to the water content w (%). Classification of the degree of compaction and the humidity should conform to the criteria in Table 3.3.10-1 and Table 3.3.10-2 also.

Table 3.3.10-1 Classification for the Moistness of Silty Soil

Porosity ratio e	Degree of compaction
$e < 0.75$	Dense
$0.75 \leqslant e \leqslant 0.90$	Moderately Dense
$e > 0.9$	Slightly Dense

Note: The density of silty soil may be classified according to in-situ tests or other measures if experience is available.

Table 3.3.10-2 Classification for the Moistness of Silty Soil

Water content w	Humidity
$w < 20$	Moisture
$20 \leqslant w \leqslant 30$	Wet
$w > 30$	Very wet

3.3.11 The plasticity of cohesive soil should be classified into hard, non-plasticity, low plasticity, medium plasticity and high plasticity according to the liquidity index I_L and should accords with the criteria in Table 3.3.11.

Table 3. 3. 11 Classification for the Moistness of Silty Soil

Liquidity index I_L	State	Liquidity index I_L	State
$I_L \leqslant 0$	Hard	$0.75 < I_L \leqslant 1$	Medium plasticity
$0 < I_L \leqslant 0.25$	Non-plasticity	$I_L > 1$	High plasticity
$0.25 < I_L \leqslant 0.75$	Low plastic		

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4 Basic Requirements for Investigation of Various Engineering

4.1 Building and Structure

4.1.1 The geotechnical engineering investigation for building and structure (hereinafter called building) shall be implemented on the basis of collecting the overlying load of the building, functional character, structural style, foundation type, embedment depth and deformation limit etc.. The main work content shall be in accordance with the followings requirements:

1 Ascertains the stability of the site and foundation, stratum structure, engineering feature of bearing layer and underlying layer, the stress history, condition of underground water and adverse geological actions etc..

2 Provide the geotechnical parameters meeting the demand of design and construction, determine the bearing capacity of foundation and forecast the deformation behavior character of foundation.

3 Put forward the recommendations about the design and the construction of the foundation, foundation pit bracing, engineering dewatering and soil treatment.

4 Put forward the recommendations about the prevention and processing scheme of the adverse geological actions acting on the existing buildings.

5 For the site which seismic fortification intensity is not less than grade 6, the seismic effect of site and foundation shall be assessed.

4.1.2 The geotechnical engineering investigation for buildings shall be implemented in several stages and the feasibility study investigation shall meet the demand of site selection. The preliminary investigation shall meet the demand of preliminary design, and the detailed investigation shall meet the demand of construction drawing design. For the engineering with complex site condition and need to be treated specially, the investigation during construction should be carried out. For the engineering with small area and without special demand, the investigation stages can be combined. If the overall layout of construction has been worked out and geotechnical data of the site or in the vicinity of the site is available, we should implement the detailed investigation directly according to the practical condition.

4.1.3 The stability and suitability of the site shall be assessed during the feasibility study investigation which shall be in accordance with the follow requirements:

1 To collect the data about regional geology, landform and geomorphy, earthquake, mine, local engineering geology, engineering geological conditions, geotechnical

engineering and construction experience etc. ;

2 On the basis of collecting and analyzing the existing data, to ascertain the site such as stratum, configuration, lithology, adverse geological actions and underground water etc. ;

3 If the engineering geological condition is very complex and the existing data cannot meet the demand, engineering geological mapping and necessary exploration work shall be carried out;

4 If there are two or more sites to be selected, analyzing and comparison shall be mode.

4.1.4 During the preliminary exploration, the stability of the site shall be assessed and the main work as follows shall be carried out:

1 To collect the data including relevant documents of the engineering, information about engineering geological and geotechnical engineering, and topographic map covering the site;

2 To ascertain preliminarily the geological configuration, stratum structure, geotechnical engineering properties and condition of occurrence of underground water;

3 To find out the origin, distribution, scale and development trend about the adverse geological actions; and to assess the stability of the site;

4 For the site which seismic fortification intensity is no less than Grade 6, the seismic effect of site and foundation shall be assessed;

5 If the site is located in a seasonal frozen region, the standard frozen depth shall be surveyed;

6 To preliminarily ascertain the corrosivity of water and the soil to building material;

7 For the preliminary investigation for tall buildings, the subsoil and foundation type, the scheme about foundation pit excavation and bracing, and dewatering shall be analyzed and assessed preliminarily.

4.1.5 The preliminary investigation shall be in accordance with the following requirements:

1 The exploratory line shall be perpendicular to the geomorphic unit, geological structure and stratiphic boundary;

2 Each geomorphic unit shall be laid out exploratory point. The exploratory points shall be allocated at the intersection of geomorphic unit and the section which stratum changes greatly;

3 The exploratory point may be laid out in grid at the even area;

4 For rocky subgrade, the exploratory line and exploratory points, and the depth of exploratory boreholes shall be designed according to the local standards and experi-

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ence on the basis of the geologic structure, the feature of rock mass and weathering condition etc.. For soil subgrade, those shall be designed in accordance with criteria of items from 4.1.6 to 4.1.10 in this section.

4.1.6 The interval of exploratory line and exploratory points in the preliminary investigation may be determined according to those specified in Table 4.1.6. For the local anomaly area, the exploratory line and exploratory points shall be densified.

Table 4.1.6 Spacing of Exploratory Lines and Exploratory Points in Preliminary Investigation (m)

Complexity of foundation	Interval of Exploration lines	Interval of Exploration points
Grade Ⅰ (complex)	50～100	30～50
Grade Ⅱ (moderately complex)	75～150	40～100
Grade Ⅲ (simple)	150～300	75～200

Note:1 The intervals are not applicable to geophysical exploration.

2 The control exploratory points should account for 1/5～1/3 of the total points and each geomorphic unit should have control exploration point.

4.1.7 The depth of exploratory borehole in preliminary investigation may be determined according to those set out in Table 4.1.7.

Table 4.1.7 Depth of Exploratory Boreholes in Preliminary Investigation (m)

Importance of engineering	General exploratory hole	Control exploratory hole
Grade Ⅰ (important engineering)	≥15	≥30
Grade Ⅱ (common engineering)	10～15	15～30
Grade Ⅲ (subordinate engineering)	6～10	10～20

Note:1 The exploratory hole includes drilling hole, exploratory well and in-situ test hole.

2 Drilling hole for spectacular purpose is excluded.

4.1.8 The depth of exploratory hole shall be adjusted properly if any conditions below is met:

1 If there is a great difference between the top elevation of exploratory hole and the ground surface elevation to be leveled, the depth of exploratory hole shall be adjusted according to the difference;

2 If there is a bedrock within the designed depth, the controlling exploratory hole shall enter the proper depth into bedrock and the other holes may be terminated when bedrock is met;

3 If there is a very thick and distributed uniformly hard subsoil (such as gravelly soil, dense sand and aged deposited soil), the controlling exploratory hole shall enter the proper depth of bedrock and the depth of general exploratory hole may be decreased appropriately;

4 If there is a soft soil within the predicted depth, the depth of exploratory hole shall be increased appropriately and parts of the controlling exploratory holes shall penetrate the soft soil or reach the predicted controlling depth;

5 For the heavy industry building, the depth of exploratory hole shall be increased appropriately according to the construction structure and the load conditions.

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4.1.9 The soil sampling and the in-situ testing shall be in accordance with the following requirements:

1 The exploratory points for soil sampling and in-situ testing shall be distributed according to the character of geomorphic unit, stratum structure and engineering properties. The number of that may be 1/4～1/2 of the total;

2 The number of soil sampling and the vertical interval of in-situ testing shall be determined according to the character of stratum and the degree of soil uniformity. Soil sampling or in-situ testing shall be performed in each layer and the number should not be less than 6.

4.1.10 The following hydrogeology work shall be carried out in preliminary exploration:

1 To find out the condition embedded of aquifer, style of underground water, recharging and drainage condition and the underground water table of each aquifer, investigate the fluctuation of underground water and set up the long-term observation borehole if necessary to monitor the variation of it;

2 If the hydrograph of underground water should be mapped out, to measure the groundwater level according to the condition of occurrence of underground water and aquifer;

3 If the foundation can be immerged by the underground water, the corrosivity shall be appraised by collecting the water sample.

4.1.11 During the detailed investigation stage, detailed data on geotechnical engineering and the geotechnical parameters for design and construction shall be put forward according to the single building or building group, the geotechnical engineering for the foundation shall be done, and the recommendations on subsoil type, foundation type, subsoil treatment, foundation pit bracing, dewatering and the prevention and processing of adverse geological actions shall be put forward. The main work is as follows:

1 To collect the data including overal layout of buildings with coordinate and elevation, elevation of ground leveled, feature, scale, load, structure feature of buildings, foundation style, embeded depth and allowable deformation of foundation and so on;

2 To find out the type, origin, distribution, development trend and hazard degree of the adverse geological actions, and put forward the recommendations about processing scheme;

3 To ascertain type, depth, distribution and engineering properties of the formation within the range of construction, and analyze and assess the stability, uniformity and bearing capacity of the subsoil;

4 For the construction needing calculate the settlement, to provide the parameters for calculation of subsoil deformation and predict the deformation character of buildings;

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5 To find out the buried objects averse to the engineering including river channel, groove, grave, bomb shelter and solitary-stone etc. ;

6 To find out the condition of occurrence of underground water and provide the groundwater level and fluctuation of it;

7 To in the seasonal frozen area, to provide the standard frozen depth of the soil in thesite;

8 To identify the corrosivity of water and soil to construction material.

4.1.12 For the site which aseismatic fortification intensity is not less than grade 6, the investigation shall comply with specifications in Section 5.7 in this code. If the pile foundation was adopted for the buildings, it shall comply with specifications in Section 4.9 in this code. If it is necessary to design the foundation pit excavation, bracing and dewatering, it shall comply with Section 4.8 in this code.

4.1.13 Influence of groundwater on engineering and environment during construction shall be demonstrated in detail investigation. For the important engineering with complicate conditions, special study shall be made when the water level changes during the service requires demonstrating and when anti-floating and waterproof water level requires putting forward.

4.1.14 For the detailed investigation, the distribution of exploratory points and the depth of exploratory hole should be established according to the construction feature and the geotechnical condition. For the rocky subsoil, it shall be established according to the geological structure, properties of rock mass and weathering condition, and combined with the demand for foundation of building, the provisional standards and or local experience. For soiled subgrade, it shall be in accordance with requirement specified in Article 4.1.15～4.1.19 in this section.

4.1.15 In detailed investigation stage, the interval of exploratory points shall be determined according to requirement specified in Table 4.1.15.

Table 4.1.15 Spacing of Exploratory Points in the Detailed Investigation

Complexity grade of subsoil	Intervals of exploratory points	Complexity of subsoil	Interval of Exploratory points
Grade Ⅰ (complex) Grade Ⅱ (Moderately complex)	10～15 15～30	Grade Ⅲ (Simple)	30～50

4.1.16 In the detailed investigation stage, the distribution of exploratory points shall be in accordance with the following requirements:

1 The exploratory points should be distributed along the boundary line and corner of the buildings. For other buildings without special demand, it may be distributed in the range of the building and the building group;

2 If the main load-bearing layer or the underlying layer within area of the same buildings fluctuates greatly, the number of exploratory points shall be densified in order to find out the variety;

3 The exploratory points shall be laid out separately for the foundation of the important equipment. The exploratory points should not be less than 3 for the foundation of the important dynamic machinery and that of the tall structure;

4 The exploration means should adopt drilling and penetration together. In the area with complex geological condition, collapsible soil, expansive rock and soil, weathered rock and residual soil, and proper number of exploratory wells should be designed.

4.1.17 For the single tall building in detailed investigation, the distribution of exploratory points shall meet the demand for the assessment of the foundation uniformity and the number shall not be less than 4. For the dense tall building group, the number can be decreased properly, but every tall building shall have at least one controlling exploratory points.

4.1.18 The depth of exploration in detail investigation shall be calculated from the bottom of foundation, and shall accord with following requirements:

1 The depth of exploratory hole shall control the main load-bearing layer of the foundation. If the width foundation bottom is not more than 5m, for the strip foundation, the depth of exploratory hole shall not be less than 3 times of foundation bottom width; for the independent column foundation, the depth shall not be less 1.5 times and not be less than 5m;

2 For the foundation for tall building and that required with deformation computation, the depth of controlled exploratory hole shall be beyond the subsoil deformation calculated depth; general exploratory hole of tall building shall reach 0.5～1.0 times of foundation width, and penetrate into the stable-distribution stratum;

3 If building only with basement or annex building of tall building cannot meet anti-floating design requirements, anti-floating pile of anchor rod shall be set up, and the depth of exploratory hole shall meet requirements of pull-resisting bearing capacity assessment;

4 When large area ground heap loading or soft under layinglayer are available, the depth of controlled exploratory hole shall be increased properly;

5 Stable layer like bedrock of thick gravelly soil is encounted within above specified depth, the depth of exploratory hole shall be adjusted according to circumstances.

4.1.19 Besides those specified in Article 4.1.18, the depth of exploratory hole in detailed investigation shall also be in accordance with the following requirements:

1 The calculated depth of foundation deformation for the medium and low compressive soil, the calculated depth of foundation deformation may be the depth above that the additional pressure which equals to 20% of the effective self-weight of overburden subsoil. For the high compressive soil, it may be the depth above that the additional pressure which equals to 10% of the effective self-weight of overburden soil;

2 For the annex in the construction plan or the basement (or the additional pres-

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sure under foundation bottom $p_0 \leqslant 0$), the depth of controlling exploratory hole may be decreased appropriately, but the hole shall penetrate into stable distributed layer and should not be less than 0.5～1.0 times width of foundation according to the load and the soil condition;

3 If the monolithic stability need to be checked, the depth of controlling exploratory hole shall meet the demand of checking computations;

4 If the site category for seismic fortification needs to be determined and there is no reliable data about the thickness of overburden layer, the wave velocity test hole shall be laid out and its depth shall meet the demand for confirming the thickness of overburden layer;

5 For the foundation on which there is large scale equipment, the depth of exploratory hole should not be less than 2 times of the width of the foundation bottom;

6 If it is necessary to implement soil treatment, the depth of exploratory hole shall meet the demand for the design and construction of soil treatment. If pile foundation is used, the depth of exploratory hole shall meet the requirements in Section 4.9.

4.1.20 Soil sampling and in-situ testing in detail investigation shall not only comply with the requirements of assessment on geological engineering, but shall also comply with the following requirements:

1 Exploratory point number for soil sampling and in-situ testing shall be determined in accordance with stratum structure, subsoil uniformity and engineering characteristic, and it shall not be less than 1/2 of the total exploratory point number, the drilling soil-borrowed point number shall not be less than 1/3 of the total exploratory point number;

2 Undisturbed soil sample or in-situ testing data of each main soil layer in site shall not be less than 6 pieces (group); when static sounding and or dynamic sounding with continuous recording are adopted as the major investigation mean, each site shall have at least 3 points;

3 In main load-bearing layer of the subsoil, interlayer or lenticular which thickness is larger than 0.5m shall be carried out with soil sampling or in-situ testing;

4 When soil layer character is not uniform, the quantity of soil sample or that in-situ testing shall be increased.

4.1.21 After the excavation of foundation pit, if the geotechnical condition does not accord with the investigation report data or the abnormal things are found out, the investigation during construction shall be implemented. During the construction and usage stage, if the subsoil, slope body and underground water vary unexpectedly, they shall be monitored, and the influence on the engineering and environment shall be analyzed and assessed.

4.1.22 The lab soil test shall meet those specified in Chapter 11. The shear strength

test for foundation pit design shall be in accordance with the requirements in Article 4.8.4.

4.1.23 The calculation of the foundation deformation should be implemented according to the current national standard "Code for Design of Building Foundation" GB 50007 or other relevant standards.

4.1.24 The bearing capacity of subsoil shall be determined by the local experience synthetically. For the site with adverse geological actions, the buildings built on the top of or at slope and the construction excavated adjacent to, beside the foundation, their stability shall be assessed.

4.2 Underground Cavity

4.2.1 This section is applicable to the geotechnical engineering investigation for the non-pressure underground cavity excavated manually.

4.2.2 The quality classification of underground cavity surrounding rock shall be in accordance with the standard adopted for underground cavity design.

4.2.3 The feasibility study investigation shall collect the data on regional geology, implement the reconnaissance and investigation, understand the landform, lithology, and geological structure, engineering geological, hydro-geological and environmental condition of the proposed scheme, assess its feasibility, and select the proper cavity position and opening.

4.2.4 The preliminary investigation shall adopt the methods of engineering geological mapping, exploration and testing. The geological setting and the environmental condition of the selected scheme shall be found out; the quality grade of surrounding rock (classification of surrounding rock) shall be determined and the stability of the cavity position and opening shall be assessed. That will provide the basis for the preliminary design.

4.2.5 For the preliminary investigation, the engineering geological mapping and survey shall find out the following problems preliminarily:

1 Landform, morphology and the origin;

2 Stratum lithology, attitude, thickness, weathering degree;

3 Feature, attitude, filling, cementing, penetration and combination of the fracture and the main fissure;

4 Type, scale and distribution of adverse geological actions;

5 Background of seismic geology;

6 Action direction of the maximum principal stress of the ground stress;

7 Underground water character including type, condition of occurrence, recharging, drainage and fluctuation;

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8 Distribution of surface water and its relation with underground water, feature of alluvial silted deposits;

9 Inter-influence of the exiting buildings above the ground, underground structures and pipelines, which is crossed by the cavity.

4.2.6 For the preliminary investigation, the exploration and the testing shall be in accordance with the following requirements:

1 The shallow earthquake profiling method or other effective measures shall be adopted to determine the insidious fracture and structural rupture zone. The embedment depth of bedrock shall be found out and the weathering zone shall be classified;

2 The exploratory points should be distributed along the outside of cavity and the interval of those should be 100～200mm. The soil sampling and in-situ testing exploratory hole should not be less than 2/3 of the total number of the exploratory points. The depth of controlling exploratory hole should be drilled 1～3m below the design elevation of cavity bottom if the rock quality designation of rock mass is Grade Ⅰ and Grade Ⅱ. The depth of controlling exploratory hole should be drilled 3～5m below the design elevation of cavity bottom if the rock basic quality grade of rock mass is Grade Ⅰ. For soils and rock mass of Grade Ⅳ and Grade Ⅴ, the depth shall be determined according the practical situation;

3 The samples shall be taken from each main rock and soil layer. If there is underground water, the water sample shall be taken. If there is harmful gas in the cavity area or the earth temperature is abnormal, the component and content of the harmful gas or the earth temperature shall be measured. For the high earth stress area, the earth stress shall be measured;

4 If necessary, the drilling elastic wave or the sound wave testing, the drilling earthquake CT testing or the drilling electromagnetic wave testing shall be carried out;

5 The lab rock tests and the soil tests shall be implemented according to specifications in the Chapter 11 in this code.

4.2.7 The detailed investigation shall include drilling, drilling geophysical prospecting and testing. If necessary, cavity exploratory may be laid out according to the construction-guiding tunnel. The cavity position, cavity opening, the engineering geological and hydro-geological condition of the routine crossed by cavity shall be found out in detail. The quality grade of rock mass (classification of surrounding rock) shall be classified in sections, the stability of cavity and surrounding rock shall be assessed and the data about the design of bracing structure and the construction scheme shall be provided.

4.2.8 The detailed investigation shall include the following work:

1 To ascertain the stratum lithology and its distribution, classify rock group and weathering degree and perform tests of physical & mechanical properties of rock;

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2 To find out the feature of fracture structure and fracture zone including the position, scale, attitude and mechanical property, and classify the structure type of rock mass;

3 To find out the type, character and distribution of adverse geological actions, and put forward the recommendations on precaution and processing measures;

4 To find out the distribution, thickness and embedment depth of the main aquifer, and the type, recharging and drainage condition of the underground water, and predict the water-out state, water yield and the corrosivity of water during the excavation;

5 If the underground cavity of city needs dewatering construction, the engineering dewatering scheme and relevant parameters shall be put forward in sections;

6 Ground buildings, the underground structures and pipelines shall be found out at the position of cavity or in its vicinity, and the potential influence after the excavation of cavity shall be predicted and the controlling measures shall be provided.

4.2.9 In the detailed exploration, shallow earthquake prospecting and drilling earthquake CT or electromagnetic wave CT testing may be adopted to find out the embedment depth of bedrock, the weathering degree of rock and the position of insidiousness body (such as karst, fracture zone and so on). The plastic wave velocity testing in the drilled hole may be done to provide the data about how to determine the quality grade of rock mass (classification of surrounding rock), to assess the intactness of rock mass and to calculate the dynamic parameters.

4.2.10 In the detailed exploration, the exploratory points should be distributed intersectedly 6～8m beyond the midline of cavity. In the mountainous district, it should be laid out according to the geological configuration and the distance of prospecting points shall not be more than 50m. In the city, if the rock and soil varies greatly, the distance of exploratory points for underground cavity should be less than 25m. If the complexity of the site is moderately complex, the distance should be 25～40m; If complexity of the site is simple, the space should be 40～80m.

The count of sampling and the in-situ testing exploratory hole shall not be less than 1/2 of the total exploratory points.

4.2.11 In the detailed exploration, the depth of controlling exploratory hole in Quaternary system shall be determined according the demands for engineering geology, hydro-geological condition, embedment depth of cavity and design of bracing etc.. The general exploratory holes can be drilled 6～10m beyond the design elevation for the bottom of foundation. The depth of controlling exploratory holes may be established according to the requirements in item 2, Article 4.2.6 .

4.2.12 Besides the preliminary exploration demand, in the detailed exploration, the laboratory test and in-situ testing for the underground cavity in city shall also include

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the following tests according to the design demand:

1 The bearing plate of which length of the side is 30cm shall be used in doing the loading test to calculate the bedding coefficient of subgrade;

2 The measure of surface heat source or the hot line correlation method shall be used to measure the heat physical index, and to calculate the heat physical parameter including the thermal diffusivity, thermal conductivity and specific heat capacity;

3 If it is necessary to get the dynamic parameters, it may be calculated according to the compressive wave velocity, v_p, and the shear wave velocity, v_s. The indoor dynamic property test may also be made to calculate the dynamic parameters.

4.2.13 The construction scheme should be implemented with the excavation of guiding cave or rough cave. If there is lots of difference with the exploratory data, the recommendations for the revised design and the construction scheme shall be put forward.

4.2.14 The stability of surrounding rock of underground cavity may be assessed by combining the analysis of engineering geology with the theoretical calculation. And it may be calculated by the numerical method or the graph method of elasticity finite element.

4.2.15 If the cavity is possible to produce the bias pressure, expansive pressure, rock burst and other special situations, special research on them shall be made.

4.2.16 In the detailed investigation, besides those specified in Chapter 14 in this code, the report of geotechnical engineering investigation for the underground cavity also shall include the following contents:

1 Classification of the type of surrounding rock mass;

2 Recommendations on the cavity position, the cavity opening and the position of cavity axial line;

3 Assessment for the stability of cavity body and the cavity opening;

4 Recommendations about the bracing scheme and the construction method;

5 Assessment for the ground deformation and its influence on the existing buildings.

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4.3 Bank Side Engineering

4.3.1 This section is suitable for the geotechnical engineering investigation for the harbor engineering, the hydraulic structure of ship-building and ship-repairing and the water-extracting structure.

4.3.2 The investigation for bank side construction shall find out the followings:

1 Geomorphic feature and complex stratum at the conjunction of geomorphic units;

2 Distribution and engineering feature of special soil including high sensitive soft

soil, luminary configuration soil and compound soil, and the rock mass with Gade Ⅴ of the rock quality designation;

3 Adverse geological actions including bank side landslide, eboulement, washout, siltation, potential erosion and sand dune etc..

4.3.3 In the feasibility study investigation, engineering geological mapping and exploration survey shall be done. The basic things and their development trend including stratigraphic distribution, structure character, landform character, shape of bank slope, washout and siltation, variety of water level, transferring of bank beach and the range of inundation shall be found out. If necessary, some exploration work shall be laid out to assess the stability of bank slope and the feasibility of the site, and the recommendations on the optimum scheme shall be put forward.

4.3.4 The investigation in the preliminary design shall be in accordance with the following requirements:

1 The engineering geological mapping shall find out the transferring of bank-line and the influence on it caused by dynamical geologic actions. It shall also ascertain the distribution of the buried river, lake, groove, and their influence on the engineering. It shall include the origin, distribution and development trend of the adverse geological actions such as potential erosion, sand dune and so on, and its influence on the stability of the site;

2 The exploratory lines shall be perpendicular to the bank strike. The interval of exploratory lines and points should be established according to the engineering demand, landform feature, geotechnical distribution and adverse geological actions etc.. The exploratory lines and points shall be increased at the bank slope and the conjunction of rock and soil layer;

3 The depth of exploratory holes shall be determined according to the engineering scale, design demand and the geotechnical condition;

4 In the water area, the shallow earthquake profiling method or other geophysical prospecting methods may be used;

5 The stability of the site shall be assessed and the recommendations on the layout, structure and the type of foundation, construction method and the prevention and processing for the adverse geological actions shall be put forward.

4.3.5 In the construction drawing design investigation stage, the exploratory lines and points shall be determined according to the overall layout of the engineering, and the landform feature, and the geological condition; and shall be increased at the complex site. The depth of exploratory holes shall be determined according to the engineering scale, design demand and geotechnical condition, besides the feature and the load of buildings and structures. The stability of bank slope, the excavation of slope, the brac-

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ing structure and the pile foundation shall be taken into account.

The recommendations on the design and construction of the subsoil and the foundation and the prevention and processing for the adverse geological actions shall be put forward according to the investigation results.

4.3.6 For the soft soil, in-situ testing, besides the specifications in Chapter 10, such as cone static penetration test or combination of cone static penetration test and pressuremeter test may be adopted to stratify, to measure the modulus, strength and the bearing capacity of subsoil. The vane shear test may be adopted to measure the undrained shear strength of the soil.

4.3.7 In selecting the shear test methods when measuring the shear strength of the soil, the following factors shall be taken into account:

1 The possibility that the unsaturated soil turns into the saturated soil during the construction and when the soil has been immersed in the water after finishing the construction;

2 The variation of the consolidation state of the soil during the construction and after the construction;

3 The influence on the soil properties caused by load relieves resulting from excavation or load increase resulting from filling.

4.3.8 In every investigation stage, the space between the investigation lines and exploratory points, the depth of the exploratory hole, the amounts of the in-situ testing and the lab tests shall be in accordance with the specifications of the current related standards.

4.3.9 If the stability of bank slope and foundation are assessed, the following factors shall be considered:

1 Right selection of the designed water level;

2 Possibility of occurrence of water head difference and water level slump sharply;

3 Temporary overload in the construction;

4 Steep side slope excavated;

5 Wave action;

6 Influence of piling construction;

7 Influence of the adverse geological actions.

4.3.10 Besides the requirements in Chapter 14 of this code, the geotechnical engineering investigation report for bank side engineering shall also cover the followings corresponding to geotechnical engineering investigation stage:

1 To analyze and assess the stability of bank slope and foundation;

2 To put forward the recommendations on the design scheme of subsoil & founda-

tion and of bracing;

3 To put forward the recommendations on prevention and processing scheme for adverse geological actions;

4 To put forward the recommendations on the monitoring of bank side engineering.

4.4 Pipeline and Suspension Line Engineering

(Ⅰ) Pipeline Engineering

4.4.1 This section is suitable for the geotechnical engineering investigation of long petroleum and gas pipeline and large scale crossing engineering.

4.4.2 The long petroleum and gas pipeline engineering may be divided into three stages including the route selection investigation, the preliminary investigation and the detailed investigation. If the geotechnical condition is simple or there is local engineering experience of the site, the exploration stages may be simplified appropriately.

4.4.3 For the route selection investigation, the main geotechnical problems of each scheme shall be mastered by the collection of the data, mapping and surveying. The stability and suitability of the planned traversing and crossing river reach shall be assessed; and the requirements as follows shall be met:

1 To investigate the landform, geological structure, stratum lithology, hydrogeology etc. along the routine, and recommend the crossing scheme of the route;

2 To investigate the special soil and the adverse geological actions in the area traversed or crossed and assess its hazard degree to the pipeline;

3 To for the controlling route, investigate the stability of the riverbed and the bank slope and put forward the recommendations about the schemes comparison;

4 To investigate the distribution of the reservoir along the route, recent and long-term plan, and water level of reservoir, backwater immersion, the range of bank failure and the influene to the route scheme;

5 To investigate the distribution of the mineral product and the cultural relics along the route;

6 To investigate the ground motion parameter and the anti-seismic fortification intensity along the route.

4.4.4 The routine that the pipeline traverses and crosses the river shall be at the advantageous section where the river reach is straight, the riverbed and the bank slope is stable, the flow is gentle, the section of riverbed is roughly symmetrical, the rock & soil composition of riverbed is simple, and there is enough construction space on both bank sides. The river reach in the following conditions wshould be kept away from:

1 The river course is crooked abnormally; and the principal flow is not regular

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and changes frequently;

2 The riverbed is composed of silty sand; the range of dilluvial and siltation is large;

3 The rock and soil of the bank slope is soft; the adverse geological actions develop strongly and there is direct impact on or potential danger to the stability of the engineering;

4 The fault river valley or the inducing-earthquake fractures.

4.4.5 The preliminary investigation shall include the followings:

1 To divide geomorphic unit along the route;

2 To ascertain preliminarily the origin, type, thickness and engineering properties of the rock and soil within the depth of embedding pipeline;

3 To investigate the feature and the distribution of the fracture with influence on the pipeline;

4 To investigate the distribution, feature and the development trend of the adverse geological actions and its influence on the pipeline;

5 To investigate the distribution of the wells and springs, and find out the condition of the underground water along the route;

6 To investigate the distribution, exploitation of the mineral resources and the conditions of goaf preliminarily;

7 To find out preliminarily the range of inundation where pipeline traverses or crosses the river and assess the stability of the bank slope.

4.4.6 The collection of data and survey is the main work for preliminary investigation. In the sections, where the river and ravine traversed or crossed by pipeline, geophysical prospecting should be performed. For the large and middle rivers with the complex geological condition, drilling exploratory shall be done. The number of the exploratory points should be 1～3 for each traversing and/or crossing scheme. The depth of exploratory holes shall comply with the specifications in Article 4.4.8 of the section.

4.4.7 In the detailed investigation stage, the geotechnical condition and the corrosivity of soil and water to the metal pipeline along the route shall be ascertained, and the geotechnical properties parameters for the engineering design shall be provided. The investigation for the traversing and/or crossing sections shall be in accordance with the following requirements:

1 To the formation, the properties and grain size distribution of the soil particle, and find out the washout and the stability of riverbed. To assess the stability of bank slope and put forward the recommendations on slope protection;

2 The exploratory in the traversing and/or crossing sections shall comply with Article 4.4.15 and 4.4.16 in this section.

4.4.8 The layout of the exploratory points in the detailed investigation shall meet the following requirements:

1 For the pipeline traversing engineering, the interval of the exploratory points (including geological points and the in-situ testing points) shall be determined according to the complexity of geological condition, which should be 200～1000m, and shall be adjusted according to the complexity of geological condition and the landform. The depth of exploratory holes should be 1～3m below the depth of the pipeline embedded;

2 For the crossing pipeline engineering, the exploratory points shall be laid out along the midline and the deviation from the midline shall not be more than 3m. The interval of the exploratory points should be 30～100m and the number of that shall not be less than 3. If the crossing mode is the duct buried in ditch, the depth of the exploratory points should be 3～5m below the maximum washout depth. If the crossing mode is pushing pipe or orientational drilling, the depth of the exploratory points shall be determined according to the design requirements.

4.4.9 If the anti-seismic fortification intensity is not less than degree 6, for the pipeline engineering, the exploratory work shall meet the requirements in Section 5.7 of this code.

4.4.10 The geotechnical engineering investigation report shall include the followings:

1 In the route selection investigation stage, the geotechnical conditions of each scheme shall be illustrated briefly and put forward the recommendations on the comparison of schemes;

2 In the preliminary exploration stage, the geotechnical conditions of each scheme shall be demonstrated in sections, and the optimum routine scheme shall be recommended. For the traversing and/or crossing engineering, the stability of the riverbed and the bank slope shall be assessed also, and the recommendations on the traversing and crossing schemes shall be put forward;

3 In the detailed investigation stage, the geotechnical conditions shall be assessed in sections and the recommendations about the design parameter for the geotechnical engineering, and about the design and construction scheme shall be put forward. For the traversing engineering, the stability of the riverbed and the bank slope shall be illustrated, and the recommendations about the measure of bank slope protection shall be put forward.

(Ⅱ) Suspension Line Engineering

4.4.11 This section is suitable for the geotechnical engineering investigation for the large scale suspension line engineering including the high voltage delivery circuit which the voltage is not lower than 220kV, and the large scale suspension cable etc..

4.4.12 The large-scale suspension engineering may be divided into two stages: the

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preliminary design investigation and the constructional drawing design investigation. The small-scale suspension line engineering may combine the investigation stages.

4.4.13 The preliminary design investigation shall be in accordance with the following requirements:

1 To investigate the landform, geological structure, stratum lithology, the distribution of the special soils, the underground water and the adverse geological actions along the route, and provide analysis and assessment in sections;

2 To investigate the distribution of mineral resources along the route, the exploitation plan and the production situation. The routine should keep away from the exploitable mining layer. For the mined zone, the stability of goaf shall be analyzed and assessed;

3 For the long crossing section, the engineering geological conditions shall be found out; the geotechnical engineering assessment shall be done and the optimum crossing scheme shall be recommended.

4.4.14 In the preliminary investigation stage, the main work is to collect and to use of aerial information. For the long crossing section, the detailed investigation and engineering geological mapping shall be made. If necessary, a little exploration and testing work shall be supplemented.

4.4.15 The construction drawing design investigation shall be in accordance with the following requirements:

1 For the plain region, the properties of tower footing soil layer including its distribution, condition embedded, physical and mechanical properties, geo-hydrological condition and the corrosivity of environmental water to concrete and the metal material shall be found out;

2 For the hill and mountainous region, besides the above specified in Item 1 of this article, the various adverse geological actions near the tower footing shall be found out and the recommendations about the control measures shall be put forward;

3 For the long crossing section, the landform and ground feature of the crossing river reach, the feature in the range of tower footing including formation, lithology, weathering degree and fracture degree, soft and weak interlayer and its physical and mechanical properties shall be found out. The adverse geological actions acting on the tower footing shall also be found out and the recommendations about the controlling measures shall be put forward;

4 For the special designed tower footing and the long crossing tower footing, if the anti-seismic fortification intensity is not less than Grade 6, the exploration shall be in accordance with the requirements in Section 5.7 of this code.

4.4.16 In the construction drawing design investigation stage, in the sections of key

tower footing where there are the angle-tower, strain-tower, terminal tower and long crossing tower etc. for the suspension line engineering, or sections where the geological condition is complex, the exploration of tower footing shall be made one by one. In the section of linear tower base, every 3～4 tower bases should be laid out one exploratory point. The depth shall be determined according to the load feature of tower rod and the geological condition.

4.4.17 The geotechnical engineering investigation report of the suspension line engineering shall include the followings:

1 In the preliminary investigation stage, the geotechnical condition along the route and the stability of the bank slope crossing the main river shall be demonstrated; and the optimum routine scheme shall be selected;

2 In the construction drawing design investigation stage, the details of the position of the tower shall be provided and the geotechnical condition and the stability of the tower shall be demonstrated. The recommendations about the design parameter, the foundation scheme and the construction measures shall also be put forward.

4.5 Waste Disposal Engineering

(Ⅰ) General Provisions

4.5.1 This section is suitable for the geotechnical engineering investigation for the disposal engineering of solid waste such as the storage yard of industry waste residue and the waste landfill site. The investigation of the nuclear waste disposal site shall also be in accordance with the requirements in relevant codes.

4.5.2 In the geotechnical engineering investigation for the disposal engineering, we should find out the following content emphatically:

1 The landform and ground feature, and the meteorological and hydrographic condition;

2 Geological structures, the distribution of the rock and soil, and adverse geological actions;

3 The physical and mechanical properties of rock and soil;

4 The hydro-geological condition and the permeability of the rock and soil and the wastes;

5 The stability of the site, subsoil and side slope;

6 The migration of contaminated, the contamination to water resource and rock and soil, the influence on environment;

7 The investigation for dam construction material and clay for seepage-proof and covering;

8 The seismic effect of Holocene Epoch active fracture, subgrade and deposit.

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4.5.3 The investigation range of the waste disposal engineering shall include buildings and structures such as residues site (reservoir area), initial stage dam, the relevant pipeline and tunnel etc., and also include its vicinity. The local construction material shall also be investigated.

4.5.4 The investigation of the waste disposal engineering shall be implemented combined with the engineering construction in several stages. It may be divided into the feasibility study investigation, the preliminary investigation and the detailed investigation, and shall be in accordance with requirements of relevant standards.

For the feasibility study investigation, the main work is site reconnaissance. If necessary, it may be supplemented with a little prospecting work. The stability and suitability of the site to be selected shall be assessed.

The main work of the preliminary investigation is primarily in engineering geological mapping. The investigation, in-situ testing and laboratory test shall be complemented. The overall layout of the works proposed, the stability of the site and the influence of the waste on the environment shall be assessed. Also the recommendations shall be put forward.

For the detailed investigation, the investigation, in-situ testing and lab test shall be adopted. If the geological condition of the site is complex, the engineering geological mapping shall be conducted to obtain the parameters needed for the engineering design. The recommendations about the design, construction and the monitoring work shall be put forward. The unstable section and the environmental influence shall be assessed, and the recommendations about treatment shall be put forward.

4.5.5 Before the investigation of the waste disposal engineering, the following technical data shall be collected:

1 The feature of the waste including the component, granularity, physical and chemical properties, daily disposal capacity, transportation and discharging method;

2 The whole capacity, effective capacity and durability of the storage yard and landfill site;

3 The coverage, precipitation amount, runoff amount, and peak flood discharge suffered for many years of the valley shaped storage yard and landfill site;

4 The length and the top elevation of the initial stage dam and the final top elevation of the heightened dam;

5 The active fracture and anti-seismic fortification intensity;

6 The protection zone for the adjacent water resource, the exploitation of water resource and the requirements for environmental protection.

4.5.6 The engineering geological mapping for the waste disposal engineering shall cover the whole site and its vicinity. For the preliminary investigation, the engineering

scale should be 1 : 2000～1 : 5000. For the complex section in the detailed investigation, it shall not be less than 1 : 1000. Besides the specifications in Chapter 8 to be followed, the followings shall be investigated preliminarily:

1 The landform shape, topographic condition and the distribution of residential area;

2 The adverse geological actions which are related with the stability of thesite, including the flood, landslide, debris flow, karst and fracture etc. ;

3 The distribution of the valuable natural landscape, cultural relics and mineral product, the exploitation and mined-out condition of the mineral product;

4 The hydrogeology problems with relation to the leakage;

5 The ecological environment.

4.5.7 The special hydro-geological investigation shall be performed for the waste disposal engineering according to the requirements in Chapter 7 of this code.

4.5.8 In the soluble rock distribution area, the development condition of karst, the distribution of Karst cavity, earth cave and collapse, the channels and flow direction of the karstic water, the leakage of the underground water and the extravasate resulting from the influence of karst on the engineering stability shall be found out.

4.5.9 The investigation for the dam construction material of the initial stage dam and the clay used for seepage-proof and covering shall include the producing area, reserves, performance index and the exploitation and transportation condition of the material. In the feasibility investigation stage, the producing area shall be found out. This work shall be completed basically in the preliminary investigation stage.

(Ⅱ) Storage Yard for Industry Waste Residue

4.5.10 The preliminary investigation of the storage yard for industry waste residue shall be in accordance with the following requirements:

1 The exploratory line should be parallel to the axial line of the structure such as storage yard, dam, tunnel and pipeline etc. . The interval of the exploratory points shall be determined according to the complexity of geological conditions;

2 For the initial stage dam, the depth of exploratory holes shall meet the demands for analysis of the stability, deformation and leakage;

3 In the key section in relation to the stability and leakage, the exploratory hole shall be densified and deepened or special exploration shall be laid out;

4 The effective geophysical method as the supplementary means of drilling and well exploratory may be adopted;

5 The tunnel investigation shall be in accordance with the requirements in Section 4.2.

4.5.11 For the investigation of the heightened dam, the investigation, in-situ testing

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and lab shall be adopted to ascertain the follows mainly:

1 The component of existing deposit, grain composition, degree of compaction and the depositing discipline;

2 The engineering and chemical properties of the piled material;

3 The position of seepage line in the accumulated body and its varying discipline;

4 The stability of the dam being operated, the suitability and stability of heightened to the design height;

5 The stability of the waste heaped dam under the action of the earthquake, the possibility of the earthquake liquefaction of the waste material;

6 The possible influence on environment when the heightened dam is being performed.

4.5.12 For the investigation of the heightened dam with waste residue, no less than 3 exploratory lines perpendicular to the axial line of dam according the heaped scale may be laid out. The interval of the exploratory points may be increased appropriately. The general exploratory holes shall be at certain depth below the natural ground surface and the depth of the controlling exploratory holes shall be designed to find out the potential soft and weak layer.

4.5.13 The geotechnical engineering assessment of the storage yard for the industry waste residue shall include the follows:

1 The influence on the engineering by the adverse geological actions such as flood, landslide, debris flow, karst and fracture etc.;

2 The stability of the dam foundation, dam scapulus and reservoir bank; and the influence on stability by the earthquake;

3 The influence on environment resulting from the leakage at the dam section and reservoir area, and the construction of the reservoir;

4 The technical and economical analysis about the quality, reserves, exploitation and the transportation condition shall be carried out.

4.5.14 Besides the requirements in Chapter 4 of this code, the investigation report of the storage yard for industry waste residue shall also meet the following requirements:

1 The geotechnical engineering shall be analyzed and assessed according to Article 4.5.13 in this section and the recommendations about the prevention and processing measures shall be put forward;

2 For the investigation of the heightened dam with waste residue, the current situation and the stability at the final height shall be analyzed and assessed; and the recommendations about the heaping method and corresponding measures shall be put forward;

3 The recommendations about the monitoring for the stability of side slope, groundwater level and the leakage of reservoir area shall be put forward.

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(Ⅲ) Waste Landfilling Site

4.5.15 Before the investigation of the waste-landfilling site, besides the requirements in Article 4.5.5 of this section, the data to be collected shall also include the follows:

1 The type, component, main properties of the waste, and the sanitation demand of landfill;

2 The landfilling mode and the landfilling procedure, the structure of seepage-proof cushion and the overburden, the layout of the collection and draining system for extravasate;

3 The allowable deformation requirement of the foundation and the waste from the seepage-proof cushion, the overburden layer, and the collection and drain system for extravasate;

4 The situation of waste cutting of dam, sewage tank, draining well, conduit and the relevant structures.

4.5.16 Besides the requirements in Article 4.5.10, the investigation and testing of the waste landfilling site shall also be in accordance with the following requirements:

1 For the site which deformation needed to be analyzed, the depth of exploration shall meet the requirements for deformation analysis;

2 The testing of rock and soil and the soil-like waste may be made according to the requirements in Chapter 10 and Chapter 11. For the non-soil waste, the back analysis method may be adopted to obtain the design parameters according to its variety, properties and the site monitoring data;

3 The chemical composition of waste extravasate shall be measured. If necessary, special tests shall be carried out to study the migration discipline of contaminant.

4.5.17 Besides the requirements in Article 4.5.13 of this section, the geotechnical engineering assessment for investigation of the waste-landfilling site shall also include the followings:

1 The monolithic stability of the engineering site, the deformation and the stability of the waste heaped;

2 The possibility of the invalidation of the seepage-proof cushion and the overburden and other facilities resulting from the deformation of foundation and waste;

3 The leakage of foundation of the dam, dam abutment, reservoir area and other relevant parts;

4 The variety of water level and its influence shall be predicted;

5 The migration of waste and its influence on water source, agriculture, rock and soil and the ecologic environment.

4.5.18 Besides the requirements in Chapter 14, the geotechnical engineering investigation report of the waste-landfilling site shall be also in accordance with the following

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requirements:

1 To analyze and assess the geotechnical engineering according to the requirements in Article 4.5.17 of this section;

2 To put forward the recommendations on measures about guaranteeing the stability, eliminating the deformation, preventing the leakage and protecting the environment;

3 To put forward the recommendations about the producing area and the relevant things of local material such as the dam construction material and clay used for seepage-proof and covering;

4 To put forward the recommendations on monitoring for the stability, deformation, water level, leakage, the chemical properties of water and soil and extravasate.

4.6 Nuclear Power Plant

4.6.1 This section is suitable for the geotechnical engineering investigation for all kinds of nuclear reaction dump land stationary-type commercial nuclear power plant. Besides the requirements in this code, the investigation for the nuclear power plant shall be also in accordance with the nuclear safety laws and relevant national and professional standards.

4.6.2 The safety classification of the geotechnical engineering investigation for nuclear power plant may be divided into the construction in relation to the nuclear safety and the routine construction.

4.6.3 The geotechnical engineering investigation for the nuclear power plant may be divided into five investigation stages, that is, investigation for the preliminary feasibility study, the feasibility study, the preliminary design, the construction drawing design and construction.

4.6.4 The preliminary feasibility study investigation is primarily to collect data, which includes the studying of regional geology, the engineering geology, hydrogeology, the classification of ground shock parameters, the document about the historical earthquakes, their influence intensity and the latest seismic activity of the site proposed. The stability of the site, the foundation condition, the environmental hydro-geological and the environmental geology shall be assessed preliminarily; and suitable recommendations about the plant-built shall be put forward.

4.6.5 For preliminary feasibility study investigation, the engineering scale of the engineering geologic mapping shall be 1 : 10000～1 : 25000. The coverage shall be the plant location and the periphery area; the area should not be less than $4km^2$.

4.6.6 Preliminary feasibility study investigation is to provide the main engineering geology delaminaton by necessary exploration and testing and the preliminary physical and

mechanical properties index, and to ascertain the feature of the rock and soil distribution near the nuclear island. It shall be in accordance with the following requirements:

1 The number of the exploratory points for every plant should not be less than 2 and the depth shall be 30～60m less than the designed terrace elevation;

2 The core shall be taken continuously in whole section. For common rock, the recovery ratio per turn shall be greater than 85%. For fractured rock, it shall be greater than 70%;

3 More than 3 groups of samples for every main geotechnical layer shall be collected. The standard penetration test shall be performed at the interval of 2～3m in the exploratory holes until moderately weathered rock is encountered. If the fully weathered rock is advanced, the standard penetration test shall be preformed more, and the interval shall not be more than 0.5m;

4 The items of the rock test shall include density, modulus of elasticity, Poisson ratio, compressive strength, soften coefficient, shear strength and compressive wave velocity etc.. The items of the soil test shall include grain size analysis, natural water content, density, specific gravity, plastic limit, liquid limit, compression coefficient, modulus of compression and shear strength etc..

4.6.7 In the preliminary feasibility study investigation stage, if the geotechnical condition of the site is complex, the geophysical prospecting as the supplement may be adopted to ascertain the composition, thickness of overburden, and the embedded feature of bedrock surface to find out the structural feature of the insidious rock and whether there is cavity and insidious soft and weak zone or not.

In the river or sea bank slope area and the side slope area of hill and mountainous area, the stability of the bank slope and side slope shall be investigated; and the preliminary analysis and assessment shall be provided.

4.6.8 The following factors shall be taken into account when evaluating the suitability of the plant site:

1 Whether there is capable and active fault and whether it will affect the stability of the plant;

2 Whether there is Holocene Epoch volcanic affecting the stability of the plant;

3 Whether it is in the region where the seismic fortification intensity is greater than grade 8, and whether there is potential geologic disaster related with the earthquake;

4 Whether there are exploitable mineral resources in and adjacent to the site, whether there are human activities, underground engineering, goaf and cave etc., which will affect the stability of the foundation;

5 Whether there is underground cavity, special geologic body, unstable bank

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slope and side slope, debris flow and other adverse geological actions which will cause the permanent deformation such as ground subsidence, settlement, upheaving and cracking etc. ;

6 Whether there is a site and subsoil for buildings of the nuclear power plant with enough bearing capacity;

7 Whether it will endanger the water-supplying resource or affect the environmental geology seriously.

4.6.9 The feasibility study investigation shall be in accordance with the following requirements:

1 To ascertain the landform and ground feature, geological structure, the distribution and feature of the fracture in the site of plant;

2 To find out the stratum origin, age, distribution of subsoil and the weathering degree; and to put forward the preliminary dynamic and static physical and mechanical parameters. To illustrate the foundation type and the scheme of subsoil treatment and put forward recommendations;

3 To find out the adverse geological actions endangering the plant site and its influence on the stability of the site. To assess the stability of the riverbank, and seashore and side slope preliminarily, and provide the preliminary treatment scheme;

4 To judge the site category of the anti-seismic designing, classify advantageous, disadvantageous and hazardous sections to the building, and determine the possibility of the earthquake liquefaction;

5 To find out the basic condition of hydrogeology and basic feature of environmental hydrogeology.

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4.6.10 The feasibility study investigation shall include the engineering geological mapping. The mapping range shall include the site and the adjacent area, the scale of engineering mapping drawing shall be 1 : 1000～1 : 2000. The mapping requirements shall comply with the requirements in Chapter 8 and other relevant regulations.

In this stage, the geotechnical engineering investigation shall combine the drilling with the engineering geophysics to find out the composition, thickness and the engineering properties of bedrock and overburden layer, and the embedded depth, weathering character of bedrock, the thickness of weathering layer and to ascertain the insidious soft and weak zone, cave and the important geological structure in the engineering area. In the water area, the marine (lake) deposit stratigraphic distribution, character and the fluctuation of the bedrock plane shall be found out according to the layout of hydraulic buildings.

4.6.11 The investigation and testing in the feasibility study stage shall be in accordance with the following requirements:

1 The exploration of the site shall be laid out in grid considering the landform and the geological condition, and the interval of exploratory points should be 150m. The layout of the controlling exploratory points shall take the buildings and the geological condition into account and the number shall not be less than 1/3 of the total. The exploratory lines shall be laid out along the axial line of the nuclear island and the routine island. The interval of exploratory points shall be densified appropriately and shall meet the layout demand of the main structure. Not less than one exploratory points for each nuclear island and each routine island shall be laid out;

2 The exploratory holes shall advance bedrock with Grade Ⅰ and the Grade Ⅱ of the rock quality designation not less than 10m below the foundation bottom for the site with shallow bedrock. And for the Quaternary subsoil, 40m below the designed ground level, or not less than 3m into bedrock with Grade Ⅰ or Grade Ⅱ of rock quality designation. The controlling exploratory hole in the nuclear island area should be drilled two times of the diameter of reactor dump workshops below the foundation bottom. The exploratory hole in the routine island area should be drilled no less than the calculated depth of foundation deformation, or 3m into bedrock with Grade Ⅰ, Ⅱ and Ⅲ of the rock quality designation below the foundation bottom. If the rock quality grade of the rock mass is Grade Ⅰ, Ⅱ or Ⅲ, the depth shall be 3m below the foundation bottom. For the hydraulic buildings, the exploratory holes should be laid out according to the underwater topography and the type of riverbank and seacoast with the consideration of the maximum washout erosion depth;

3 The gross section continuous coring drilling shall be adopted. For common rock, the recovery ratio per turn shall be greater than 85%. For fractured rock, it shall be greater than 70%. The RQD, number of joint and the angle of inclination shall be counted. For each main rock layer, the number of the rock sample group shall be more than 3;

4 To select suitable in-situ test methods to measure the characteristic index of rock and soil according to the geotechnical condition. And to adopt the sound wave test to assess the integrity degree and to classify the weathering degree of the rock mass;

5 In the nuclear island position, by single-hole method and cross-hole method, to select 1～2 exploratory holes to measure the compressive wave velocity and shear wave velocity, and to calculate the dynamic parameters of rock and soil;

6 Besides the requirements in Article 4. 6. 6 of this section, the laboratory test shall include the dynamic parameters such as dynamic elastic modulus, dynamic Poisson ratio and dynamic damping ratio of every sample.

4. 6. 12 In the feasibility study stage, the investigation and assessment of underground water shall be in accordance with the following requirements:

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1 To find out the underground water type, the feature of aquifer, number of aquifer, embedded depth, dynamic variation discipline of aquifer, the hydraulic connection with surrounding water body, and the chemical component of underground water according to the regional hydro-geological condition;

2 The water-injection test, water-pumping test and water-pressure test of the main aquifers shall be conducted respectively, combining with the engineering geologic drilling to obtain the permeability coefficient and the unit water absorption rate of the stratum to assess the integrity of rock mass and the hydro-geological condition preliminarily.

3 If necessary, to arrange the proper long-term observation hole to observe and record the water level periodically and analyze the water quality quarterly through water sampling and laboratory test. The observation period shall not be shorter than one hydrological year.

4.6.13 In the feasibility study stage, the investigation of side slope, the earthwork and building material shall be implemented according to the geotechnical condition and engineering demand. The detailed requirements shall comply with Section 4.7 and other relevant standards.

4.6.14 The preliminary design investigation shall be divided into four sections: the nuclear island, the routine island, the subordinate buildings and hydrotechnical buildings, and shall be in accordance with the following requirements:

1 To find out the origin, type, physical and mechanics properties parameters of rock and soil in each construction section, and put forward the subsoil treatment scheme;

2 To ascertain the distribution and the property of fault in the investigation area and its influence on the stability of the site, and put forward the recommendations about the treatment scheme;

3 To investigate the side slope with influence on the engineering construction, analyze and assess its stability, put forward the recommendations about the design parameters and the treatment scheme of side slope;

4 To find out the hydro-geological condition in the construction section;

5 To ascertain the adverse geological actions with influence on the construction, put forward the recommendations about the treatment scheme.

4.6.15 The preliminary design investigation for the nuclear island section shall meet the design and construction demand. The layout, number and depth of exploratory hole shall be in accordance with the following requirements:

1 The exploratory points shall be laid out at the perimeter the middle part of the reactor dump workshops. If the geotechnical condition is complex, the exploratory

points may be densified along the crossing line or the exploratory range may be extended. The intervals of the exploratory points should be 10～30m;

2 The number of the exploratory points shall control the distribution of stratum lithology in the nuclear section and shall meet the requirements of the in-situ testing demand. The exploratory points shall not be less than 10 in each nuclear island, and should not be less than 5 in the reactor dump workshops. The controlling exploratory points shall be more than half of the total;

3 The depth of the controlling exploratory hole should be two times of reactor diameter below the foundation bottom. The depth of the general exploratory hole should be no less than 10m below the foundation bottom for the rock mass whose rock quality designation is Grade Ⅰ or Ⅱ. The depth of the exploratory hole used for wave velocity testing shall not be less than that of the controlling exploratory hole.

4.6.16 The investigation of the routine island during the preliminary design stage, besides the requirements specified in Section 4.1, shall be in accordance with the following requirements:

1 The exploratory points shall be laid out along the outline, axis of the buildings or the main column and row line, and the total number of the exploratory points in routine island shall not be less than 10, among which, the controlling exploratory points should not be less than 1/4 of the total number of the exploratory points;

2 For the rocky subgrade, the controlling exploratory hole shall advance Grade Ⅰ or Ⅱ rock mass at least 3m below the foundation bottom; for the soil subsoil, the hole shall be drilled 10 to 20m below the compressive soil layer. The general exploratory hole shall be 3 to 5m down into the moderately weathered rock layer, and to the bottom of compressive layer of the soiled subgrade.

4.6.17 In the preliminary design stage, the exploration for the hydraulic buldings shall be in accordance with the following requirements:

1 In the pumping house area, the exploration shall consider the feature of stratum lithology and the embedded depth of foundation. The number of exploratory points in every pumping house shall not be less than 2. The general exploratory hole shall be drilled to 1～2m below the foundation bottom and the controlling exploratory hole shall be drilled 1.5～3m into the moderately weathered rock layer; For the soiled subgrade, the exploratory holes shall be drilled to 5～10m below the compressive layer;

2 For the inlet pipeline located in the soil site, the interval of the exploratory points should not be more than 30m; the general exploratory hole should be drilled 5m below the pipeline bottom; the controlling exploratory hole shall be drilled 1.5～3m into the moderately weathered rock layer;

3 For the sea embankment and anti-wave embankment related with the nuclear

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safety, the drilling shall be laid out according to the special geological environment. To find out the physical and mechanical properties of rock and soil and the adverse geological actions. The exploratory points shall be laid out along the axial line of the embankment. The general exploratory hole should be drilled 10m below the designed level of the embankment bottom, the controlling exploratory hole should be drilled 1.5～3m into the moderately weathered rock layer.

4.6.18 Besides the requirements in Section 4.1 of Chapter 10 and Chapter 11 of this code, the investigation testing in preliminary design stage shall be also in accordance with the following requirements:

1 According to the geotechnical properties and the engineering demand, suitable in-situ testing methods including wave velocity test, dynamic penetration test, water-pumping test, water-injection test, water-pressure test and static loading test of rock mass shall be selected; wave velocity testing by cross-hole method and elastic modulus test by drilling in the subsoil of the nuclear reactor workshops shall be made to calculate its wave velocity and the stress-strain characteristics of rock;

2 Besides the routine tests, the laboratory tests for measuring dynamic and static elastic modulus, dynamic and static Poisson ratio, dynamic damping ratio, dynamic and static shear modulus, dynamic shear strength and wave velocity shall be done.

4.6.19 In the construction drawing design stage, the investigation for subordinate buildings and other hydrotechnical buildings other than main hydrotechnical buildings shall be completed; the complement investigation for nuclear island, the routine island and the main hydrotechnical buildings shall be done according to demand. The contents and requirements may be implemented according to the requirements of the preliminary design stage. There shall be more than one controlling exploratory hole in each subordinate building related with the nuclear safety.

4.6.20 In the engineering construction stage, the main investigation work includes in-situ inspection and monitoring, the content and requirements shall be in accordance with that in Chapter 13.

4.6.21 The judgment for liquefaction of nuclear power plant shall comply with the current national standard "Code for Seismic Design of Nuclear Power Plants" GB 50267.

4.7 Side Slope Engineering

4.7.1 The investigation for side slope engineering shall find out the followings:

1 The landform. If there are adverse geological actions such as landslide, crag, eboulement and debris flow etc., it shall be in accordance with the requirements in Chapter 5 of this code;

2 The type, origin and engineering properties of rock and soil, overburden thickness, shape and gradient of bedrock surface;

3 The feature of the principle structural plane including type, attitude, extending, closure degree, filling condition, water-filling condition, mechanical properties and combination relationship, the relationship of principle structural plane and free plane, and whether there is extroversion structural plane or not;

4 The character of underground water such as type, water level, hydraulic pressure, quantity of water, recharging and fluctuation, permeability of rock and soil, and emergence of underground water;

5 The regional meteorological condition (in particular, the rain period and rainstorm intensity), catchments, the vegetation covering the slope, the erosion of surface water to the surface and foot of slope;

6 The physical and mechanical properties of rock & soil, the shear strength of the soft and weak structural plane.

4.7.2 The investigation for large-scale side slope should be conducted in stages, and that in each stage shall be in accordance with the following requirements:

1 In the preliminary investigation stage, the geological data shall be collected; engineering geological mapping and a little of exploration and lab test shall be done; the stability of side slope shall be assessed preliminarily;

2 In the detailed investigation stage, the engineering geological mapping, exploration, testing, observation, analysis and calculation for the potential unstable side slope and its adjacent section shall be conducted; the stability shall be assessed; the optimum excavation slope angle for the side slope shall be found out and the recommendations about the treatment of the side slope to be potential failure shall be put forward;

3 In the construction investigation stage, the geological log, checking up and supplementation for the investigation data from the to former stage shall be done in consideration of construction excavation. If necessary, to forecast the safety of construction and put forward the recommendations about the revised design.

4.7.3 Besides the requirements in Chapter 8 of this code, the engineering geological mapping of side slope shall also find out the shape and slope angle of the natural side slope, the attitude and properties of the soft and weak structural plane. The range of the mapping shall include all the sections affecting the stability of side slope.

4.7.4 The exploratory lines should be laid out perpendicular to strike of side slope and the distance of exploratory points shall be determined according to the geological condition. If the weak interlayer or the adverse structural planes are encountered, the exploratory points shall be densified. The exploratory holes shall be drilled through the potential slipping plane and 2～5m into the stable layer. Besides the routine drilling, the ex-

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ploratory hole, exploratory trench, exploratory well and crooked hole shall also be adopted if necessary.

4.7.5 Samples shall be taken from the main geotechnical layer and the soft and weak layer. For the soil layer, the sample of each layer shall not be less than 6 pieces; for the rocky stratum, it shall not be less than 9 pieces, for the soft and weak layer, it should be continuously sampled.

4.7.6 The selection of the maximum confining pressure in the tri-axial shear test and the maximum normal pressure in the direct shear test shall be similar to the actual load-bearing condition of the sample in the side slope. For the soft and weak structural plane controlling the stability of side slope, in-situ-shear test shall be done. For the large-scale side slope, if necessary, stress testing, wave velocity testing, dynamic testing, pore-water pressure testing and model testing shall be made.

The shear strength index shall be determined according to the factual observation result combining with local experience, and shall be verified through back-analysis method. For permanent side slope, the effect of possible strength decreasing with time shall also be considered.

4.7.7 The stability assessment of side slope shall be carried out on the basis of the determination of failure mode of side slope. It may be assessed synthetically by engineering geology analogy, graphic analytic method, limit equilibrium method and finite-element method. If the condition of each section is different, they shall be analyzed separately.

For the new designed side slope and the important engineering, the stability coefficient F_s of side slope should be 1.30～1.50. For the common engineering, it should be 1.15～1.30, for the secondary engineering, it should be 1.05～1.15. For the peak strength, the bigger value should be taken. For the residual strength, the smaller value should be taken. To calculate the stability of the existing side slope, F_s should be 1.10～1.25.

4.7.8 The monitoring is necessary for the large-scale side slope and the monitoring content may include slope deformation, groundwater fluctuation, and weathering velocity of weathering-susceptible rock.

4.7.9 Besides the requirements in Chapter 14 of this code, the geotechnical engineering investigation report for side slope shall illustrate the following contents:

1 To the engineering geological condition of side slope and the parameters of geotechnical engineering calculation;

2 To analyze the stability of the side slope and the buildings on the slope, and its influence on the construction built at the bottom of side slope;

3 To put forward the recommendations about the optimum slope shape and slope angle;

4 To put forward the recommendations about the rectification measure of the unstable side slope and the monitoring scheme.

4.8 Foundation Pit Engineering

4.8.1 This section is suitable for the investigation of the soiled foundation pit. For rocky foundation pit, it shall be investigated as per the local standards and experience according to the geological structure, feature of rock mass, weathering condition and excavation depth etc..

4.8.2 For the engineering needed to design the foundation pit, the investigation of foundation pit engineering shall be carried out. In preliminary investigation stage, the possible problems resulting from the excavation and bracing measures shall be judged according to the geotechnical condition. In detailed investigation stage, investigation shall be made according to the design requirements of foundation pit. In the construction stage, if necessary, the supplementary investigation shall be implemented.

4.8.3 The range and depth of the investigation for the foundation pit shall be determined according to the site condition and the design requirements. The depth of investigation should be 2～3 times of the depth of the excavation. If it encounters the hardy cohesive soil, gravelly soil and rock in the depth, the depth may be decreased according to classification of rock and soil and the design requirements for the bracing. The investigation range should be 2～3 times of the excavation depth beyond the excavated boundary. In the thick and deep soft soil area, the investigation range and depth shall be extended appropriately. Out of the excavation boundary, the investigation is primarily by mean of surveying, collecting and studying the existing data. There shall be an amount of exploratory points in the complex site and slope site.

4.8.4 Within the area affected by the excavation of foundation pit and where it is possible to set the bracing structure, the distribution of subsoil shall be found out and the shear strength index for the design of bracing shall be provided in layers. The shear strength test for soil shall be in accordance with the design requirements for the foundation pit design, and shall conform to the design standard and be illustrated in the investigation report.

4.8.5 When hydro-geological condition of the site is complex, and the underground water needs to be controlled (dewatering or seepage-proof) during excavation process, when the existed data cannot meet the requirement, special hydro- geological investigation shall be carried out.

4.8.6 If the excavation of foundation pit will lead to the permeable destruction such as quick sand, soil flow and piping effect, special investigation shall be carried out and the

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possibility and its influence on the engineering shall be analyzed. If there is leakage in the process of foundation pit excavation, the seepage effect of underground water should be determined by seepage calculation.

4.8.7 For investigation of foundation pit engineering, the environmental condition shall be investigated; the practical situation, structural features and the bearing capacity for the excavation deformation of the adjacent construction and the underground facilities shall be ascertained. If the underground pipe network distributed densely in the city, the type, layout, embedded depth and scale of the pipeline shall be found out according to geographical information system and other document data. If necessary, the underground pipeline shall be detected by the effective method.

4.8.8 The investigation of foundation pit in the special rock and soil distribution area may be performed according to the requirements in Chapter 6 of this code; impact on the foundation pit due to the creep and long-term strength of soft soil, dehydration and disintegration of soft rock and extreme soft rock, expansibility and fissure of the expansive soil, humidification and softening of unsaturated soil shall be analyzed and assessed.

4.8.9 The recommendations about the treatment of foundation pit side slope shall be put forward according to the excavation depth, geotechnical condition, underground water condition and the environmental demand.

4.8.10 The investigation of foundation pit shall provide the relevant calculation parameters and recommendations according to analysis of the follows:

1 The local stability, monolithic stability of side slope, and the anti-heaving stability of the foundation pit bottom;

2 The seepage stability of the bottom and side wall of foundation pit;

3 The possible deformation of retaining structure and the side slope;

4 The dewatering effect and its influence on environment;

5 The influence resulting from the excavation and dewatering on the adjacent buildings and underground pipelines.

4.8.11 In the geotechnical engineering investigation report, the part related with the foundation pit shall include the followings:

1 The site condition, subsoil condition and engineering condition related to the foundation pit excavation;

2 Recommendations about the treatment, calculation parameters and selection of bracing structure;

3 Recommendations on the controlling method, calculation parameters and construction controlling of underground water;

4 Recommendations about the construction method and the prevention and processing measures for the possible problems;

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5 Recommendations on the environmental protection and the monitoring work during the construction.

4.9 Pile Foundation

4.9.1 The geotechnical engineering investigation for pile foundation shall include the followings:

1 To find out type, depth, distribution, engineering properties and the variation discipline of subsoil;

2 If the bearing layer of pile is bedrock, the character of bedrock such as lithology, configuration, rock plane variation and weathering degree shall be found out; the hardness, integrity degree and basic rock quality designation shall be determined; and to identify whether there is cavity, free face, fragmented rock and soft and weak rock layer;

3 To find out the hydro-geological condition; assess the influence of underground water on design and construction of pile foundation; and judge the corrosivity of underground water to the building material;

4 To ascertain the adverse geological actions, the distribution of liquefaction soil layer and the special rock and soil and their hazard degree, and put forward the recommendations about the prevention and processing measure;

5 To illustrate the possibility of pile-driving, the constructing condition of the pile and its influence on environment.

4.9.2 The interval of the exploratory points for soil foundation shall be in accordance with the following requirements:

1 For end bearing pile, it should be 12～24m; the elevation difference of the bearing layer discovered between adjacent exploratory holes should be within 1～2m;

2 For friction pile, it should be 20～35m. If the stratum condition is complex or the design demand is special, the exploratory points shall be densified appropriately;

3 For the single column with corresponding single pile engineering in the complex subsoil, a exploratory point should be set for each column.

4.9.3 The drilling, penetration test and other in-situ testing shall be adopted for the geotechnical engineering investigation of pile foundation. The testing method for soft soil, cohesive soil, silty and sandy soil should be cone static penetration test and standard penetration test. For gravelly soil, the heavy cone dynamic penetration test or the super-heavy cone dynamic penetration test should be adopted.

4.9.4 The depth of exploratory holes shall be in accordance with the following requirements:

1 The depth of general exploratory hole shall be drilled (3～5)d (d is the diameter of the pile) below the pile end and must not be less than 3m. For larger diameter

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pile, it must not be less than 5m;

2 The depth of controlling exploratory hole shall meet the checking calculation demand of underlying layer. For the pile foundation needed to be calculated the deformation, it shall be greater than the calculated depth of the foundation deformation;

3 When soft and weak layer is encountered within the predicted depth, the depth of that shall be increased. When hard rock is encountered, the depth shall be decreased appropriately;

4 For the socket pile, it shall be drilled to (3～5) d below the predicted imbedded rock plane of pile end and through the karst cavity and fractured zone to stable layer;

5 If the pile length is various, it shall be determined depending on the longest pile.

4.9.5 The geotechnical laboratory test shall meet the following requirements:

1 If it is needed to estimate the side resistance force and the end resistance force of the pile and to verify the strength of the underlying layer, the tri-axial shear test or unconfined compressive strength test should be made. The stress condition of the tri-axial shear test shall simulate the practical situation of engineering;

2 If the pile foundation engineering needs to estimate the deformation of pile foundation, compression test shall be performed. The maximum pressure shall be more than the sum of overburden self-weight pressure and additional pressure;

3 If the bearing layer is bedrock, rock sample shall be taken and saturated uniaxial compressive strength test of the rock sample shall be performed. If necessary, softening test shall also be conducted. For soft rock and extremely soft rock, uniaxial compressive strength test of natural moisture may be conducted. For frangible and extremely frangible rock, in-situ testing should be performed.

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4.9.6 The vertical and horizontal bearing capacity of the single pile shall be determined according to engineering grade, properties of rock and soil, result of in-situ testing and the local experience. If the design grade for the foundation is Grade Ⅰ and the area where there is little experience, static loading test shall be advised to be conducted. The number of the static loading test should not be less than 1% of the number of engineering piles and shall be more than 3 for each site. For the pile bearing more horizontal load, horizontal loading test of pile is advised to be conducted. For the pile bearing uplifting force, anti-uplifting test is advised to be conducted. The investigation report shall provide the estimated value of skin friction resistance force and end resistance force of pile foundation from rock and soil. If necessary, it shall provide the esimated value of the vertical and horizontal bearing capacity and anti-uplifting capacity.

4.9.7 For the pile foundation needed to calculate the deformation, the deformation parameters of each layer shall be provided and the deformation shall be estimated according

to the task demand.

4.9.8 Besides the requirements in Chapter 14 of this code and the bearing capacity and deformation shall be provided as per Article 4.9.6 and Article 4.9.7, the geotechnical engineering investigation report for pile foundation engineering shall also include the followings:

1 To provide the optional pile foundation type, pile end bearing layer and the recommendations about the length and the diameter of pile;

2 If there is soft and weak underlying layer, to verify the strength of the underlying layer;

3 For the engineering with under-consolidated soil and with large area load heaped, the possibility of negative skin friction of pile to be caused and its influence on the bearing capacity of pile foundation shall be analyzed, and to provide the negative skin friction coefficient and the recommendations about the measure for reduction of negative skin friction;

4 To analyze the possibility of pile-driving, and the influence of pile-driving and soil-squeezing shall be analyzed, and put forward the recommendations about the protection measure;

5 If the bearing layer is inclined stratum, the bedrock surface is uneven or there is cavity in the rock and soil, the stability of pile shall be assessed and put forward the recommendations about treatment.

4.10 Subsoil Treatment

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4.10.1 The geotechnical engineering investigation for the subsoil treatment shall meet the following requirements:

1 To provide the geotechnical properties parameters needed for the design and construction of subsoil treatment according to the adoptable subsoil treatment scheme;

2 To predict the influence from the treatment on the environment and the adjacent buildings;

3 To provide the recommendations about subsoil treatment scheme;

4 To if the site condition is complex and there is little experience, test or contrast test shall be made for the proposed schemes in the construction site to examine the design parameters and treatment effect;

5 To during the construction stage of subsoil treatment, the construction quality and the influence of construction on environment and the adjacent engineering shall be monitored.

4.10.2 The geotechnical engineering investigation for the replacement and filling method should include the followings:

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1 To ascertain the distribution range and the embedded depth of the adverse soil layer to be replaced and filled;

2 To measure the optimum water content and the maximum dry density of the replacement and the filling material;

3 To assess the bearing capacity and the sliding resistance stability of the soft & weak underlying layer, and estimate the settlement of buildings;

4 To assess the influence of the replaced and the filled material on the underground water environment;

5 To put forward the recommendations for the course of the replacement and filling process;

6 To carry out inspection or in-situ test on the quality of the replacement and the filling cushion.

4.10.3 The geotechnical engineering investigation for preloading shall include the followings:

1 To ascertain the formation condition, the horizontal and the vertical distribution of subsoil, the embedded depth and thickness of water drainage layer and sand intercalation, the supplying and drainage condition of the underground water;

2 To provide pre-consolidation pressure, compressibility parameters, consolidation property parameters, shear strength index and the growth discipline of strength during the course of preloading;

3 To estimate steps, increment, loading rate, preloading period, the possible growth of intensity and the possible settlement of the preload;

4 For important engineering, it is recommended to select representative test; to area to do preloading test; to adopt the laboratory test, in-situ testing, in-situ monitoring of deformation and pore-water pressure etc. to reckon coefficient of consolidation of soft soil, the relationship between the degree of consolidation and time and the final settlement, and to provide reliable basis for design and construction of preloading;

5 To examine the effect of preloading. If necessary, to conduct the loading test in the site.

4.10.4 The geotechnical engineering investigation for dynamic compaction method should include the followings:

1 To ascertain composition, distribution, intensity, compressibility of subsoil, water permeability and the underground water condition within the depth effected by dynamic compaction;

2 To find out the position and elevation of the underground pipeline and structures in the construction site and surroundings affected. To ascertain whether there are facilities sensitive to vibration, and whether need monitoring during the construction of

dynamic compaction;

3 To select the representative test area to do dynamic compaction test, with laboratory test, in-situ testing and field monitoring to find out the effective stabilization depth, compaction energy, the relationship between compaction frequency and compacted settlement through dynamic compaction, vibration and the upheaval of the ground, the growth and the dissipation discipline of pore-water pressure surrounding the area where dynamic compaction is done.

4.10.5 The geotechnical engineering investigation for pile and soil composite foundation should include the followings:

1 To find out the distribution and embedded depth of blind pond, blind groove, blind drain and cavity and so on;

2 To find out the composition, distribution, physical and mechanical properties of subsoil, the thickness and embedded depth of soft and weak soil, embedded depth of the relative hard layer which may be the bearing layer of pile foundation;

3 To predict the possibility of pile-driving (Whether there are underground obstacles, underground cavity, underground pipeline and cable etc.) and the impact of pile-driving on the surrounding soil mass, the adjacent buildings, the engineering facilities and the environment (noise, vibration, lateral soil-squeezing, ground subsidence and ground upheaval), the interaction between the pile and the water and soil (corrosivity of the underground water to pile material and the contamination of pile material to surrounding water environment);

4 To assess the bearing capacity of soil inter-pile and estimate the bearing capacity of single pile and the composite foundation;

5 To assess the soil inter-pile, the pile body, composite foundation, and the compressibility of the subsoil in the calculated depth of deformation under the pile end. Estimate the settlement of the composite foundation if necessary;

6 For the engineering needed to checking calculate the stability of composite foundation, the shear strength of the soil inter-pile and the pile body shall be provided;

7 If necessary, to conduct static loading test of soil inter-pile, single pile and composite foundation according to the design of composite foundation to inspect the bearing capacity of composite foundation.

4.10.6 The geotechnical engineering investigation for grouting should include the followings:

1 To find out the grain size distribution and the porosity of subsoil or fracture width and distribution discipline of rock, permeability of rock and soil, the embedded depth, flowing direction and flowing velocity of the underground water, the chemical component and the organic content of rock and soil. The permeability of rock and soil

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should be determined by field test;

2 To select the grout and the grouting method (permeation grouting, splitting grouting and compression grouting) according to the geotechnical properties and the engineering requirement to determine centration, viscosity, pressure, condensation time, effective stabilization radius or range according to local experience and field test, and to assess the bearing capacity, compressibility, stability and impermeability of the stabilized foundation;

3 In the stabilization procession, to conduct deformation observation of existing buildings and underground pipeline to control the grouting sequence, grouting pressure and grouting rate;

4 To inspect the effect of grouting stabilization through excavation, laboratory test, dynamic test and other in-situ tests;

5 After the grouting stabilization, the settlement of the buildings or structure shall be observed until the settlement reaches stable. The observation time should not be less than half of a year.

4.11 Load Augment and Protection of Existing Buildings

4.11.1 The geotechnical engineering investigation for the load augment and protection of existing buildings shall be in accordance with the following requirements:

1 To collect the data such as buildings load, structure features, function features and intactness, and foundation type, embedded depth, layout, foundation base contact pressure and deformation observation data, and water-exploitation history, water level lowered, drop rate of underground water in the site and its region, ground subsidence, ground deformation, occurrence and development of ground crack;

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2 When assessing the impact on the buildings due to floors-adding, load augment and large area load heaped in the area adjacent to the site, the bearing capacity of subsoil, the possible additional settlement and differential settlement caused by the load augment shall be found out. For buildings built at the slope, its stability shall be also checking calculated;

3 For the successive buildings or the new buildings to be built near the existing building, the change of stress condition and its influence on the subsoil of existing building caused by the new buildings built shall be analyzed;

4 When assessing the influence on the existing buildings caused by underground water pumping, the influence on the existing buildings resulting from consolidation of the subsoil, ground subsidence, inclination, flexure, and fracture caused by water-pumping shall be analyzed, and its development trend shall be predicted;

5 When assessing the influence on existing buildings by foundation pit excava-

tion, the shear upheaval of the foundation pit bottom caused by the excavation unloading, piping effect caused by water head difference inside and outside of the foundation pit, the deformation and displacement and failure of the pit wall soil shall be analyzed. At the same time, the adverse environmental effect of differential ground subsidence caused by foundation pit dewatering shall also be analyzed;

6 When assessing the effect of the underground engineering construction acting on the existing buildings, the deformation and rupture such as the ground subsidence and flexure caused by stress redistribution of rock and soil, the environmental effect of dewatering, meanwhile, the impact on the existing buildings due to deformation or collapse of surrounding rock acting shall be analyzed;

4.11.2 The geotechnical engineering investigation for the floors-adding and load-augment of the existing buildings, and large area load heaped in the neighboring area shall include the followings:

1 To analyze the practical load-bearing condition degree of subsoil, the structure and material status of the existing building, and its adaptive capacity of the new added load and additional settlement;

2 The exploratory points shall be laid out along the outside of foundation. If any, they should be placed along the center line of foundation, and not less than 3 exploratory points should be set for each building. Certain number of exploratory points should be set at the suitable space away from outside of the foundation;

3 Besides the drilling, the method of exploration should include exploratory well, cone static penetration test or pressuremeter test. The interval of sampling and pressuremeter test should be 0.5m within the depth of foundation width below the foundation bottom; beyond the depth, it may be 1m. If necessary, the exploratory well should be specially laid out to ascertain the type, size and material of foundation, and subsoil treatment condition;

4 In the result of the compressive test, there shall be e-lg$p$ curve, the pre-consolidation pressure, compressive index, rebounding index, coefficient of consolidation which is relevant to the vertical effective pressure of soil after the load augment, and the result of tri-axial unconsolidated un-drained shear test. If there will be more floors-adding or the larger load-augment, static loading test shall be conducted to provide linear limit load, ultimate load, deformation modulus and rebounding modulus of the main load-bearing layer;

5 In the geotechnical engineering investigation report, the bearing capacity of subsoil after load augment shall be analyzed and assessed mainly; the possible additional settlement and differential settlement shall be predicted; and the recommendations aboutthe design scheme, construction measures and the deformation monitoring shall be

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put forward.

4.11.3 The geotechnical engineering investigation for successive buildings or the new buildings built near the existing buildings shall meet the following requirements:

1 Besides the requirements in the Item 1 in Article 4.11.2 of this code, the structure of buildings and the capacity of adapting the local flexure of the material shall also be assessed;

2 Besides the relevant requirements of the layout of exploratory points for the newly built building in Section 4.1, the exploratory points at intersection of successive construction or the new construction near the existing building shall be also set out for studying of subsoil, foundation structure and the material status. Among which there should be exploratory well and cone static penetration test hole and the number of those should not be less than 3 and the interval of sampling should be 1m;

3 In the result of compression test, there shall be e-lg$p$ curve, pre-consolidation pressure, compressive index, rebounding index, coefficient of consolidation which is relevant with the vertical effective pressure of soil after load augment, and the result of tri-axial unconsolidated un-drained shear test;

4 In the geotechnical engineering investigation report, assessment of new compression and relevant differential settlement resulting from the load of newly built buildings acting on the subsoil under the existing buildings shall be performed. The impact on the existing buildings due to excavation, dewatering and piling shall be assessed, and the recommendations on the design scheme, construction measures and the deformation monitoring shall be put forward.

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4.11.4 The geotechnical engineering investigation for dewatering and pumping of underground water shall be in accordance with the following requirements:

1 To study the relationship between the pumping and dewatering of underground water, with embedded condition of aquifer, thickness of compressible soil layer, compressibility of soil and stress history etc., and to make assessment and prediction;

2 The depth of exploratory holes shall exceed the lower limit of compressible layer, and samples lab test or the in-situ testing shall be performed;

3 In the result of compression test, there shall be e-lg$p$ curve, pre-consolidation pressure, compressive index, rebounding index, coefficient of consolidation which is relevant with the vertical effective pressure of soil after load augment, and the result of tri-axial un-consolidated un-drained shear test provided;

4 The geotechnical engineering investigation report shall analyze the possible ground subsidence, deformation, fracture and their influence, and shall put forward measures to protect the existing buildings.

4.11.5 The geotechnical engineering investigation for assessment of the impact on ad-

jacent buildings due to the excavation of foundation pit shall be in accordance with the following requirements:

1 To collect and analyze the data about the adaptive capacity of the existing buildings to the additional settlement and differential settlement, its location relationship with the foundation pit to be excavated in horizon and vertical, the data about dewatering, excavation and bracing likely to be adopted etc.;

2 To find out engineering properties such as stratum structure, the feature, water level and permeability coefficient of aquifer, the shear strength and deformation parameters of soil affected by dewatering and excavation;

3 Besides the requirements in Section 4.8, the geotechnical engineering investigation report shall also analyze and predict the danger of the rebounding at the bottom of the pit and ground surface out of the pit emphatically after unloading, the deformation displacement of the soil surrounding the pit, the shear upheaval and piping effect at the bottom of the pit. To analyze the land subsidence range caused by dewatering and its impact on the adjacent buildings, and put forward the recommendations about the scheme of excavation, bracing, dewatering and monitoring.

4.11.6 The geotechnical engineering investigation for assessment on the influence on the buildings caused by the excavation of foundation pit shall be in accordance with the following requirements:

1 To analyze the existing investigation data. If necessary, some supplementary investigation testing work shall be done;

2 To analyze the groove shape ground subsidence along the principle axis of the underground engineering, the possibility of surface inclination and flexure at the both sides and its surroundings, and its influence on the existing buildings at both sides, and put forward recommendations about the safe and reasonable construction scheme and the measures for protecting the existing buildings;

3 To put forward recommendations on monitoring about ground deformation, the stress state of surrounding rock, and precursor phenomenon of surrounding rock or buildings foundation failure.

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5 Adverse Geological Actions and Geological Disasters

5.1 Karst

5.1.1 **Investigation for karst should be done where there is the existence of karst in or surrounding the site, which affects on the safety of works proposed.**

5.1.2 Investigation for karst should take composite measures such as engineering geological mapping and survey, geophysical prospecting, drilling exploration and so on, and should in compliance with the requirements below:

1 Investigation for feasibility study should ascertain the development condition of Karst cavity and porosity and earth caves and identify its seriousness of damage to the works and development trend, then give preliminary assessment on the stability of the site and suitability of the project;

2 Preliminary investigation should ascertain distribution, development degree and development law of the karst cavities and porosity and its associated earth holes, then give areal division according the stability and suitability of the site;

3 Detailed investigation should ascertain location, scale and depth embedded of karst cavities and porosity and earth caves in the site and its area of influence, characteristic of karst filler and the feature of underground water. Then to put forward recommendations on the designing of foundation and processing of karst;

4 Investigation during construction should be a complementary investigation conducted specially for certain areas or the unsettled special problem. When socket pile with larger diameter is to be performed, special investigation for pile foundation should be conducted.

5.1.3 The engineering geological mapping and survey at karst region should include the followings besides requirements in Chapter 8 of this Code:

1 Distribution, shape and development discipline of karst cavity and porosity;

2 Relief and shape of surface of rock mass, thickness of overburden;

3 Storage condition of underground water, variation of water level and movement discipline;

4 Relationship between karst development and landform, tectonic, lithology, and underground water;

5 Distribution, shape and development law of soil cave and collapse;

6 Origin and development trend of earth cave and collapse;

7 Local experience about processing of karst, soil cave and collapse.

5.1.4 Feasibility study and preliminary investigation should be mainly by means of engineering geological mapping and comprehensive geophysical prospecting. The interval of exploration points shall not exceed that specified in Chapter 4 of this Code, and shall be densified in the karst developed areas. Verifying borehole shall be set at representative section if abnormality is found by geophysical probing and geological mapping. The controlling exploration borehole shall be drilled through karst developed zone.

5.1.5 Detailed investigation shall be in accordance with the following requirements:

1 Exploratory lines should be distributed along the axis of buildings, the interval of exploratory points shall not exceed that specified in Chapter 4 of this Code. Every independent foundation shall be set exploratory point if it is in complicated condition;

2 The depth of exploratory borehole shall be in accordance with the requirements in Chapter 4 of this Code, furthermore, some or all of the boreholes should enter bedrock if thickness of underlying subsoil below foundation is not in accordance with Item 1 of Article 5.1.10 in this section;

3 When there is the existence of earth cave within the predicted depth which may affect the stability of foundation, boreholes shall be drilled exceeding 2m below the surface of bedrock, boundary-line of caves should be set if necessary;

4 For foundation of one column supported with single pile, exploratory point should be distributed pile by pile;

5 In the earth cave and collapse developed area, the detailed distribution of that may be ascertained by means of Cone static penetration test, light dynamic penetration test, and drilling with small diameter;

6 Appropriate amount of exploratory pits and exploratory wells may be set when it is needed to ascertain conditions of faults, boundary-line of petrofabric, shape of cavern porosity, earth cave, and collapse;

7 Effective methods for geophysical probing shall be adopted according to the physical condition to carry out verification through drilling at the abnormal point. If there is or might be existing cavity found which is danger to the engineering, exploratory points shall be densified;

8 All the cavities that people can entered shall be entered and explored inside. For those impossibly being entered should be probed through under-well television and so on.

5.1.6 Work amount of investigation during construction should be designed according to the foundation design of karst area and construction requirements. Cone static penetration tests and light dynamic penetration test might be designed in trench excavated at cavities and collapse section. But for key projects or those with larger loading, drilling with small diameter may be set at the bottom of the trench for inspection. For socket

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pile with larger diameter, exploration point should be designed pile by pile. And the depth of exploration shall not be less than 3 times of the pile diameter, meanwhile, not less than 5m below the pile end. When fluctuation of bedrock surface is great below adjacent piles, depth of exploratory should be deepened.

5.1.7 The location of cavities and cavity groups should be ascertained at the following sections in karst area:

1 Development sections of thin soil layer, fissure in soil and cavities of its underlying rock mass;

2 Open fissure developed on rock surface, stone sprout or interface between outcrops rock and soil mass;

3 Intersection of two tectonic fissures and wide fissure belts;

4 Blind karst trough, karst trench, funnels and so on, the negative rock surface section overburdened with soft and weak soil;

5 At the interface of rock and soil with strongly action of underground water and considerably artificial rainfall area;

6 Depression area and near surface water.

5.1.8 Testing and observing of investigation for karst should be in accordance with the following requirements:

1 Connectivity test may be conducted for tracing relationship of blind cavity porosities;

2 Physical and mechanical properties test of rock sample from cavity roof and soil sample from cavity filling may be performed for assessing stability of cavern porosity. And loading test on the roof may be conducted in the site if necessary;

3 If it is necessary to ascertain relationship between soil's character and formation of cavity, humidifying, dilatant, solubility and shear test may be done;

4 When the hydraulic condition of underground water, erosion, connection between surface water and underground water is needed to be ascertain and possibility and development of cavities and collapse is needed to be predicted, the flow speed, flow direction, water level and water quality shall be long time observed.

5.1.9 When one of the following conditions exists, the site can be assigned as unfavorable section as foundation unless treated:

1 Shallow cavites or karst cavites group, big diameter of cavities and unstable section;

2 Covered funnel, trough and so on, and overburdened with soft soil;

3 Where cavities or collapse developed in group;

4 Where karst water can't be drained smoothly and is possible to be temporarily submerged.

5.1.10 When the foundation belongs to one of the followings, adverse impact on the stability of karst can be ignored for Grade Ⅱ and Ⅲ project:

1 The thickness of soil below the foundation exceeds 3 times of the wideness of individual foundation or 6 times that of strip foundation, and there is no condition to form cavities or other ground deformation;

2 Soil thickness between the bottom of foundation and the roof of cavity is less than the above of Clause 1 in Article 5.1.10, but shall be in accordance with one of the followings:

1) Holes or karst funnel is filled with dense deposit and which is impossible to be washed out by water flow;
2) The rock quality designation of cavity is Grade Ⅰ or Ⅱ, the thickness of the roof of cavity exceeds or equals to the span of cavity;
3) The cavity is small and the size of bottom of foundation is larger than the size of cavity with enough supporting length;
4) The section of vertical cavity with width or diameter of less than 1.0m, near sinkhole.

5.1.11 If it is noting in accordance with the conditions in Article 5.1.10 of this Code, the stability of foundation of cavity should be analyzed in accordance with the followings:

1 The roof of cavity isn't stable, but the cavity is filled with dense deposit and no movement of water flow, it can be considered that the deposit is bearing load and assessed as uneven foundation;

2 When calculation parameters are available, the roof of cavity can be taken as the structure of self-bearing weight system to undergo the mechanical analysis;

3 For the area where engineering experience is available, analogy method can be used for assessment of stability;

4 When there are cavity and free face near the foundation, the possibility of overturning or slipping along the critical face shall be verified;

5 When the foundation is soluble rock, such as gypsum and salted rock, adverse effect of continuous soluble erosion should be taken into consideration;

6 Subsoil treatment or pile foundation may be recommended for unstable karst cavities.

5.1.12 Investigation report for karst shall not only be in accordance with the requirements of Chapter 14 in this Code, also include the contents below:

1 The geological background and forming condition of karst development;

2 The pattern, location and elevation of top and bottom of cavity and porosity, earth cave and collapse;

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3 Analysis for stability of karst;

4 Recommendations on karst procession and monitoring.

5.2 Landslide

5.2.1 If there is landslide or possibility of landslide in or surrounding the site, which will affect the safety of works proposed, special investigation for landslide shall be done.

5.2.2 Investigation for landslide shall adopt engineering geological mapping and survey with the coverage of landslide and its surroundings. 1 : 200～1 : 1000 of the scale can be selected for it. And 1 : 200～1 : 500 of that can be used for processing design.

5.2.3 Engineering geological mapping and survey in landslide areas should include the follows also, besides requirements of Chapter 8 in the code:

1 To collect related information about geology, hydrology, weather, earthquake, human activity and so on;

2 The pattern factors and evolvement process of landslide, setting boundary of landslide;

3 The distribution of surface water, underground water, stream and marsh and so on;

4 The abnormal shape of trees and deformation of engineering facilities;

5 The local experience of landslide processing.

Kinescope or photographon shall be taken at the critical sections of landslide.

5.2.4 The distribution of exploratory lines and points shall be designed according to the engineering geological condition, underground water condition and shape of landslide. Exploratory lines shall not only be distributed along the principle slide direction; also some should be along the secondary slide direction. The interval of exploratory points should not be greater that 40m. The exploratory points should be also distributed in the turning point of landslide and place which is predicted to be processed.

Exploration method should not only include drilling exploration, but certain amounts of exploration wells.

5.2.5 Exploratory borehole should be drilled through the lowest landslide surface and enter the stable layer. The controlling exploratory borehole shall enter certain depths of the stable layer and meet the need of landslide processing.

5.2.6 Investigation for landslide should include the followings:

1 To ascertain the location of the surface (belt) of slide in every layer;

2 To ascertain the location, flow direction and character of underground water;

3 To conduct lab test of rock & soil samples collected from the slide, slide surface (belt) and stable layer.

5.2.7 The strength test of soil should be in accordance with the follows during the in-

vestigation for landslide:

1 Superposition shear test at sliding plane in lab and field should be adopted; the multi-shear test of remolded or undisturbed soil should be done for the slide belt and get shear strength of multi-shear and residue-shear;

2 To adopt the method in the condition of load bearing similar to that during sliding;

3 To adopt reverse analysis method to verify the index of shear strength at the slide surface.

5.2.8 The calculation of landslide stability shall be in accordance with the following requirements:

1 To correctly choose representative analysis section and divide the tractive section, main slide section and slide-resistance section;

2 To correctly choose strength index which should be decided synthesizely according to the inspection and testing result, back analysis and local experience;

3 To water pressure and buoyancy force should be taken into consideration, if any.

4 To according to the condition of the slide surface (belt), to choose correct calculation model of plane, circular arc and polygonal line;

5 To when local slide is possible, local stability of should also be checking calculated, not limit to the Mongolic stability;

6 Such factors as seismic, erosion and human activity and so on, which impact on the stability, should be taken into consideration.

5.2.9 The stability synthetic assessment of landslide shall be conducted according to the slide scale, main inducting factors, landslide auspice, and the engineering geological and hydro-geological condition, also stability verifying result. The development trend and hazard degree should be analyzed and the recommendations on processing should be put forword.

5.2.10 Investigation report for landslide shall include the following requirements, besides requirements in Chapter 14 in this Code:

1 The geological background and forming condition of landslide;

2 The pattern factors, properties and evolvement of landslide;

3 Provide the layout of landslide, section of landslide and geotechnical engineering properties index of rock and soil;

4 Analysis on landslide stability;

5 Recommendations on landslide precautions and processing, and monitoring.

5.3 Crag and Eboulement

5.3.1 If there are crags or eboulement in or surrounding the site, which have impact on

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the safety of the works proposed, investigation for the crags and eboulement shall be done.

5.3.2 Investigation for crags and eboulement should be done during the stage of feasibility studying investigation or preliminary investigation stage ascertain the condition, scale, type and range of eboulement occurred, to assess the suitability of project construction, and to give the recommendations on prevention and processing.

5.3.3 The scale of engineering mapping for crags and eboulement should be 1∶500～1∶1000, that for principal profile in eboulement direction should be 1∶200. Besides requirements in Chapter 8 of this Code to the complied with, the followings shall be ascertained:

1 Landform and relief feature, the type, scale, range of eboulement, the size of ebouled body and its direction;

2 The rock quality designation, lithologic feature and weathering degree;

3 Geological configuration, the structural type of rock mass, attitude of structural plane, combination relationship, closure degree, mechanical properties, extending and penetration condition;

4 Meteorology (key point is atmospheric precipitation), hydrology, earthquake and underground water movement;

5 The auspice of eboulement and the cause of eboulement;

6 Local experience for precaution and processing of eboulement.

5.3.4 When the stability of crags needs to be identified, tensile crack should be monitored. For the huge crags with serious damage, forecast should be given about the time, scale, falling direction, path and destruction degree of the possible eboulement in combination with the result of monitoring.

5.3.5 The geotechnical engineering assessment on various crags and eboulement shall be in accordance with the following requirements:

1 The place where there is very large-scale crags and eboulement, with very serious destruction and difficult to be processed shouldn't be selected as project site and the route shall keep away from it;

2 The place where there are relative larger-scale crags and eboulement with serious destruction, crags possible to fall should be stabilized and treated and precautions for the route should be taken;

3 The place with small scale crags and eboulement with slightly destruction can be used as project site. But the unstable crags should be processed.

5.3.6 The geotechnical engineering investigation report for crags and eboulement shall not only in compliance with the requirements in Chapter 14 of this Code, shall also illustrate the range, type of crags and eboulement, and suitability as project site and put forward recommendations on precautions and processing for crags and eboulement.

5.4 Debris Flow

5.4.1 If there is debris flow in or surrounding the site, which is dangerous to the works proposed, special investigation for debris flow shall be done.

5.4.2 Investigation for debris flow shall be done during the feasibility study or preliminary investigation stage, and shall ascertain the forming condition of debris flow and its type, scale, developed stage, and movement rule. Furthermore, the suitability assessment of the site and recommendations on precautions and processing shall be given.

5.4.3 Investigation for debris flow shall be primary in engineering geological mapping and investigation. Mapping shall cover all area from ravine to watershed and area possibly affected by debris flow. The scale of mapping should be in 1 : 50000 for the whole areas and in 1 : 2000～1 : 10000 for the middle and lower stream. The followings shall be investigated also besides the requirements in Chapter 8 of this Code:

1 Melt of ice and snow, intensity of rainstorm, the maximum eboulement at one time, average and largest debris flow, the movement of underground water and so on;

2 Relief and landform characters including the development of ravine, cutting, gradient, bending and roughness; and to classify the forming section, flow section and depositing section of debris flow, then to map the catchments area of the whole ravine;

3 The type of water resource, water amount, catchments condition, gradient of hill, subsoil properties and weathering degree; and to ascertain development of adverse geological action such as fault, landslide, eboulement, talus and so on, and distribution range of solid matter possible to form debris flow;

4 Feature of ravine vertical and horizontal, water drop, and sudden bending in flow section; to ascertain gradient of the slope and stability of ravine, wash and silted deposit of riverbed and trace of debris flow;

5 The distribution of deposit fan, surface configuration, vertical slope, vegetations, transferring of channel, and washing and depositing of deposit section; to ascertain properties, levels, thickness, normal grain size and the maximum grain size of deposit; to identify the origin, depositing rate, and estimating the maximum deposits amount once;

6 The history of debris flow ravine, the ever happened time, frequency, scale, forming procession of all debris flows, the rainfall situation before it and the destruction after it;

7 Human activities such as mining and disposal, building road and cutting slope, cutting woods, land reclamation at steep slope, overgrazing and so on;

8 Local precautions and processing experience of debris flow.

5.4.4 When precautions and processing need to be taken for debris flow, exploration

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and testing shall be conducted to ascertain properties, structure, thickness, solid matter component, the maximum grain size, flow speed, flow amount, amount of washed out and deposited amount of debris flow deposit.

5.4.5 Engineering classification of debris flow should be in compliance with requirements of Appendix C in this Code.

5.4.6 Assessment on suitability of engineering construction in the debris flow area shall comply with the follow requirements:

1 Ravine of class I_1 and class II_1 debris flow shall not be taken as project site and all the routes should keep away from it;

2 Ravine of class I_2 and class II_2 debris flow should not be taken as project site, otherwise, it should be processed when it must be used as project site. The routes should avoidto go through deposit fan directly and should cross it through bridge (pier) projected at the ravine mouth;

3 Deposit section of ravine of class I_3 and class II_3 debris flow can be used as project site, but the mouth of ravine should be bypassed; the routes may go through the deposit fan, and can project bridge in sections and take measures of flood drainage, guiding flow instead of transforming or combining ravines;

4 When there is a lot of debris disposal at the upper stream or project is in progress and change original balance between supply and drainage, the possibility of new debris flow should be predicted again.

5.4.7 The geotechnical investigation report for debris flow should not only be in accordance with the requirements in Chapter 14 of this Code, shall also include the follows:

1 The geological background and forming condition of debris flow;

2 The distribution and properties of forming section, flow section and deposit section, mapping the special engineering geological map;

3 To classify type of debris flow and assess on the suitability of engineering construction;

4 The recommendations on debris precaution and processing and monitoring.

5.5 Goaf

5.5.1 This chapter is applicable to geotechnical engineering investigation for old, present and future goaf. Investigation for goaf shall ascertain the overlying rock formation stability of old goaf, predicte the surface displacement and deformation feature and rule in old goaf, and assess its suitability as the engineering site.

5.5.2 The investigation in goaf area should be primarily to collect information, to make survey and inquiring, and to ascertain the followings:

1 The distribution, amount, thickness, depth, and embedded feature of mineral bed and the lithologic feature and structure of overlying rock formation;

2 The mining range of mineral bed, depth, thickness, time, method and roof management; collapse of goaf, compactness, gap and water log and so on;

3 The deforming feature and distribution, including the ground surface depression pit, stage, location of crack, shape, size, depth, extending direction and relationship with other geological structure, mining boundary, advancing direction of working area and so on;

4 The feature of ground surface depression basin; and to classify middle area, inside edge area and outside edge area, then to determine the characteristic value of ground surface deforming and displacement;

5 The water pumping and draining condition near the goaf and its effect on the stability of the goaf;

6 To collect the deformation of building and prevention and processing experience.

5.5.3 For old and present goaf which features cannot be identified through engineering geological survey, geophysical and drilling exploration shall be done;

5.5.4 For present and future goaf, characteristic value of ground surface displacement and deformation shall be predicted by calculating; the calculating method should refer to that specified in "Specification for Buildings, Water Body, Railway and Main Shaft Coal Column Design and Press Coal Mining".

5.5.5 Goaf should be classified into the unsuitable construction site and relatively stable site according to the mining condition, ground moving basin and deformation feature, and in accordance with the followings:

1 The followings should not be selected as project site:

1) Where discontinuous deformation section is possible to occurred during the procession of mining;

2) Where ground surface moves area actively;

3) Where specially thick mineral bed and the thick outcrop mineral bed with angle of inclination of over 55°;

4) Where the side slope failure and cliff collapse area that is caused by the displacement and deformation of ground surface;

5) Where ground surface inclination is over 10mm/m, ground surface curvature is over 0.6mm/m^2 or ground surface horizontal deformation is over 6mm/m.

2 The suitability should be assessed when take the following area as a project site:

1) Where the ratio of mining depth to thickness is less than 30;

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2) Where the mining depth is small, overlying rock formation is very hard and method of mining is not normal;

3) Where the ground surface inclination is 3～10mm/m. The ground surface curvature is between 0. 2～0. 6mm/m^2 or surface horizontal deformation is 2～6mm/m.

5. 5. 6 For the kiln goaf with small mining range and serious surface deformation and discontinuous deformation, the location, size, embedded depth, mining time, mining method, filling collapse and water filling condition of the goaf and shaft should be ascertained through collecting information, surveying and geophysical, drilling exploration, at the same time, surface crack, location, shape, size, depth, extending direction of pit of depression and relationship with the goaf should be found out.

5. 5. 7 The buildings in the kiln goaf should bypass the ground surface crack and pit of depression. For sub-ordinate building in the area where the ratio of mining depth and mining thickness is over 30, when the ground surface reach stable, the stability assessing is not necessary; when the ratio of mining depth and mining thickness is below 30, the stability of foundation can be assessed according to the foundation base pressure, the depth, range of the goaf and the feature of overlying rock formation, and put forward recommendations on the treatment according to the experience of mining area.

5. 6 Ground Subsidence

5. 6. 1 This section is applicable to geotechnical engineering investigation for large area ground subsidence that is caused by pumping underground water or the lowering of water pressure.

5. 6. 2 For the area where that the ground subsidence has occurred, the investigation for ground subsidence shall be done to ascertain its cause and current situation, and predict the developing trend and put forward the measure of prevention and processing.

For the area where it is possible for ground subsidence to take place, the possibility shall be predicted, and estimated the possible subsidence layer and amount of subsidence, and bring forward the recommendations on prevention and processing ground subsidence.

5. 6. 3 For the cause of ground subsidence, the followings shall be investigated:

1 The landform and micro landform of the site;

2 The age, origin, thickness, embedded condition and soil properties of the Quaternary sediments and distribution of hard layer and soft and weak compressible layer;

3 The consolidated state and deformation parameters of compressible layer below the level of underground water;

4 Embedded condition and pressure feature of aquifer and aquifuge, the permea-

bility coefficient, storage coefficient and other hydro-geological parameters;

5 The condition of recharging, runoff and drainage of underground water, the relationship of aquifers or connection between underground water and surface water;

6 The fluctuation and changing rate of underground water level and water head in the previous;

7 The extracting amount and injecting amount of underground water before and the layers of extracted and injected in the previous;

8 The formation and development procession of dropping funnel of underground water and reverse funnel of underground water injection.

5.6.4 The survey for the current situation of ground subsidence shall be in accordance with the following requirements:

1 To observe the subsidence in the long term according to requirements of precious level surveying, and set elevation benchmark, ground subsidence benchmark and subsidence benchmark in layers according to different structural unit;

2 To observe fluctuation of underground water level, amount of extraction and injection, chemical component, contamination situation and pore-water pressure dissipation and growth;

3 To survey the effect of ground subsidence on the buildings, including settlement of buildings, inclination, crack and their occurring time and development procession;

4 To draw contour map of on ground subsidence in different time, and analysis the relationship between ground subsidence center and water level droped funnel, and relationship between ground rebound and reverse funnel of underground water;

5 To draw the engineering geological zone division map in terms of the feature of ground subsidence.

5.6.5 For the ground subsidence area, according to the engineering geological and hydro-geological condition, the following prevention and processing measures are recommended:

1 To decrease the extraction of underground water and water level depression depth, adjust the extracting sequence, reasonable exploitation; extraction shall be stopped temporarily when serious ground subsidence happened;

2 To artificially recharge and inject to the underground water, and the quality of injected water should be controlled to prevent underground water from contamination;

3 To restrict artificial lowering of the underground water level in the project construction.

5.6.6 For the possible ground subsidence area, shall predict possibility of ground subsidence and estimate amount of ground subsidence and the following prediction and precautions measures may be taken:

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1 To predict the distribution of compressible formation according to engineering geological and hydro-geological condition;

2 To calculate and analyze the amount of ground subsidence and development trend according to test results and observation data such as water-pumping compression test, permeability test, pre-consolidation pressure test, rheological test, loading test and other detect results and subsidence observation materials;

3 To put forward the recommendations on reasonable utilization of underground water, and restriction artificial lowering the groundwater level and the corresponding measures shall be taken for engineering construction in the ground subsidence area.

5.7 Seismic Effect of Site and Foundation

5.7.1 In the area where anti-seismic fortification intensity is equal to or greater than 6 degree, geotehcnical engineering investigation for seismic effect of site and foundation shall be done. Meanwhile, anti-seismic fortification intensity and designed basic seismic acceleration as well as design seismic grouping shall be put forward, and characteristic periodical zoning shall be designed according to national ground motion parameters zoning approved and other-rules.

5.7.2 Sites shall be classified category when the investigation is carried out in the area where anti-seismic fortification intensity is equal to or greater than 6 degree. When the sites lie in dangerous location, special study advises shall be proposed according to the requirements of current standard of the nation "Code for Seismic Design of Buildings" GB 50011.

5.7.3 For the project needing time interval analysis, geological profile, thickness of overburden and shear wave velocity and other related parameters shall be provided according to the design requirement. Seismic safety estimating or seismic fortification zoning may also be done if necessary.

5.7.4 When the data is not enough, exploratory holes set classifying the category of the site shall be drilled beyond the depth of overburden. When the thickness of overburden is over 80m, the exploratory hole should be over 80m deep, and the shear wave velocity of every layer should be measured. For class Ⅲ and Ⅳ buildings with 10 floors and height below 30m, the shear wave velocity of soil should be estimated according to subsoil type and properties as per requirements of the current national code "Code for Seismic Design of Buildings" GB 50011 if there is no shear wave velocity measured.

5.7.5 When the anti-seismic fortification intensity is 6 degree, the liquefaction can be neglected, but for Grade B buildings sensitive to ground subsidence, liquefaction may be identified according to 7 degree. For Grade A engineering, special liquefaction exploration shall be done.

5.7.6 Liquefaction of the site shall be preliminarily judged firstly. Initial judge should be done in the yard seism liquefaction, when liquefaction is possible judged through preliminary determination, and then the further judged shall be done. The judgment of liquefaction shall make use of many methods to determine synthetically the class and possibility of liquefaction.

5.7.7 Preliminary judgment of liquefaction shall be done according to the current relevant national seismic codes, standards and specifications, and shall also include the followings:

1 Analysis of land form, ground feature, formation, underground water of the site and site condition in relation to liquefaction;

2 When there is historical seismic liquefaction vestige in or surrounding the site, analysis of the repeating possibility of liquefaction;

3 When the site in inclined or liquefiable layer incline to water surface or free face assessment of, the possibility of soil mass sliding caused by liquefaction.

5.7.8 The further judgment of seismic liquefaction shall be performed within 15m below the ground surface; for pile foundation and natural foundation with embedded depth of over 5m, the judgment depth should be deepened to 20m. The exploratory points allocated to determine liquefaction shall not be less than 3, and the depth of exploratory hole shall be deeper than that of of judgement liquefaction.

5.7.9 The further judgment on seismic liquefaction shall not only be in accordance with requirements in the current national code "Code for Seismic Design of Buildings" GB 50011 but also adopt other mature methods to conduct comprehesive judgment.

When standard penetration test is used to determine liquefaction, blows of SPT recorded in every hole shall be based on. In the stratum to be judged, the vertical interval of test should be 1.0～1.5m and tests in every layer should not be less than 6.

5.7.10 For all the liquefied sites, liquefaction index and class shall be determined according to requirements in the current national code "Code for Seismic Design of Buildings" GB 50011.

Investigation report should not only illustrate the liquefiable stratum and liquefaction index of every hole, also determine synthetically the site liquefaction class according to liquefaction index of every hole.

5.7.11 Possibility of seismic subsidence should be identified and the amount of subsidence should be estimated for the area where there is thick soft soil and anti-seismic fortification intensity is equal to or greater than 7 degree.

5.7.12 When there is adverse geological action such as landslide, slipping, eboulement, collapse, debris flow, goaf in or surrounding the site, special investigation shall be done to analyse and assess the stability under earthquake action.

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5.8 Active Fracture

5.8.1 Investigation for active fracture (hereinafter called fracture) shall be done in the key site with anti-seismic fortification intensity equal to or greater than 7 degree. Investigation for fracture shall ascertain location and type of fracture and analysis its activities and seismic effect, predict its possible effect on the engineering construction, and propose treatment for it.

For investigation for fracture of nuclear power station, special research shall be conducted as per the codes and guidelines of nuclear safety.

5.8.2 Seism engineering classification of fracture shall be in compliance with the following requirements:

1 Holocene Epoch active fracture is the fracture that seismic activity has occurred since Holocene geological epoch (ten thousand years) or is going on recently, and it may be continue in the coming 100 years; that magnitude of earthquake equal to or greater than 5 degree has happened in the medium-term of or recently (in recent 500 years), or may happen in the coming 100 years may be designated fracture inducting earthquake.

2 Non-Holocene Epoch active fracture: the seismic activity has happened before 10 thousand years, but never happened in the recent 10 thousand years.

5.8.3 The Holocene Epoch active fracture may be classified into the follows according to Table 5.8.3.

Table 5.8.3 Classification of Holocene Epoch Active Fracture

Index / Fracture classification		Activities	Average Activity Velocity (mm/a)	Historial earthquake magnitude (M)
Ⅰ	Strongly Holocene Epoch active fracture	Having activity since Middle-Late Pleistocene and has strongly activity in Holocene Epoch	$v>1$	$M\geqslant 7$
Ⅱ	Moderately Holocene Epoch active fracture	Having activity since Middle-Late Pleistocene and moderately strong activity in Holocene Epoch	$1\geqslant v\geqslant 0.1$	$7>M\geqslant 6$
Ⅲ	Slightly Holocene Epoch active fracture	Having slightly activity in Holocene Epoch	$v<0.1$	$M<6$

5.8.4 Investigation for fracture shall collect and analyse related referenced documents, including satellite aerophotograph, regional tectonic geology, and epicenter distribution of strong earthquake, ground-stress and ground strain, and earthquake happened before and recently and so on.

5.8.5 Engineering geological mapping for fracture investigation shall also investigate the follows, besides shall be in accordance with the requirements in Chapter 8 of this Code:

1 Landform and geomorphologic feature: mountainous area or plateau continuously ascending and be eroded or having long-distance smooth boundary-line; steep slope, cliff, deep cutting linear valley not caused by lithology, a series of landslide, eboulement and dilluvial deposit fan overlapped in front of mountain, oriental dash linear remaining hill, depression, swamp, bulrush land, salina, lake, water drop, spring, thermal spring and so on; oriental distributed water system or accordant distortion, dislocation and so on;

2 Geological character: the Quaternary distortion and dislocation remained by recent fracture activity, feature of underground water and vegetation; the rupture and cementation of fracture belt and so on; radioactivity carbon14 (C^{14}) method should be used for dark-color material and thermal resolution light or uranium series method for light-color material, to measure the geological age of dislocated formation and non-dislocation formation, and decide the latest period of fracture activity;

3 Seismic character: fault, ground crack, eboulement, landslide, seismic lake, transferring of river course and liquefaction of sandy soil and so on in relation to earthquake.

5.8.6 Large-scale industrial construction site shall be recommended to keep away from Holocene Epoch active fracture and fracture incurring earthquake during feasibility research investigation. The distance away from it should be decided synthetically according to the class, scale, properties of fracture, overburden thickness, seismic intensity and other related factors, combined with related criteria. On the contrast, non-Holocene Epoch active fracture needn't to be avoided. But when it is shallow embedded and rupture belt of it is well developed, it may be treated as uneven foundation.

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6 Special Rck & Soil

6.1 Collapsible Soil

6.1.1 The section is applicable to the geotechnical engineering investigation for collapsible gravelly soil, collapsible sandy soil and other collapsible soil except collapsible loess in drought and semiarid areas. As for the investigation for collapsible loess , the current national standard "Code for Building Construction in Collapsible Loess Regions" GB 50025 should be executed.

6.1.2 While the laboratory collapsible test cannot be carried out with sample, the field loading test shall be done to ascertain collapsibility. If the ratio of the additional collapse verse the width of the loading plate is equal to or greater than 0.023 achieved by soaking loading test under the 200kPa pressure, the soil should be judged as collapsible soil.

6.1.3 The in-situ investigation of collapsible soil should abide by the rule in Chapter 4 of the Code, at the same time, should be in accordance with the following requirements:

1 The space between exploratory holes should take the small value specified in Chapter 4. If the distribution of collapsible soil is extremely uneven, exploratory holes should be densified;

2 The control exploratory holes should penetrate through the layer of collapsible soil;

3 The age, origin, distribution and interlayer, contains, the ingredient feature and component of cement shall be ascertained through investigation;

4 To ascertain the mechanical properties of collapsible gravelly soil and collapsible sandy soil, should adopt dynamic penetration test and standard penetration test;

5 Un-disturbed soil samples shall be taken from exploratory well;

6 Besides to measure the routine physical & mechanical properties of un-disturbed soil samples, the soil collapsibility and soaking test shall be done;

7 If un-disturbed soil samples can't be taken, large volume method should be adopted to mensure the density and water content of collapsible soil;

8 As for the collapsible soil with the thickness above 2m, soaking loading test should be separately carried in the different depth and not affected by neighboring one.

6.1.4 The geotechnical engineering assessment for collapsible soil shall accord with the requirements below:

1 The classification of the collapsible degree of collapsible soil shall be in accordance with that specified in Table 6.1.4;

2 Loading test or other in-situ test should be adopted to measure bearing capacity of collapsible soil;

3 As for the slope of collapsible soil, when the strength of collapsible soil itself or the contacting plane with underlying stratum reduces due to soaking factors, stability assessment shall be carried on.

6.1.5 When collapsible subsoil is soaked, it will sink and at last be stable. The total collapse Δ_S(cm), should be calculated by the formula below:

$$\Delta_S = \sum_{i=1}^{n} \beta \Delta F_{si} h_i \qquad (6.1.5)$$

Where ΔF_{si}——Additional collapse (cm) of the i layer under soaking loading test;

h_i——The thickness of the i layer, calculated from the foundation base (from 1.5m under the ground in preliminary investigation), while $\Delta F_{si}/b < 0.023$, not calculated;

β——Modified coefficient (cm^{-1}). While the area of loading plate is 0.50m^2, $\beta = 0.014$; while the area of loading plate is 0.25m^2, $\beta = 0.020$.

Table 6.1.4 Classification of the Collapsibity

Test / Conditions Collapsible degree	Additional collapse ΔF_s (cm)	
	Area of loading plate 0.50m^2	Area of loading plate 0.25m^2
Slight	$1.6 < \Delta F_s \leqslant 3.2$	$1.1 < \Delta F_s \leqslant 2.3$
Moderate	$3.2 < \Delta F_s \leqslant 7.4$	$2.3 < \Delta F_s \leqslant 5.3$
Strong	$\Delta F_s > 7.4$	$\Delta F_s > 5.3$

Note: As for collapsible silty sand that the undisturbed sample can be obtained by sampler, the test method and the assessment standard should be executed according to the current standard "Code for Building Construction in Collapsible Loess Regions" GB 50025.

6.1.6 The collapse grade of collapsible soil subgrade should be judged according to the Table 6.1.6.

6.1.7 The treatment of collapsible soil subgrade should be determined comprehensively by such factors as soil character, collapse grade and local construction experience.

Table 6.1.6 Collapse Grade of Collapsible Soil Subgrade

Total collapse settlement Δ_s (cm)	Total thickness of collapsible soil (m)	Collapse grade
$5 < \Delta_s \leqslant 30$	>3	Ⅰ
	$\leqslant 3$	Ⅱ
$30 < \Delta_s \leqslant 60$	>3	
	$\leqslant 3$	Ⅲ
$\Delta_s > 60$	>3	
	$\leqslant 3$	Ⅳ

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6.2 Red Clay

6.2.1 The section is applicable to the geotechnical engineering investigation for red clay (including original red clay and secondary red clay). If the clay with high plasticity is reddish brown or brownish yellow in color, covers above carbonate rock, its liquid limit is greater than or equal to 50%, then the clay should be judged as original red clay. After conveying and sedimentation, if its basic feature is still preserved and its liquid limit is above 45%, it can be judged as secondary red clay.

6.2.2 The geotechnical engineering investigation in red clay areas should focus on ascertaining its distributing state, fissure development character and subgrade uniformity.

1 The state of red clay is judged besides by liquidity index, and also by the index specified in Table 6.2.2-1;

Table 6.2.2-1 Classification of Red Clay State

State	Ratio of water content α_w
Hard	$\alpha_w \leqslant 0.55$
Non- plastic	$0.55 < \alpha_w \leqslant 0.70$
Low plastic	$0.70 < \alpha_w \leqslant 0.85$
Medium plastic	$0.85 < \alpha_w \leqslant 1.00$
High plastic	$\alpha_w > 1.00$

Note: $\alpha_w = w/w_L$.

2 The structure of red clay can be classified according to fissure development character in Table 6.2.2-2;

3 Repeated soakage character can be classified according to Table 6.2.2-3;

4 Subgrade uniformity of red clay can be classified according to Table 6.2.2-4.

Table 6.2.2-2 Classification of Red Clay Structure

Soil mass structure	Fissure development character
Dense	Fissure seen occasionally (<1 strip/m)
Chunk	More fissure (1~2 strips/m)
Fragmentary	Abundant fissure (>5 strips/m)

Table 6.2.2-3 Repeated Soakage Feature Classification of Red Clay

Class	Relation between I_r and I'_r	Repeated soakage character
Ⅰ	$I_r \geqslant I'_r$	Repeated soakage swell after shrinkage, can be restored to original state
Ⅱ	$I_r < I'_r$	Repeated soakage swell after shrinkage, can not be restored to original state

Note: $I_r = w_L/w_P$, $I'_r = 1.4 + 0.0066 w_L$.

Table 6.2.2-4 Subgrade Uniformity Classification of Red Clay

Subgrade uniformity	Composition of rock & soil within subgrade compressive layer
Uniform subgrade	Fully composed of red clay
Nonuniform subgrade	Composed of red clay and rock

6.2.3 The geotechnical engineering mapping and investigation in red clay areas should

be carried on according to the requirements in Chapter 8 of this code, and emphatically ascertain the following contents:

1 Red clay characters and differences in different topography unit such as distributing, thickness, material composition and soil properties;

2 Underlying bedrocks sproperty, karst's development character and the relation between them and red clay's property, thickness variation;

3 Ground crack distribution, development character and origin, soil mass structure, the density, depth, extending direction and its development mechanism of the fissure in soil mass;

4 Distributing, dynamic state of ground surface waters and groundwater and the relation between them and vertical zoning of red clay status;

5 The crack cause analysis of existing building, local investigation, design, construction experiences etc..

6.2.4 The distribution of exploratory holes in red clay areas shall keep smaller space to ascertain the variation of the thickness and the state of red clay. The space of 30～50m is suitable for preliminary investigation points. As for uniform subgrade, the 12～24m space is suitable for detailed investigation and as for uneven subgrade, the 6～12m. In the section of an area that thickness and state vary greatly, the space between exploratory holes can still be densified. At each stage, the depth of exploratory hole shall be executed according to the relative requirements in Section 4.1 of this code. As for uneven subgrade, the depth of exploratory hole shall reach bedrock.

As for uneven subgrade, while soil cave existing or pile end-bearing on rock being adopted, investigation during construction is suitable to be carried; its space between exploratory holes and the depth of exploratory hole should be decided according to demand.

6.2.5 When geotechnical engineering assessment need to ascertain in detail groundwater embedding conditions, movement discipline and season variation, works such as investigation, test and observation on groundwater should be as supplementary done based on the mapping. Relative requirement should be executed according to requirement in Chapter 7 of the code.

6.2.6 Besides red clay laboratory test should satisfy the requirements in Chapter 11 of the code, for red clay with fissure development conventional triaxial test or unconfined compression strength test should be done. When necessary, shrinkage test and repeated soakage test can be done. When it needs to appraise the stability of slope, repetitive shear test is suitable.

6.2.7 Subgrade bearing capacity of red clay should be decided by the requirements of the Item 4.1.24 in the code. While there is foundation embedded shallowly, outside

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ground surface inclining, with free face or larger horizontal load bearing, the bearing capacity of red clay should be decided comprehensively the factors below:

1 Impact of soil mass structure and fissure on bearing capacity;

2 Impact of excavated surface's exposure for a long time, fissure development and repeated soakage on soil property.

6.2.8 Geotechnical engineering assessment of red clay should be in accordance with the following requirements:

1 Buildings should avoid across dense zone or deep and long ground crack zone;

2 The light building's foundation buried depth should be greater than the depth of stratum affected sharply by the atmosphere; the foundation of high temperature equipment such as kiln should consider uneven shrinkage deformation of subsoil; while digging open canal, the impact of soil mass wet/dry cycle should be considered; in the section that stone spout clint is exposed, the deformation of ground surface resulting from surface water seepage should be considered;

3 While selecting suitable bearing stratum and foundation type, foundation should be embedded shallowly with provision that it meet the requirement, to utilize hard crust at the top layers, but the bearing capacity of underlying stratum shall be checked; while it not satisfy the requirement on bearing capacity and deformation, subsoil treatment or pile foundation should be proposed;

4 While foundation pit is dug, measures should be taken to keep wet and to maintain slope timely, in order to prevent dry shrinkage due to absence of water.

6.3 Soft Soil

6.3.1 Fine-grained soil that its natural porosity ratio is greater than or equal to 1.0 and its natural water content is greater than liquid limit should be judged as soft soil, including sludge, sludgy soil, peat, peaty soil etc..

6.3.2 Soft soil investigation should be besides in accordance with general requirements, and should ascertain the following contents:

1 Formation types, stratification condition, distributing discipline, and stratification character, horizontal and vertical uniformity;

2 The distributing and thickness of hard crust at the ground top, the buried depth and fluctuation of underlying hard soil layer or bedrock;

3 Consolidation history, stress level and impact of structure failure in strength and deformation;

4 Micro topographic form, distributing and buried depth of blind pond, creek, trench, pit cave, and their filling conditions;

5 Impact of excavating, backfill, bracing, engineering dewatering, piling, open

caisson etc. on stress state, strength and compressibility of soft soil;

6 Local engineering experiences.

6.3.3 Investigation in soft soil areas should adopt the combinative methods of boring sampling and cone static penetration test. The distribution of exploratory holes should be decided by soil's origin and subgrade's complexity. While layer of soil varies greatly or there is blind pond, creek, trench, pit cave, the exploratory holes should be densified.

6.3.4 Soft soil sampling should adopt thin wall sampler, and its specification should be in accordance with the rules in Chapter 9 of the code.

6.3.5 In-situ test for soft soil should adopt cone static penetration test, pressuremeter test, vane shear test, dilatometer test and spiral plate loading test.

6.3.6 Mechanical parameters of soft soil should be ascertained by laboratory test, in-situ test and local experiences. If possible, it can be determined based on test, and in-situ monitoring back-analysis. Shear strength index should be got from tri-axial test; in-situ test should bet vane shear test.

Coefficient of compressibility, pre-consolidation pressure, compressive index, rebound index, coefficient of consolidation can be respectively ascertained by using methods such as general consolidation test and high pressure consolidation test.

6.3.7 Geotechnical engineering assessment of soft soil should include the following contents:

1 To judge the possibility of subgrade failure and producing differential deformation; while project locates nearby pond, riverbank and side slope, its stability should be checked;

2 Soft soil subgrade bearing capacity should be ascertained according to laboratory test, in-situ test and local experiences, at the same time comprehensively considering the following factors:

1) Mechanical character such as soft soil stratification condition, stress history, constructibility, sensitivity etc. and drainage condition;

2) Type, rigidity, load property and distribution of upstructure, the sensitivity to uneven settlement;

3) Foundation's type, size, buried depth and rigidity etc.;

4) Construction method and procedure.

3 When building load among adjacent higher and lower buildings differs greatly, deformation difference and interaction should be analyzed; if there is large areas load heaped, adverse impact on adjacent buildings should be analyzed;

4 Stratified summation method or soil stress history method can be adopted to calculate subgrade settlement, simultaneously modify it according to local experiences, if

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necessary, secondary consolidation effect of soft soil should be considered;

5 To bring forward the recommendation on foundation type and bearing stratum; as for double layer soil subgrade that hard layer is in the upper and soft soil in the lower, underlying soft stratum should be checked.

6.4 Mixed Soil

6.4.1 The soil blending with fine-grained soil, coarse-grained soil and being lack of medium size should be judged as compound soil.

While the mass of fine-grained soil smaller than 0.075mm exceeds 25% of the total in gravelly soil, it should be named as coarse-grained compound soil; while the mass of coarse-grained in silt or clay greater than 2mm exceeds 25% of the total mass, it should be named as fine-grained compound soil.

6.4.2 The investigation for compound soil should accord with the following requirements:

1 To ascertain the landform and geomorphic feature, origin and distributing of compound soil, embedded conditions of underlying subsoil or bedrock;

2 To ascertain the composition and uniformity of mixed soil, its varying discipline in horizontal and vertical direction;

3 The space between exploratory holes and the depth of exploration hole should besides satisfy the requirement in Chapter 4 of the code, should also be appropriately increased in density and in depth;

4 There should exist a certain number of exploratory well, and large bulk soil sample should be collected for grain size analyzing and physical and mechanical properties measurement;

5 As for coarse-grained compound soil, cone dynamic penetration test should be adopted, and a certain number of boreholes or exploratory well shall be designed for inspection;

6 The loading bearing plate diameter of field loading test and the shear plane diameter of field direct shear test, should be larger than the 5 times of the largest grain size of test soil layers, the area of loading bearing plate for loading test should not be smaller than 0.5m^2, the area of shear plane for direct shear test shouldn't be smaller than 0.25m^2.

6.4.3 Geotechnical engineering assessment for compound soil should include the following contents:

1 Static loading test and cone dynamic penetration test should be adopted to ascertain bearing capacity of mixed soil, with consideration of local experiences;

2 The allowable gradient value of compound soil slope can be ascertained accord-

ing to site investigation and local experiences. For important projects, special test researches should be conducted.

6.5 Fill

6.5.1 According to material composition and filling pattern, fill can be classified into 4 kinds below:

1 Plain fill: composed of one or several components such as the gravelly, sandy, silty and cohesive soil etc., containing no or much less sundries;

2 Miscellaneous fill: containing large numbers of debris such as constructional debris, industrial waste material or life waste etc.;

3 Alluvial fill: formed by hydraulic fill mud and sand;

4 Compacted fill: formed by tightly compacting or ramming compaction layer by layer with controlling of material composition, density and water content according to a certain standard.

6.5.2 Fill investigation should include the following contents:

1 To gather information, to survey the transferring of landform and ground feature, the sources, the age and accumulated form of fill soil;

2 To ascertain distribution, thickness, material composition, grain size distribution, uniformity, compactness, compressibility and collapsibility of fill;

3 To judge groundwater's corrosivity to construction material.

6.5.3 On the basis of the requirements in Chapter 4 of the code, fill investigation should increase the density of exploratory holes to ascertain the scope of covered pond, creek, pit. The depth of exploratory hole should penetrate the fill layers.

Exploration method should be determined by fill property. As for plain fill composed of silt or clay, the combinative method of drill sampling, light drilling tool and in-situ test can be employed; as for plain fill and miscellaneous fill containing more coarse grained particles, dynamic penetration test, boring test should be adopted, and there should have certain number of exploratory wells.

6.5.4 Fill's engineering properties index should be ascertained by the following testing methods:

1 The uniformity and compactness of fill should be determined through penetration test, and laboratory test auxiliary;

2 The compressibility and collapsibility of fill should be determined through laboratory consolidation test or field loading test;

3 The density test of miscellaneous fill should adopt large volume method;

4 As for compacted fill, before being compacted, the optimum water content and the maximum dry density should be measured, after being compacted, dry density

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should be measured and compacted coefficient should be calculated.

6.5.5 Geotechnical engineering assessment of fill should accord with the following requirements:

1 To illustrate fills composition, distribution and heaped time, to judge subgrade's uniformity, compressibility and compacted degree; if necessary, different layer or zone should be divided and appraised by thickness, strength and deformation character;

2 As for plain fill heaped for a longer time, dradge filling and compound fill composed of construction debris or industrial waste material that character is stable, when they are more uniform and dense, they can be taken as natural foundation; life waste full of organic materials and mixed filling composed of industrial waste material which erode foundation is unsuitable to be taken as natural foundation;

3 Fill subgrade bearing capacity should be comprehensively ascertained by the Article 4.1.24 in the code;

4 When natural slope of fill is above 20%, its stability should be checked.

6.5.6 After pit of fill subgrade is dug, the pit should be examined during construction. After treatment, fill subgrade should be inspected in quality. As for composite foundation, large area loading test should be conducted.

6.6 Permafrost Soil

6.6.1 The soil that contains solid-state water and its freezing state continuously lasts two years or more should be judged as permafrost soil.

6.6.2 According to the amount of thawing settlement coefficient, permafrost soil can be divided into five grades of no thawing settlement, weak thawing settlement thawing settlememt, strong thawing settlement and thawing collapsibility, and the classification should be in accordance with the requirements in Table 6.6.2. Frozen soil's mean thawing settlement coefficient δ_0 can be calculated by the following formulas:

$$\delta_0=\frac{h_1-h_2}{h_1}=\frac{e_1-e_2}{1+e_1}\times 100(\%) \qquad (6.6.2)$$

Where h_1, e_1——The height (mm) and porosity ratio of frozen soil sample before thawed;

h_2, e_2——The height (mm) and porosity ratio of frozen soil sample after thawed;

Table 6.6.2 Classification of Thawing Settlement of Permafrost Soil

Soil type	Total water content w_0(%)	Mean thawing settlement coefficient δ_0	Grades of thawing settlement	Classification of thawing settlement	Frozen soil's type
Gravelly soil, gravel, coarse sand, medium sand (particle smaller than 0.075mm is less than 15%)	$w_0<10$	$\delta_0\leqslant 1$	I	No thawing settlement	Less ice frozen soil
	$w_0\geqslant 10$	$1<\delta_0\leqslant 3$	II	Weak thawing settlement	More ice frozen soil

Table 6.6.2 (continued)

Soil type	Total water content w_0(%)	Mean thawing settlement coefficient δ_0	Grades of thawing settlement	Classification of thawing settlement	Frozen soil's type
Gravelly soil, gravel, coarse medium sand (particle less than 0.075mm is more than 15%)	$w_0<12$	$\delta_0\leqslant1$	Ⅰ	No thawing settlement	Less ice frozen soil
	$12\leqslant w_0<15$	$1<\delta_0\leqslant3$	Ⅱ	Weak thawing settlement	More ice frozen soil
	$15\leqslant w_0<25$	$3<\delta_0\leqslant10$	Ⅲ	Thawing settlement	Abundant ice frozen soil
	$w_0\geqslant25$	$10<\delta_0\leqslant25$	Ⅳ	Strong thawing settlement	Saturated ice frozen soil
Silty sand, fine sand	$w_0<14$	$\delta_0\leqslant1$	Ⅰ	No thawing settlement	Less ice frozen soil
	$14\leqslant w_0<18$	$1<\delta_0\leqslant3$	Ⅱ	Weak thawing settlement	More ice frozen soil
	$18\leqslant w_0<28$	$3<\delta_0\leqslant10$	Ⅲ	Thawing settlement	Abundant ice frozen soil
	$w_0\geqslant28$	$10<\delta_0\leqslant25$	Ⅳ	Strong thawing settlement	Saturated ice frozen soil
Silt	$w_0<17$	$\delta_0\leqslant1$	Ⅰ	No thawing settlement	Less frozen soil
	$17\leqslant w_0<21$	$1<\delta_0\leqslant3$	Ⅱ	Weak thawing settlement	More ice frozen soil
	$21\leqslant w_0<32$	$3<\delta_0\leqslant10$	Ⅲ	Thawing settlement	Abundant ice frozen soil
	$w_0\geqslant32$	$10<\delta_0\leqslant25$	Ⅳ	Strong thawing settlement	Saturated ice frozen soil
Clay	$w_0<w_p$	$\delta_0\leqslant1$	Ⅰ	No thawing settlement	Less ice frozen soil
	$w_p\leqslant w_0<w_p+4$	$1<\delta_0\leqslant3$	Ⅱ	Weak thawing settlement	More ice frozen soil
	$w_p+4\leqslant w_0<w_p+15$	$3<\delta_0\leqslant10$	Ⅲ	Thawing settlement	Abundant ice frozen soil
	$w_p+15\leqslant w_0<w_p+35$	$10<\delta_0\leqslant25$	Ⅳ	Strong thawing settlement	Saturated ice frozen soil
Ice layer containing soil	$w_0>w_p+35$	$\delta_0>25$	Ⅴ	Thawing collapsibility	Ice layer containing soil

Note: 1 Total water content w_0 includes ice and unfrozen water;

2 The table does not include salined frozen soil, frozen peaty soil, humus soil, highly plastic clay.

6.6.3 Geotechnical engineering investigation for permafrost soil should be conducted based on the design principle of permafrost soil, the type and character of permafrost soil, and it shall ascertain the following contents:

1 Distributing scope and the upper limit depth of permafrost soil;

2 Type, thickness, total water content, structural feature, physical and mechanical and thermal property of permafrost soil;

3 Existing form and interrelation of water above permaforst, water in permafrost

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and water below permafrost soil, and its impact on engineer;

4 Grades of thawing settlement of permafrost frozen soil and grades of frost heave of seasonal melting layer;

5 Morphological feature, formation conditions, distributing scope, occurring and developing discipline of adverse geological actions such as thick underground ice, icy centrum, deumlins, frozen soil swamp, slide due to heat melting, heat melting lake and pond, melting and frozen mud flow etc., and its hazard degree on engineering.

6.6.4 The space between exploratory holes in permafrost soil areas should besides satisfy the requirement in Chapter 4 of the code, and be appropriately enhanced in density; the depth of exploratory holes should satisfy the following requirements:

1 As for the subgrade to be designed at frozen state, it should not be less than 2 times of its foundation width below foundation base, as for pile foundation should exceed the end of pile by 3～5m;

2 The foundation to be designed under gradual melting states and under beforehand melting states should be in accordance with the requirements of unfrozen soil foundation;

3 Whatever adopting any design principle, adopting the depth of exploratory holes all should exceed permafrost soil's upper limit depth by 1.5 times;

4 In the permafrost soil's unstable zone, lower limit depth of permafrost soil should be ascertained; while subgrade is saturated frozen soil or icy layer containing soil, that should be penetrated.

6.6.5 The exploratory test for permafrost soil should satisfy the following requirements:

1 Drilling in permafrost soil areas should shorten construction time, and adopt large caliber low-speed drilling. Final hole diameter should not be less than 108mm. If necessary, low temperature mud can be used, avoiding causing artificial melt zone or in-hole freezing nearby exploratory hole;

2 Underground water level should be measured in layers;

3 The exploratory hole at the section to be designed at frozen state should be immediately backfilled after finishing measuring in-hole temperature;

4 Vertical interval for sampling should besides satisfy the requirement in Chapter 4 of the code, and be appropriately enhanced in density at seasonal melting layers, samples should avoid melting in the process of taking, carrying, storing and testing;

5 Test items should be done not only including routine requirements, if necessary, but other test items should be done such as total water content, volume ice content, relative ice content, unfrozen water content, frozen temperature, coefficient of thermal conductivity, frost heaving value, thawing compression; as for salined permafrost soil

and peaty permafrost soil, soluble salt content and organic matter content should still measured respectively;

6 If project needs, the spot to observe the ground temperature can be established for measuring it;

7 When adverse geological actions related to frozen soil melting need to be ascertained, investigation works should be conducted from February to May; the upper limit depth investigation for permafrost soil should be done in September and October.

6.6.6 Geotechnical engineering assessment of permafrost soil should be in accordance with the following requirement:

1 The subgrade bearing capacity of permafrost soil should be ascertained distinctively between subgrade keeping frozen state and subgrade allowing melting, and they can be comprehensively ascertained by loading test or other in-situ test method combining with local experiences, as for sub-ordinary building, it can be determined based on local engineering experiences.

2 Except secondary project, buildings should avoid the zone of saturated frozen soil and section of icy layers containing soil, icy pyramid, drumlins, heat melting lake, thick underground icy layer, the transition zone between melting areas and permafrost soil, and be laid hard rock stratum, the section of less ice frozen soil and more ice frozen soil, the section of lower groundwater level or lower water level above frozen soil layers and plateau with gentle landform.

6.7 Expansive Rock & Soil

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6.7.1 If rock and soil contain a great deal of hydrophilic minerals, its volumes vary more greatly with humidity and produce greater internal stress when its deforming is confined, the rock and soil should be judged as expansive rock and soil. Preliminary judgment of expansive rock and soil should be in accordance with the requirements in Appendix D of the code; on the basis of preliminary judgment, final judgment should be carried in accordance with Article 6.7.7 of the section.

6.7.2 Expansive rock and soil's site can be divided into plain site and sloping site according to topography and landform and geomorphic conditions. The site that accords with one of the following conditions should be designated as plain site:

1 Landform slope less than 5°, moreover local height difference within the same building not exceeding 1m;

2 Landform slope greater than 5° and less than 14°, zone of slopecrest with the horizontal distance above 10m from shoulder of slope.

The site that does not accord with the above conditions should be designated as sloping site.

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6.7.3 Geotechnical engineering mapping and survey in expansive rock and soil's areas should include the following contents:

1 To ascertain expensive rock and soil's property, geological age, origin, altitude, distribution and appearance features such as color, joint, crack etc. ;

2 To divide geomorphic units and site types, to ascertain whether there are shallow landslides, ground crack, and ravine and micro-landform shape, vegetation conditions;

3 To survey surface water's drainage and accumulating conditions, the type, water level, changing discipline of underground water;

4 To gather local meteorological data such as precipitation, evaporation force, air temperature, ground temperature, dry and wet season, drought lasting time etc. , to ascertain climate influenced depth;

5 To investigate local construction experiences.

6.7.4 Investigation for expensive rock and soil should abide by the following rules:

1 Exploratory holes should be laid with consideration of geomorphic units and micro-landform shape; the amount should appropriately be more than that of non-expensive rock and soil, among these the exploratory holes for sampling should not be less than half of all exploratory holes;

2 Besides satisfying foundation buried depth and additional stress's affecting depth, the depth of exploratory hole should still not exceed climate influenced depth; controlling exploratory hole should not be less than 8m deep, general exploratory hole should not be less than 5m deep;

3 In the climate influenced depth, every control exploratory hole should collect soil sample of Grade Ⅰ, Ⅱ, sampling interval should not be greater than 1.0m, beyond the climate influenced depth, sampling interval can be 1.5～2.0m; in the depth from 1m below ground surface to 5m, general exploratory hole can collect soil sample of grade Ⅲ to measure natural water content.

6.7.5 Besides abiding by the requirements in Chapter 11of the code, expensive rock & soil's laboratory test should yet measure the following index:

1 Free swelling rate;

2 Swelling rate under certain pressure;

3 Coefficient of contraction;

4 Swelling force.

6.7.6 In important engineering site and ones with special requests field soaking loading test, shear test or pressuremeter test should be carried. As for expensive rock & soil, clay mineral composition, volume swelling amount and unconfined compression strength test should be carried. For anisotropic expensive rock soil, different direction's

swelling rate, swelling force and coefficient of contraction should be measured.

6.7.7 As for the areas preliminarily judged as expensive rock and soil, swelling deformation value, contracting deformation value and swelling, contracting deformation value should be calculated; and contacting and swelling grades should be divided. The method to calculate and divide expensive rock and soil should be in accordance with the requirements of the current national standard "Specification for Construction Technology in Expensive Rock and Soil's Areas" GBJ 112. If regional experiences are available, it can also be divided with consideration of local experiences.

When there are projects destroyed by expensive rock and soil at or nearby the site, it should be judged as expensive rock and soil, Investigated in detail and expensive rock and soil's damage mechanism to project should be analyzed; and the value of swelling force and the grade of swelling and contracting should be estimated.

6.7.8 Geotechnical engineering assessment of expensive rock and soil should be in accordance with the following requirement:

1 As for the building built on expensive rock and soil, its foundation buried depth, subsoil treatment, pile foundation design, overall layout, architecture and structure measure, construction and maintenance, should accord with the requirements of the current national standard "Specification for Construction Technology in Expensive Rock and soil's Areas" GBJ 112;

2 Grade Ⅰ engineering's subgrade bearing capacity should be ascertained through adopting soaking loading test; Grade Ⅱ project's should adopting soaking loading test; Grade Ⅲ project's can be calculated by adopt unconsolidated and un-drained tri-axial shear test under saturated conditions or can be ascertained according to the existing experiences;

3 As for side slope and the project built on side slope, stability should be checked; when checking, the change of water content in slope body should be considered; for homogeneous soil friction circle arc slipping method can be adopted, for soil containing expensive rock and soil and weak interlayer, the most disadvantageous sliding surface should be checked; expensive rock and soil's side slope with swelling, contracting crack, and ground crack should be checking calculated along crack sliding.

6.8 Salined Rock & Soil

6.8.1 If soluble salt content is above 0.3%, and having engineering character such as dissolved collapsibility, salted heaving, corrosion etc., rock and soil should be judged as salined rock and soil.

6.8.2 According to main ingredient of mineral containing salt, salined rock can be divided into gypsum salined rock and mirabilite salined rock etc.. According to salt chemi-

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cals and salt content, salined soil can be classified as Table 6.8.8-1 and Table 6.8.2-2.

Table 6.8.2-1 Salined soil's Classification as Per Salt Chemicals

Salined soil's name	$\frac{c(Cl^-)}{2c(SO_4^{2-})}$	$\frac{2c(CO_3^{2-})+c(HCO_3^-)}{c(Cl^-)+2c(SO_4^{2-})}$
Chlorine salined soil	>2	—
Chloritic salined soil	2~1	—
Sulfite salined soil	1~0.3	—
Sulfate salined soil	<0.3	—
Alkality salined soil	—	>0.3

Note: $c(Cl^-)$ in the table is chlorine ion's milli-mol number in the soil weighting 100g, others is the same.

Table 6.8.2-2 Salined Soil's Classification as Per Salt Content

Salined soil's name	Even salt content (%)		
	Chlorate and chlorite salt	Sulfate and Sulfite salt	Alkality salt
Weak salined soil	0.3~1.0	—	—
Moderate salined soil	1~5	0.3~2.0	0.3~1.0
Strong salined soil	5~8	2~5	1~2
Supersalined soil	>8	>5	>2

6.8.3 The investigation in salined rock and soil areas shall include the following contents:

1 Salined rock and soil's origin, distributing and character;

2 Saliferous chemical components, salt content and its distributing in the rock and soil;

3 Corrosion hole's developing degree and distributing;

4 To gather meteorological and hydrological information;

5 Underground water's type, buried conditions, water quality, water level and its seasonal variety;

6 Plant growth conditions;

7 Hydrated depth of gypsum salined rock mainly containing gypsum, ground temperature of salined rock containing more mirabilite at the section crossed by tunnel;

8 To investigate local engineering experiences.

6.8.4 Exploratory test of salined rock and soil should accord with the following requirements:

1 Besides abiding by the requirements in Chapter 4 of the code, exploratory holes layout should satisfy requirement to ascertain salined rock and soil's distributing feature;

2 Rock and soil sampling should be carried in the dry season, disturbed soil sampling used for measuring saliferous ion should accord with the requirements in Table 6.8.4:

Table 6.8.4 Requirements of Soil Samping of Disturbed Salined Soil

Investigation stage	Depth	Interval of soil sampling	Percentage of sampling hole in proportion to total exploratory hole
Preliminary investigation	<5	1.0	100
	5~10	2.0	50
	>10	3.0~5.0	20
Detailed investigation	<5	0.5	100
	5~10	1.0	50
	>10	2.0~3.0	30

Note: The depth of shallow foundation's sampling can be terminated at 10m.

3 If engineering needs, adverse capillary water elevating height should be measured;

4 On the basis of salined soil's lithology character, proper in-situ test method such as loading test should be selected; as for dissolved collapsibility salined soil, soaking loading test should yet be carried to ascertain its dissolving collapsibility;

5 As for salt heaving salined soil, its effective salt heaving thickness and total salt heaving amount should be measured in the site; if sodium sulfate content in soil is not above 1%, salt heaving can not be considered;

6 Besides routine laboratory test, dissolved collapsibility test and chemical ingredient's analysis should still be carried; if necessary, microstructure appraisal should be done for rock and soil's structure ;

7 Dissolved collapsibility index can be measured by collapsible test method for collapsible soil.

6.8.5 Geotechnical engineering assessment for salined rock and soil should include the following contents:

1 Saliferous type in the rock and soil, salt content and impact of main saliferous minerals on geotechnical engineering character;

2 Rock and soil's dissloved collapsibility, salt heaving, corrosion and suitability for engineering construction;

3 Saline soil subgrade's bearing capacity should be ascertained through loading test, while adopting others in-situ test method, it should be in contrast with the result of loading test;

4 While ascertaining salined soil subgrade's bearing capacity, water-solubility's impact of salined rock should be considered;

5 Salined rock's slope should be properly designed gentler than soft rock's slope gradient of non-salined rock, weak intercalated layer and fracture zone should be partly and wholly protected;

6 The assessment for corrosivity of salined rock and soil to construction materials should be executed according to Chapter 12 in the code.

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6.9 Weathered Rock and Residual Soil

6.9.1 If rock undergoes weathering, and its structure, ingredient and property produce variation with different degree, the rock should be named as weathered rock. If rock has completely weathered to soil and has not been conveyed, it should be named as residual soil.

6.9.2 The investigation for weathered rock and residual soil should focus on ascertaining the following contents:

1 Parent rock's geological age and rock name;

2 Classification of rock's weathering degree according to Table A.0.3 in the Appendix A of the code;

3 Globular weathered body's (solitary stone) distributing in dyke and weathered granite;

4 Rock and soil's uniformity, fracture zone and weak interlayer's distributing;

5 Groundwater's buried conditions.

6.9.3 Exploratory test of weathered rock and residual soil should accord with the following requirements:

1 Space between exploratory holes should take the smaller value specified in Chapter 4 of the code;

2 There ought to be a certain number of exploratory wells;

3 It should to take sample in the exploratory well with dual pipe, tri-pipe, and not less than 3 groups in every weathered zone;

4 In-situ test and laboratory test should be simultaneously adopted, in-situ test can be cone dynamic penetration test, standard penetration test, and wave velocity test and loading test;

5 Besides executing laboratory test in accordance with requirements in Chapter 11 in the code, as for the rock mass equivalent to extremely soft rock and extremely frangible rock, the test can be executed according to the requirements of soil test; as for residual soil, if necessary, collapsibility test and soaking test shall be done.

6.9.4 As for granite residual soil, natural water content w_f, plastic limit w_p and liquid limit w_l of fine-grained soil shall be measured.

6.9.5 To ascertain subgrade bearing capacity and deformation modulus of granite residual soil, loading test should be carried. While having local mature experiences, as for the engineering which design grade of foundation is grade Б or grade C, that can be comprehensively ascertained by in-situ test results such as standard penetration test etc. combining with local experiences.

6.9.6 Geotechnical engineering assessment of weathered rock and residual soil should

be in accordance with the following requirements:

1 Highly weathered and fully weathered rock with thick layers should be further divided into fragment state, chipping state and soiled state combining with local experiences; thick layer residual soil can be further divided into non-plastic residual soil and plastic residual soil, yet into clay, sandy clay and gravelly clay according to gravel content or sand content;

2 The engineering buildings on interbedding of soft and hard layers or subgrade with different weathering degree, should analyze impact of uneven settlement on the engineering;

3 After the pit is dug, it should be timely checked, as for rocks easy to be weathered, foundation or other measures should be timely done to prevent weathering development;

4 As for dyke and globular weathered body (solatary stone), the impact on subgrade (including pile foundation) shall be analyzed and assessed, and corresponding recommendations shall be put forward.

6.10 Contaminated Soil

6.10.1 Due to the contaminating substance's invasion, the soil compositions, structures and properties are changed greatly, the soil hereby shall be determined to be contaminated soil. Naming of contaminated soil may add "contaminated" in front of the original classification name.

6.10.2 This section is applicable to investigation of industrial contaminated soil, tailings contaminated soil and waste landfill percolating water contaminated soil, but not applicable to investigation of nuclear contaminated soil. Assessment of contaminated soil on the environmental impact may be made according to the mission requirement.

6.10.3 Contaminated soil sites and foundation may be classified into the following types, and the investigation for sites or foundation in different types shall give prominence to the key points:

1 The existing site and foundation contaminated;

2 The proposed site and foundation already being contaminated;

3 The already existing site and foundation possible to be polluted;

4 The proposed site and foundation possible to be polluted.

6.10.4 The investigation of contaminated soil site and foundation shall adopt feasible investigation means according to the engineering characteristics and the design requirement, and it shall also meet the following requirements:

1 Based on the field investigation, contamination source, contamination history, contamination pathway, contamination compositions, affected level of the existed build-

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ing on the contaminating sites and circumferential environment shall be put emphasis on for the industrial pollution. For tailings pollution, different mineral species and chemical compositions shall be mainly investigated, so as to understand the technology, additive and its chemical property and compositions used for mineral separation. For the waste landfill, the investigation shall focus on the waste composition, daily capacity, heaped capacity, service life, anti-seepage structure, deformation requirement and circumferential environment;

2 Adopt drilling or pit exploring soil sample, on-site observe the color, state, odor and appearance structure of the contaminated soil, and compared with the normal soil, as well as find out the distribution and depth of the contaminated soil;

3 Sampling equipment directly contacting with test sampled shall be strictly kept, clean, after each sampling, the next sample may be adopted after clean water flushing; for sample of unstable components like easily to be break down or volatile, the contacting time of the soil sampling and the air shall be reduced as far as possible, so as to prevent running off of the volatile substance and prevent oxidation; after soil sampling collection, proper preservation method should be adopted and then, the sample shall be delivered to the laboratory within the time specified;

4 For the contaminated soil requires determination for the engineering property of the foundation soil, more means giving priority to the in-situ testing should be adopted; when the bearing capacity on foundation of the contaminated soil requires determination, load test should be made.

6.10.5 For the exploration and test of the contaminated soil, when contamination is harmful to human health or corrosive to machinery tools and apparatus, necessary protective measures shall be adopted.

6.10.6 The investigation of proposed site contaminated soil should be classified into two phases: preliminary investigation and detail investigation. When the condition is simple, detail investigation may be made directly.

Preliminary investigation shall give priority to field investigation, assorted with a small amount of exploration and test, find out the nature of the contamination source and the contamination path, and preliminarily find out the distribution and contamination degree of the contamination soil; detailed investigation shall be targeted to lay out the investigation workload, find out the distribution, contamination degree, physical mechanics and chemical index of the contaminated soil and provide parameters for the contaminated soil treatment on the basis of the preliminary investigation combined with the engineering characteristics and possibly adopted treatment measures.

6.10.7 The layout of the exploration and testing workload shall be combined with the distribution of the contamination source and contamination path. The interval of explo-

ration points near the contamination source should be densified, while the interval of the exploration points far away from the contamination source should be sparse. To find out the depth of the distributive exploratory hole of contaminated soil, contaminated soil shall be penetrated into. The interval of contaminated soil sampling shall be determined comprehensively according to its thickness and possibly adopted treatment measures for the detailed investigation. When determining the contaminated soil and uncontaminated soil boundary, the sampling soil interval should not be greater than 1m.

6.10.8 The exploratory hole with underground water shall adopt groundwater sampling with different depth, and find out the spatial distribution of the contaminant in the underground water. When groundwater sampling with different depths are adopted in the same drill, rigid isolation measures shall be adopted to prevent the conclusion judging impacted by the adoption of mixed water sampling level.

6.10.9 The indoor test of contaminated soil and water shall make the following tests according to the pollute conditions and mission requirements:

1 Chemical compositions of contaminated soil and water;

2 Physical mechanic property of contaminated soil;

3 Assessing index on corrosion of the constructional materials;

4 Assessing index on environmental impact;

5 The mechanical testing items and test methods shall consider fully the special feature of the contaminated soil and also make corresponding test, like swelling, humidification and collapsibility test;

6 If necessary, special experimental investigation shall be made.

6.10.10 The contaminated soil shall be assessed according to the mission requirement, and the site and building foundation shall be assessed according to the following requirements:

1 Position, composition, property, contamination history and circumferential impact of the contamination source;

2 Distributive plane scope and depth of the contaminated soil or the spatial scale of the groundwater being contaminated;

3 Physical mechanic property of contaminated soil, assess the contamination incidence to the soil engineering characteristics index;

4 When the engineering requires, provide bearing capacity on foundation and distortion parameters, anticipate the foundation deformation characteristics;

5 Corrosiveness of the contaminated soil and water to the constructional material;

6 Impact of contaminated soil and water on the environment;

7 Analyze the trend of contamination development;

8 Comprehensive assessment on the perniciousness of the already existing projects

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or suitability of the proposed projects.

6.10.11 Corrosion assessment of contaminated soil and water to the constructional materials and corrosiveness classification shall comply with relevant requirements of Chapter 12 of this Code.

6.10.12 Contamination incidence to the soil engineering characteristics may be classified according to Table 6.10.12. Comprehensive assessment with such engineering characteristics indexes as strength, deformation and permeation may be adopted according to physical circumstances of the engineering.

Table 6.10.12 Contamination Incidence on the Soil Engineering Characteristics

Incidence	Slight	Moderate	Big
Variable rate of the engineering characteristic index (%)	<10	10~30	>30

Note: The variable rate of the engineering characteristic index refers to the D-value of engineering characteristic index before and after the contaminated to the index before the contamination ratio.

6.10.13 Contaminated soil and water to the environmental impact shall be assessed by combining with the specific requirements of the engineering; when no definite requirements is available, it may be assessed according to the current national standard "Environmental Quality Standard for Soils" GB 15618, "Quality Standard for Ground Water" GB/T 14848 and "Environmental Quality Standards for Surface Water" GB 3838.

6.10.14 Treatment and restoration of the contaminated soil shall be comprehensively considered according to contamination degree, distribution range, soil property, restoration standard, treatment construction period and processing cost.

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7 Underground Water

7.1 Investigation Requirements of Underground Water

7.1.1 In the process of geotechnical engineering investigation, the following hydro-geological conditions should be mastered through collecting data and investigation work as the project demanded:

1 The underground water type and its existing state;

2 The distribution discipline of main aquifers;

3 The regional climate data, including annual precipitation, evaporation capacity, its changes and their influence on underground water level;

4 The recharging and the drainage condition of underground water, the recharging and the drainage relationship between underground water and surface water, and its influence on underground water level;

5 The underground water level during investigation, the highest underground level in the previous, the highest underground level in the latest 3～5 years, the variety trend of water level and the main affecting factors;

6 Whether there are contaminated sources to the underground water and the surface water and their possible contaminated degree.

7.1.2 For the area short of monitoring data of underground water level, it is necessary to set long term observation holes to monitore the underground water in relevant layers, during the preliminary investigation stage of tall buildings or important projects.

7.1.3 For tall buildings and important projects, if the hydro-geological condition greatly affects the subsoil assessment, the anti-buoyancy analysis of foundation and the engineering dewatering, special hydro-geological investigation should be carried out.

7.1.4 The special hydro-geological investigation should accord with the following requirements:

1 To find out the characters of aquifer and aquifuge including buried condition, the type, flow direction, water level and fluctuation of underground water. If there is more than one aquifer of underground water affecting the engineering, the underground water level should be measured in layers and the recharging relation between them should be found out too;

2 To ascertain the influence of geological conditions on the existing state and the seepage state of underground water. If necessary, to establish the observation holes or bury the pore pressure cell at different depth to measure the variance of hydraulic head

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pressure with the depth;

3 To obtain hydrogeological parameters such as permeability coefficient of stratum by the field test.

7.1.5 The sampling and the test of water sample should accord with the following requirements:

1 The water sample shall represent the water quality in natural state;

2 The sampling and the test items of water should followed the requirements in Chapter 12;

3 The water sample should be tested in time. For clean water, the placement time should not be more than 72 hours. For slightly contaminated water, it should not be more than 48 hours. For the contaminated water, it should not be more than 12 hours.

7.2 Measurement of Hydro-geological Parameters

7.2.1 The measuring method for hydro-geological parameters should accord with the requirements in Appendix E.

7.2.2 Measurement for groundwater level shall be in accordance with the following requirements:

1 It shall measure water level when encounter with groundwater;

2 (This item is cancelled);

3 The water level measurement for multilayer aquifer that influencing the engineering shall adopt water-proof measures and separate the being measured aquifer from others.

7.2.3 The initial water level and the stable water level can be measured in boreholes, exploratory wells, and piezometers. The interval of stable time of the water level is determined by the permeability of stratum. For the sandy soil and the gravelly soil, it should not be less than 0.5h. For the silt and the cohesive soil, it should not be less than 8h. The stable water level should be measured at same time after the investigation completed. The approximation of reading should be in centimeter and the deviation should not be more than ±2cm.

7.2.4 Geometry method may be adopted to measure the current direction of underground water, and not less than 3 observation holes distributed in triangle should be laid. The space of observation points should be determined according to the properties of rock and soil including permeability, hydraulic gradient, and slope of landform, it should be 50～100m. The water level in each hole shall be measured simultaneously to determine the flow direction of underground water.

The flow velocity of underground water can be measured by indicator method or "mise-a-la-masse" method.

7.2.5 The pumping test should accord with the following regulations:

1 The methods of pumping test can be selected from Table 7.2.5;

2 In the water-pumping test, the water level should be lowered three times and the maximum depth reduced should be close to the water level needed for the design of engineering;

3 Same method and the same apparatus shall be adopted for measuring water levels. For the pumping hole, the reading should be in centimeter. For the observation hole, the reading should be in millimeter;

4 When the curve about water yield and time, and the curve of dynamic water level vs. time fluctuate at a certain of range and without going up or down continuously, the water level can be considered as stable;

5 The recovered water level after the pumping shall be measured.

Table 7.2.5 Method and Application of Pumping Test

Test Methods	Application
Extracting water simply from borehole or exploratory well	To estimate the permeability coefficient of poor aquifers roughly
Pumping without observation holes	To measure the permeability coefficient of aquifer preliminary
Pumping with observation holes	To measure all kinds of coefficient of aquifer correctly

7.2.6 The water permeation test and the water injection test can be made in test pit or in bore hole. For sandy soil and silt, the test pit monocycle method can be adopted. For the cohesive soil, the test pit forked loop method can be adopted. If the test depth is too large, the drilling method can be adopted.

7.2.7 In water-pressure test, the test holes location shall be determined according to the engineering requirement, combined with the data of engineering geological mapping and drilling; the test units shall be divided on the basis of the permeability of rock formation; the initial pressure, the maximum pressure, and pressure increments as required shall be determined; the curve of pressure verse water amount pressed in time shall be mapped to calculate the water permeating rate, and to determine the type of p-Q curve.

7.2.8 The measurement of pore water pressure should accord with the following regulations:

1 The measuring method can be established according to Table E.0.2 in Appendix E;

2 The measuring points should be laid out according to the geological condition and the demand of analysis;

3 The installation and embedding of piezometer should accord with the relevant installation technological regulations;

4 To analyze and coordinate the test data timely. If there is abnormity, try to find out the reason and take corresponding measures.

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7.3 Assessment of Underground Water Action

7.3.1 For the geotechnical engineering investigation, the effect and action of underground water should be assessed and prevention measures should be put forward.

7.3.2 Assessment for mechanical action of groundwater shall include the following content:

1 For fundament, underground structure and retaining wall, it shall consider buoyancy of groundwater acting on the structures under the most adverse combination condition. For rock that the joint does not develop and clay soil, if there are local experience or measured data, the float effect may be determined according to experience;

When seepage appears, the hydraulic head and the effect of groundwater should analyze and assess by seepage calculation;

2 When checkout stability of side slope, it shall consider adverse impact of the groundwater and its hydrodynamic pressure on the stability of slope;

3 Within the influence scope of groundwater level lowered , it shall consider land subsidence and its influence on engineering; when groundwater level rises again, it shall consider the possible rebound and additional uplift force;

4 When the wall back fillings are silty sand, silt or cohesive soil, and to check calculation stabilization of the bracing structures, it shall assess acting of underground hydrostatic pressure and dynamic water pressure to bracing structures according to different drainage conditions;

5 When the upwards seepage appears caused by the hydraulic head pressure difference, it shall assess the possibility of potential erosion, shifting sand soil flow and piping;

6 When excavate foundation pit or underground engineering under the groundwater level, it shall analyze and assess feasibility of dewatering or water-proof measures as well as analyze and assess its influence to foundation pit stabilization and neighborhood engineering according to permeability of rock and soil and groundwater recharge conditions.

7.3.3 The assessment of physical and chemical actions of underground water should include the following contents:

1 For the engineering structure below the underground water level, the corrosivity of underground water to the concrete and the metals should be appraised, and the assessment method should accord with that in Chapter 12;

2 For the soft rock, strongly weathered rock, residual soil, collapsible soil, expansive rock and soil, and salined rock and soil, the harmful actions should be anessed,

such as softening, disintegration, collapsibility, swelling and contraction, potential erosion etc. resulting from gathering and dissipating of groundwater;

3 In the frozen soil area, influence of underground water on the frost heaving and the dissolved collapse of soil should be assessed.

7.3.4 The measures to lower the water level of underground water should accord with the following regulations:

1 During construction, the underground water level should be kept 0.5～1.5m below the bottom of foundation pit;

2 During dewatering, effective measures should be taken to avoid the loss of soil;

3 To avoid the surge caused by deep confined water, if necessary, measures should be taken to reduce the confined head below the foundation pit.

7.3.5 If the engineering dewatering is necessary, the suitable dewatering method shall be selected according to the permeability of aquifer and the requirement of reducing water depth. If several methods are relatively inter-complemented, they can be used assembly.

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8 Engineering Geological Mapping and Investigation

8.0.1 The engineering geological mapping and survey shall be carried out for the sites with exposed stones and fairly complex land features and geological conditions. For the sites with simple geological conditions, the engineering geological mapping can be replaced with the geological investigations.

8.0.2 The engineering geological mapping and survey should be done during the feasibility study or the preliminary investigation stage. When collecting the data during the feasibility study stage, the interpretation outcome of aerial photographs and satellite photographs should be included. During the detailed investigation stage, the supplementary investigations may be conducted for some special geological problems.

8.0.3 The range of the engineering geotechnical mapping and survey shall cover the site and the adjacent sections. The plotting scale and precision of the geotechnical mapping shall comply with the following requirements:

1 The plotting scale, for the feasible study investigation, shall be 1 : 5000～1 : 50000. For preliminary investigation, it shall be 1 : 2000～1 : 10000; and for the detailed investigation, it shall be 1 : 500～1 : 2000. If the conditions are complex, the plotting scale can be amplified properly;

2 The geological units that shall have great impacts on the engineering (such as land slides, geological faults, soft and weak interlayers, caves etc.) can be represented with an amplified scale;

3 The mapping precision for geologic boundaries and geological surveying spots shall not be lower than 3mm.

8.0.4 The layout, density and positions of geological surveying spots shall be in accordance with the following requirements:

1 There shall be geological surveying spots at the tectonic lines, strata contact lines, lithologic demarcation lines, in standard strata and each geological unit;

2 The density of geological surveying spots shall be determined according to the land features, geological conditions of the site, the plotting scale and the engineering requirements, etc., and shall be representative;

3 The natural or existing manual outcrops should be fully utilized for the geological surveying spots. If the outcrops are rather few, a certain amount of exploration pits or exploratory trenches shall be set in accordance with the actual conditions;

4 For the geological surveying spots, proper methods shall be adopted according

to the precision requirements. The special geological surveying spots such as he tectonic lines, strata contact lines, lithologic demarcation lines, soft and weak interlayers, the groundwater outcrops and adverse geological actions shall be positioned with apparatuses.

8.0.5 The engineering geological mapping and investigation shall include:

1 To find out the features of landforms and ground feature and their relationships with the strata, tectonics, unfavorable geological actions and divide geomorphic units.

2 The age, origin, properties, thickness and distribution of rock and soil strata; to identify the weathering degree for the rock strata and to distinguish the newly sedimentary soil and other special soils;

3 To find out the structure type of rock mass, the attitudes and properties of various structural planes (especially soft and weak structural planes), the characteristics of rock & soil contact plane and the soft and weak interlayer and so on, the vestiges of geotectonic movements and their relationships with the seismic activities;

4 To find out the types, recharging resources and drainage conditions of ground water, the locations of wells and springs, the rock characteristics, buried depth, water table variations and contamination situations of aquifer and its relationships with the surface water;

5 To collect such data as meteorology, hydrology, vegetation, standard frost depth of soil. To investigate the highest flood, its occurrence time and inundation range;

6 To ascertain the formation, distribution, configuration, scale, development degree of such adverse geological actions as karst, soil cave, landslide, eboulement, debris flow, galley, land subsidence, fracture, earthquake disaster, ground crack, shore scouring and so on and their influences on the engineering construction;

7 To investigate the influences of human activities on the stability of the construction site, including the manual cavities, underground goaf, large-scale excavation and filling, pumping and drainage, the induced earthquakes by the water reservoirs, etc.;

8 The deformation of buildings and engineering experiences.

8.0.6 The outcome data of the engineering geological mapping and survey shall include the actual material drawings, comprehensive engineering geological map, engineering geological zoning maps, comprehensive geological log, engineering geological profile, various sketch drawings, photographs, and text instructions and so on.

8.0.7 When the engineering geological mapping is conducted through the interpretation of remote sensing image data, in field checking geological surveying spots shall be 30% to 50% of the engineering geological surveying spots. The field work shall include:

1 Checking the interrelated marks;

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2 Verifying the interrelated outcomes;

3 Checking the extrapolated results;

4 Field supplementing the data that cannot be gained through the indoor interpretation.

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9 Exploration and Sampling

9.1 General Provisions

9.1.1 If it is required to ascertain the distribution and properties of rock and soil, to gain rock and soil samples or conduct in-situ tests, the drilling, well and trench exploration, cave exploration and geophysical exploration, etc. may be adopted. The selection of exploration methods shall comply with the exploratory purpose and the characteristics of rock and soil.

9.1.2 In arranging the exploratory holes, the influences of the exploration work on the natural environment shall be taken into account to avoid destroying the underground pipelines, underground engineering and natural environments. After completion of the drilling, well exploration, trench exploration, cave exploration, and the filling work shall be done properly.

9.1.3 When the cone static penetration test and dynamic penetration test are adopted as the exploration means, they shall be combined matching with other exploration means.

9.1.4 During the drilling and well, trench and cave exploration, the effective measures shall be adopted to ensure the construction safety.

9.2 Drilling

9.2.1 The drilling methods may be selected according to the rock and soil types and exploratory requirements as per Table 9.2.1.

Table 9.2.1 Applicable Scope of Drilling Methods

Drilling methods		Drilled strata					Exploration requirements	
		Cohesive soil	Silt	Sandy soil	Gravelly soil	Rock	Identify it directly and get undisturbed samples	Identify it directly and get disturbed samples
Rotary	Auger boring	++	+	+	—	—	++	++
	No core drilling	++	++	++	+	++	—	—
	Core drilling	++	++	++	+	++	++	++
Percussion	Percussion drilling	—	+	++	++	—	—	—
	Hammering drilling	++	++	++	+	—	++	++
Vibration drilling		++	++	++	+	—	+	++
Washboring		+	++	++	—	—	—	—

Note: ++: represents that it is applicable; +: represents that it is partly applicable; and —: represents that it is not applicable.

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9.2.2 For the exploration for the shallow soil layers, the following drilling methods can be adopted:

1 Drilling with the small-diameter screw auger (or soil lifted drill);

2 Drilling with the small-diameter bucket auger;

3 Drilling with driving pipe.

9.2.3 The drilling caliber and specification shall comply with the specifications of the current national standards. The caliber of finished holes shall satisfy the requirements of sampling, testing and drilling technologies.

9.2.4 Drilling shall be in accordance with the following requirements:

1 The measurement accuracy of drilling depth and stratification depth of rock and soil shall be no less than ±5cm;

2 The advance of the discontinuous core drilling per turn shall be strictly controlled to make the stratification precision meet the requirements;

3 It shall make dry drilling for holes to identify the natural humidity of strata above the groundwater level; when it is requiring to add water or using recycled fluid, it shall adopt double core barrel drilling;

4 The recovery ratio of the core drilling, for the integral rock or secondly integral rock, shall not be lower than 80%; for the secondly frangible and frangible rock mass, shall not be lower than 65%; for the places (sliding zones, soft and weak interlayer, and so on) that need to be ascertained imperially with much efforts, the cores shall be gained continuously with double core barrel;

5 When if requites determining rock quality designation RQD, it shall adopt double core barrel (N-type) with 75mm caliber and diamond drilling bit;

6 (This item is cancelled).

9.2.5 The detailed methods for the drilling operation shall be implemented according to the Technical Standard for "Geotechnical Boring of Building Engineering Geology" JGJ 87.

9.2.6 The log and documentation of bore hole shall be in accordance with the following requirements:

1 The field record shall be consigned to the personnel with special professional training; and the records shall be exact and timely, and shall be made according to the drilling advance a turn; the post-recording are prohibit;

2 In the drilling site, the naked-eye identification and handy-feel methods can be adopted; if available or with clear requirements for the investigation, the micro-penetrometer or other quantitative and normalized means can be adopted;

3 The drilling outcome can be identified with the bore log or recordings in layers; the rock and soil core samples may be stored for a certain period or a long time according

to the engineering requirements; or the color photos for the rock cores and soil cores also can be added into the investigation outcome data.

9.3 Well, Trench and Cave Exploration

9.3.1 When the drilling methods cannot ascertain the underground situations, the well, trench and cave exploration means may be adopted for the investigation. In the investigation of dam sites, underground engineering, large-scale side slopes, if it is required to find out in detail the properties and structural characteristics of deep rock layers, the shaft or adit maybe adopted.

9.3.2 The exploratory well should not be deeper than the groundwater table. The depth, length and section of a shaft and adit should be determined according to the engineering requirements.

9.3.3 The exploratory well, trench, cave should be not only described with texts and recordings, the lithology, strata demarcation, tectonic feature, locations of sampling and in-situ tests of the exploratory well, trench, but also the cave wall and bottom should be reflected through the geologic profiles and diagram and so on, accompanied by the color photos for the representative places.

9.4 Sampling of Rock & Soil

9.4.1 The quality of the soil samples can be divided into four grades according to testing objective.

Table 9.4.1 Quality Grades of Soil Samples

Grade	Disturbance degree	Test contents
Ⅰ	Undisturbed	Nomination of the soil, water content, density, strength test, consolidation test
Ⅱ	Slightly disturbed	Nomination of the soil, water content , density
Ⅲ	Markedly disturbed	Nomination of the soil, water content
Ⅳ	Completely disturbed	Nomination of the soil

Note: 1 Undisturbed refers to such facts that although the stress status has changed, the configuration, density and water content of soil change very little, which can meet the variety of requirements of laboratory tests.

2 Except the engineering which the design grade of subgrade and foundation is grade A, if it is allowable in engineering technologies, the soil samples of the Grade Ⅰ, Ⅱ, Ⅲ, Ⅳ can be used for the strength and consolidation tests, but the soil specimens for identifying its disturbed degree should be taken to judge their feasibility for the test; and the test outcome should be utilized by combining with the local experiences.

9.4.2 The sampling tools and methods should be selected according to Table 9.4.2.

9.4.3 The technical specifications of sampler shall be implemented according to that in Appendix F of the code.

9.4.4 During collecting the sand samples of Grade Ⅰ and Ⅱ in the bore hole, the undisturbed sand sampler may be adopted, and the related current standards should be implemented.

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Table 9.4.2 Sampling Tools and Methods for Samples of Different Grades

Quality grade of soil samples	Sampling tools and methods		Suitable soil type										
			Cohesive soil					Silt	Sandy soil				Gravelly sand angular gravelly soil, Soft rock
			Flowing plastic	Soft plastic	Plastic	Hard plastic	Hard		Silty sand	Fine sand	Medium sand	Coarse sand	
I	Thin wall sampler	Fixed piston	++	++	+	—	—	+	+	—	—	—	—
		Hydraulic fixed piston	++	++	+	—	—	+	+	—	—	—	—
		Free piston	—	+	++	—	—	+	+	—	—	—	—
		Open	+	+	+	—	—	+	+	—	—	—	—
	Rotary sampler	Single-acting triple tubes	—	+	++	++	+	++	++	++	—	—	—
		Double-acting triple tubes	—	—	—	+	++	—	—	—	++	++	+
	Block soil samples from the exploration well (trench)		++	++	++	++	++	++	++	++	++	++	++
II	Thin wall sampler	Hydraulic fixed	++	++	+	—	—	+	+	—	—	—	—
		PistonFree	+	++	++	—	—	+	+	—	—	—	—
		Piston Open	++	++	++	—	—	+	+	—	—	—	—
	Rotary sampler	Single-acting triple tubes	—	+	++	++	+	++	++	++	—	—	—
		Double-acting triple tubes	—	—	—	+	++	—	—	—	++	++	++
	Thick-wall open sampler		+	++	++	++	++	+	+	+	+	+	—
III	Thick-wall open sampler		++	++	++	++	++	++	++	++	++	+	—
	Standard penetrometer		++	++	++	++	++	++	++	++	++	++	—
	Screwed drill bit		++	++	++	++	++	+	—	—	—	—	—
	Core drill bit		++	++	++	++	++	++	+	+	+	+	+
IV	Standard penetrometer		++	++	++	++	++	++	++	++	++	++	—
	Screwed drilling bit		++	++	++	++	++	+	—	—	—	—	—
	Core drilling bit		++	++	++	++	++	++	++	++	++	++	++

Note: 1 ++: represents that it is applicable; +: represents that it is partly applicable; and —: represents that it is not applicable.

2 The supplementary measures to avoid losing the samples shall be taken during the sampling of sandy soils.

3 If there are experiences, the ringed-line barrel sampler may be adopted instead of the thin-wall sampler.

9.4.5 Sampling the soil samples of Grade Ⅰ and Ⅱ in the bore hole shall satisfy the following requirements:

1 In the soft soil and sandy soil, the mud fluid should be adopted to protect the hole walls; if the casing pipes are adopted, it should be assured that the water table in the pipe shall be equal to or slightly higher than the groundwater table and the sampling position shall be three times of hole diameter below the bottom of casing pipe;

2 If the washing, percussion, vibrodrilling and other drilling means are adopted, it shall be altered with rotary drilling when the depth is above 1 m from the sampling position;

3 Before laying down the sampler, it should clean the borehole carefully and get rid of the disturbed soil, with the thickness of residual drift soil of no greater than the length of waste soil section in the sampler (except the piston sampler);

4 It is advisable to adopt quick static-pressure continuous driving method during the sampling;

5 The concrete operation methods shall be implemented according to the current national standard, "Technology Standards for Sampling of Undisturbed Soil" JGJ 89.

9.4.6 The soil samples of Grade Ⅰ, Ⅱ and Ⅲ shall be sealed properly to prevent the changes of humidity, and the insolation and frost are not allowed. The vibration during the transportation shall be avoided, and the retention time should not exceed three weeks. For the soil samples that tend to be liquefied due to the vibration and be segregated from water, they should be tested in the nearest lab.

9.4.7 The rock samples can be made of the rock cores from the drilling or got from the exploratory pit, trench, shaft and adit. The size of the rough samples should meet the requirements of making test specimen. Under the special conditions, the sample shape, size, direction should be determined according to the design of rock mechanics tests.

9.5 Geophysical Exploration

9.5.1 In the geotechnical engineering investigation, the geophysical exploration may be adopted in the following areas:

1 Being the pioneer means of drilling methods, the geophysical exploration can be used to find out the blind geologic boundaries, interfaces or abnormal spots;

2 Adding some geophysical exploration spots between the boreholes, and the basis for the interpolation and extrapolation of drilling outcome;

3 The geophysical exploration means, as in-situ testing mean, can be used to measure the wave velocity, dynamic elastic modulus, dynamic shearing modulus, predominant period, resistivity, radioactive radiation parameters of rock and soil mass, the corrosivity of soil to metals and so on.

9.5.2 While applying the geophysical exploration methods, the following conditions shall be met:

1 There are obvious physical characteristics differences between the objects to be measured and the surrounding media;

2 The measured objects are of certain buried depth and scale, and the geophysical abnormity is of certain intensity;

3 It is possible to constrict the disturbance and differentiate the useful signals from the interfering signals;

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4 The effective test for the means can be conducted in the representative sections.

9.5.3 For the geophysical exploration, the effective methods should be adopted according to the buried depth, scale of measured object and the physical differences between the object and the surrounding media.

9.5.4 In the interpretation and judging of the outcome of geophysical exploration, the multi-resolution should be taken into account, and the useful signals should be differentiated from the interfering signals. If necessary, the variety of methods should be adopted for the prospecting to interpret and judge the geotechnical conditions comprehensively, which should be verified with the known geophysical parameters or a certain amount of bore holes.

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10 In-situ Tests

10.1 General Provisions

10.1.1 The in-situ testing methods shall be selected according to geotechnical conditions and the requirements of design on parameters, the local experiences, the applicability of the testing methods and so on.

10.1.2 If the geotechnical engineering characteristic parameters are estimated or the geotechnical problems are assessed by utilizing the local experiences on the base of in-situ test outcome and the parameters and the assessment outcome shall be compared with the laboratory test outcome to verify the reliability.

10.1.3 The apparatus and instruments for in-situ tests shall be examined regularly and calibrated.

10.1.4 When analyzing the outcome data of in-situ tests, attention shall be paid to the influences of the apparatuses and instruments, test conditions, test methods on the tests and the abnormal data shall be weeded out.

10.2 Loading (Plate) Tests

10.2.1 Loading test may be used to measure bearing capacity and deformation modulus of rock and soil under the loading bearing plate within dominating influence scope of the stress. Shallow plate loading test is applicable to shallow subsoil; deep plate loading test is applicable to deep subsoil and large-diameter pile end soil; screw plate loading test is applicable to deep subsoil or subsoil below groundwater level. The testing depth of the deep plate loading test shall not be less than 5m.

10.2.2 The loading test shall be conducted at the representative spot, and there are at least three test spots in each site; if the rock and soil in the site is not uniform, the spots shall be increased properly. The shallow plate loading test shall be conducted at the elevation of foundation bottom.

10.2.3 The technical requirements of the loading test shall comply with the following specifications:

1 The width or diameter of a test pit for the shallow plate loading test shall not be less than three times of that of the loading bearing plate. The diameter of the test well for the deep plate loading test shall be equal to that of the loading bearing plate. When the diameter of the test well is greater than that of the loading bearing plate, the height of the soil close to surrounding the loading bearing plate shall not be less than the diam-

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eter of the loading bearing plate;

2 To avoid a disturbance to the rock and soil at the bottom of the test pit or well and keep its original configuration and natural humidity. Level the surface of sand cushion by layer under the load bearing plate with no thicker than 20mm, install the test equipment as soon as possible. When the bit of screw plate enters into the soil, the operation shall be done at a thread pitch per round to reduce the disturbances to the soil;

3 Round rigid loading bearing plate in the loading test and appropriate size for the plate should be chosen according to the soil hardness or fracture density of rock mass. The area of the loading bearing plate for the shallow plate loading test shall not be less than 0.25m^2, and for the soft soil or the fill with fairly larger grain size, the area shall not be smaller than 0.5m^2. The area of the loading bearing plate for the deep soil plate loading test should be 0.5m^2. The area of the load bearing plate for the rock loading test shall not be less than 0.07m^2;

4 The loading method in the loading test shall adopt the stepped maintained load method with the relative stable settlement (routine low method). If local experiences are available, the stepped loading with non-stable settlement method (quick method) or the constant settlement rate method can be adopted. The loading steps should be 10 to 12, and no less than 8 steps. The measure accuracy for the load shall not be less than $\pm 1\%$ of the maximum load;

5 The settlement of the load bearing plate can be measured with a dial gauge or an electrical displace-meter with the accuracy of no less than $\pm$0.01mm;

6 For the slow method, if the tested object is soil mass, the settlement shall be measured at the interval of 5 min, 5 min, 10 min, 10 min, 15 min and 15 min after each increment, and later on, the settlement shall be measured every 30 min. If the settlement per hour is less than 0.1mm in successive two hours, it is thought that the settlement has reached the relative stable standard and the next increment can be loaded. If the tested object is rock mass, the settlement shall be measured at the interval of 1 min, 2 min, 2 min and 5 min, and later on, the settlement shall be measured every 10 min. If the readings difference in the continuous three times is less than or equal to 0.01mm, it is thought that the settlement has reached the relative stable standard and apply the next increment;

7 If anyone of the followings is met, the test can be terminated:

1) The soil around the load bearing plate is markedly extruded to the sides; the obvious heaving happens in the surrounding rock and soil or the radial fissure develops continuously;

2) The settlement more than under the load of this step is more than 5 times that of the former one, and there is a marked drop in the load-settlement curve;

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3) Under the certain step of load, the settlement rate in the 24 hours cannot reach the relative stable standard;

4) The ratio of the settlement verse the diameter (or width) of the load bearing plate exceeds 0.06.

10.2.4 According to the outcome analysis requirements of the loading test, the curve of load (p) vs. the settlement (s) shall be plotted. If necessary, the curve of the settlement under each step of load vs. the time (t) or the logarithm of time ($\lg t$) shall be plotted.

According to yielding point of curve p-s, if necessary, by combining the characteristics of s-lg$t$, the linear limit pressure and ultimate pressure shall be determined. If the p-s takes on slowly varying curve characteristics, the corresponding pressure of a certain relative settlement value (that is s/d, and d is the diameter of the load bearing plate) shall be adopted to assess the bearing capacity of the subsoil.

10.2.5 The deformation modulus of soil, based on the initial straight line section of p-s curve, shall be calculated according to the elasticity theory of the homogeneous isotropic half-infinite elastic media.

The deformation modulus E_0 (MPa) from the shallow plate loading test shall be calculated according to the following formula:

$$E_0 = I_0(1-\mu^2)\frac{pd}{s} \tag{10.2.5-1}$$

The deformation modulus E_0 (MPa) from the deep plate loading test and the screw plate loading test shall be calculated according to the following formula

$$E_0 = \omega\frac{pd}{s} \tag{10.2.5-2}$$

Where I_0——Shape factor of rigid load bearing plate, for the round plate, it is 0.785, and for the rectangular plate, it is 0.886;

μ——Poisson's ratio of the soil (for the gravelly soil, it is 0.27. For the sandy soil, it is 0.30. For the silt, it is 0.35. For the silty clay, it is 0.38. For the clay, it is 0.42);

d——Diameter or side length of the load bearing plate (m);

p——Pressure of the linear section of the p-s curve (kPa);

s——Settlement corresponding with p (mm);

ω——Coefficient related to the test depth and the soil types, which can be determined according to Table 10.2.5.

10.2.6 The reference bedding coefficent K_v, based on the plate loading test with the side length of the load bearing plate of 30cm, shall be calculated according to the following formula:

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$$K_v = \frac{p}{s} \tag{10.2.6}$$

Table 10.2.5 Calculation Coefficient ω for the Deep Loading Test

Soil / d/z	Gravelly soil	Sandy soil	Silt	Silty clay	Clay
0.30	0.477	0.489	0.491	0.515	0.524
0.25	0.469	0.480	0.482	0.506	0.514
0.20	0.460	0.471	0.474	0.497	0.505
0.15	0.444	0.454	0.457	0.479	0.487
0.10	0.435	0.446	0.448	0.470	0.478
0.05	0.427	0.437	0.439	0.461	0.468
0.01	0.418	0.429	0.431	0.452	0.459

Note: d/z is the ratio of the diameter of the load bearing plate to the depth of the load bearing plate bottom surface.

10.3 Cone Static Penetration Test

10.3.1 The cone static penetration test is applicable to the soft soil, the common clay, the silt, the sandy soil and the soil with small amount of gravelly soil. The cone static penetration test, based on the engineering requirements, can adopt the single bridge probe, double bridge probe or the single and double bridge probe with measuring apparatuses for the pore-water pressure, and be used to measure the penetration resistance (p_s), the cone resistance (q_c), the skin friction (f_s) and the pore water pressure (u) in the course of the penetration.

10.3.2 The technical requirements of the cone static penetration test shall comply with the following specifications:

1 The cross section area of the probe cone shall be 10cm^2 or 15cm^2. The side wall height of the single bridge probe shall be 57mm or 70mm, and the side wall area of the double bridge probe shall be 150 to 300cm^2; and the cone angle of the cone top shall be 60°;

2 The probe shall be driven into the soil at a constant speed, and the penetration speed shall be 1.2m/min;

3 The probe force transducer, together with the apparatus and the cable, shall be calibrated regularly. In probe calibrating indoors, the nonlinear error, repetitive error, lag error, temperature drift and return-to-zero error of the force transducer shall be less than 1% FS, and the return-to-zero error in the field test shall be less than 3%, and the insulation resistance shall not be less than 500MΩ;

4 The error of depth recordings shall not be greater than ±1% of the penetration depth;

5 When the penetration depth exceeds 30m, or the probe enters into the hard soil

layer after passing through the thick soft soil layers, some measures shall be adopted to prevent from crooking of hole or the rod breaking, also the inclinometry probe can be used to measure the oblique angle of the penetration hole and to calibrate the depth of the soil layer boundary line;

6 Before the pore pressure probe penetrates into the soil, it is required to assure that the strain cavity in the probe where the air bubbles are excluded in doors shall be saturated with the liquid. Some measures shall be taken in the site to maintain the probe saturated until the probe enters into subsoil below the underground water table. The probe shall not be lifted throughout press procession of the test.

7 When the pore pressure dissipating test is conducted at the predicted depth, the pore pressure with time after penetration terminated shall be measured, and the time interval shall be controlled rationally from dense to disperse. During the testing process, the probe rod shall not be loosened.

10.3.3 The analysis of the cone static penetration test outcome shall include the following contents:

1 Plotting various kinds of penetration curves. For the single bridge and double bridge probe, the p_s-z curve, q_c-z curve, f_s-z curve, R_f-z curve shall be plotted. For the pore pressure probe, the u_i-z curve, q_t-z curve, f_t-z curve, B_q-z curve and pore pressure dissipating curve, u_t-lg$t$ curve shall be plotted:

Where R_f——Ratio of friction to resistance;

u_i——Pore water pressure measured when the pore pressure probe enters into the soil (that is the initial pore pressure);

q_t——True cone resistance (corrected by the pore pressure);

f_t——True skin friction (corrected by the pore pressure);

B_q——Pore pressure coefficient for the cone static penetration, $B_q=\dfrac{u_i-u_0}{q_t-\sigma_{vo}}$;

u_0——Static water pressure at the testing depth (kPa);

σ_{vo}——Total overburdened pressure at the testing depth (kPa);

u_t——Pore water pressure at the time of t during the pore pressure dissipating.

2 According to the characteristics of the penetration curve and combining the adjacent drilling data and local experiences, divide the soil layers and identify the soil types. After calculate the average of the related test data of each layer from the cone static penetration tests or counting and analyzing the data, and provide the space variation discipline of the data from the static cone penetration test.

10.3.4 According to the data from the cone static penetration test and utilizing the local experiences, to divide the soil layers based on its mechanical properties, to estimate the plastic state or the compacted degree, the strength, the compressibility, the bearing

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capacity of subgrade, the bearing capacity of single pile, the driving pile resistance and to judge of liquefaction. The coefficient of consolidation and permeability coefficient can be estimated according to the pore pressure dissipating curve.

10.4 Cone Dynamic Penetration Test

10.4.1 The cone dynamic penetration tests can be classified into light duty, heavy duty and super heavy duty of, and the specifications and suitable soil types shall accord with the specification in Table 10.4.1.

Table 10.4.1 Type of Cone Dynamic Penetration Test

Type		Light duty	Heavy duty	Super heavy duty
Drop hammer	Mass of the hammer (kg)	10	63.5	120
	Drop distance (cm)	50	76	100
Probe	Diameter (mm)	40	74	74
	Cone angle (°)	60	60	60
Diameter of probe rod (mm)		25	42	50～60
Index		Reading with 30cm penetration N_{10}	Reading with 10cm penetration $N_{63.5}$	Reading with 10cm penetration N_{120}
Main applicable rock & soil		Shallow fill, sandy soil, silt, cohesive soil	Sandy soil, moderately dense gravelly soil and the extremely soft rock	Dense and very dense gravelly soil, soft rock, extremely soft rock

10.4.2 The technical requirements of cone dynamic penetration test shall comply with the following specifications:

1 Adopting the automatic drop hammer set;

2 The maximum skewness of the probe rod shall not exceed 2%, and the hammering penetration shall be driven continuously. Meanwhile, it should to prevent the eccentric hammering and probe rod inclining or lateral swashing and to maintain the verticality of drilling rod. The hammering rate shall be 15 to 30 blows per minute;

3 The probe rod should be turned one and a half round per 1m depth penetrated and turn round the probe rod once every 20cm depth penetrated while the total penetrated depth is over 10m;

4 For the light dynamic penetration test, when $N_{10}>100$ or the blows within 15cm depth penetrated exceeds 50, the test may be terminated. For the heavy dynamic penetration test, when $N_{63.5}>50$ for three continuous times, the test can be determined or replaced with the super heavy dynamic penetration test.

10.4.3 The analysis of the test outcome from the cone dynamic penetration test shall include the following contents:

1 For the single-hole continuous cone dynamic penetration test, the curve of the

blows verse the penetration depth shall be plotted;

2 In calculating average value of the penetration index of single hole in layer, the values within the critical depth and the abnormal values within the leading and lagging influence range shall be weeded out;

3 The average value and the variation coefficient of the penetration index in stratums for the site shall be calculated with the thickness weighted mean method, according to average value of the penetration index in layers of each hole.

10.4.4 According to the cone dynamic penetration test indexes and local experiences, divide the soil layers based on its mechanical properties, assess the uniformity and physical properties (the state or the compacted degree) of the soil, the soil strength, the soil deformation parameters, the bearing capacity of subgrade, the bearing capacity of single pile, find out the soil caves, sliding surfaces, the interface of the soft and hard soil layer and check the subsoil treatment effect. When making use of the test outcome, whether the test outcome have to be corrected or how to correct shall be determined according to the concrete situation in establishing the statistics relationship.

10.5 Standard Penetration Test

10.5.1 The standard penetration test shall be applicable to the sand soil, silt and common cohesive soil.

10.5.2 Equipment of standard penetration test shall comply with the requirements specified in Table 10.5.2.

Table 10.5.2 Specifications of Equipment for Standard Penetration Test

Drop hammer		Mass of hammer (kg)	63.5
		Drop distance (cm)	76
Penetrator	Split duct	Length (mm)	>500
		External diameter (mm)	51
		Internal diameter (mm)	35
	Pipe shoe	Length (mm)	50～76
		Blade angle (°)	18～20
		Thickness of blade (mm)	1.6
Drill stem		Diameter (mm)	42
		Relative bending	<1/1000

10.5.3 The technical requirements of the standard penetration test shall comply with the following specifications:

1 The standard penetration test hole shall be driven with the rotary drilling method; and the water table in the hole shall be kept a little higher than the groundwater table. If the borehole wall is not stable, it can be protected with the mud fluid. When the

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borehole bottom is 15cm above the pre-test elevation, it should to clear away the residual soil at the hole bottom and then carry out the tests;

2 Hammering with the self-releasing free hammer and reduce the friction resistance between the guide rod and the hammer. The eccentricity and lateral swing during the hammering shall be avoided. The verticality of the penetrator, the probe rod and the guide rod after the connection shall be kept, and the hammering rate shall be less than 30 blows/min;

3 After the penetrator enters into the soil 15cm, the blow number per 10cm depth penetrated shall be recorded. The blow number of accumulated 30cm depth penetrated is the blow number N of the standard penetration test. When blow number has reached 50, but the penetration depth has not reached 30cm, the actual penetrated depth of 50 blows should be recorded, which shall be converted into the blow equivalent to the blow number of the standard penetration test in the penetrated depth of 30cm with the following formula, and the test should be terminated:

$$N=30\times\frac{50}{\Delta S} \tag{10.5.3}$$

Where ΔS——Penetration depth of 50 blows (cm).

10.5.4 The outcome of the standard penetration test can be directly marked on the engineering geological profile, or the curve of the blow number N of the standard penetration test verse the depth of single hole or the histogram can also be plotted. During counting the average value of the blow number of the standard penetration test, the abnormal values shall be weeded out.

10.5.5 Based on the blow number N of the standard penetration test, the physical characteristics of the sandy soil, silt, clay, the soil strength, the deformation parameters, the subgrade bearing capacity, the bearing capacity of single pile, the liquefaction of sandy soil and silt, and the possibility of pile-driving can be assessed. In using the test outcome, whether the test outcome have to be corrected or how to correct them shall be determined according to the concrete situation after establishing the statistics relationship.

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10.6 Vane Shear Test

10.6.1 The vane shear test can be used to measure the undrained shear strength and sensitivity of the saturated soft clay ($\varphi\approx0$).

10.6.2 For the layout of the vane shear test spots, the vertical interval may be 1m for the homogeneous soil. For the non-homogeneous soft cohesive soil or the soft cohesive soil with thin silty and fine sand layers, the cone static penetration test should be carried out firstly, and then consideration of the variation of the soil layers to choose the proper soft clay for the test.

10.6.3 The main technical requirements of the vane shear test shall comply with the following specifications:

1 The shape of the vane plate bit should be rectangular with the ratio of diameter to high of 1 : 2 and the plate thickness of 2 to 3mm;

2 The depth of the vane plate bit into the borehole bottom shall not be less than 3 to 5 times of the diameter of the borehole or the casing tube;

3 When the vane is advanced the test depth, it should rest for 2 to 3 min and then start the test;

4 The torsion shear rate shall be (1°～2°)/10s, and after the peak strength has been measured, the readings shall still be recorded for 1 min;

5 After the measurement of the peak strength or the stable value completed, the vane shall turn six rounds in the direction of the torsion to measure the un-drained shearing strength of the remolded soil;

6 For the open-steel-ring vane shear apparatus, the influence of the friction resistance between the rod and the soil shall be revised.

10.6.4 The test outcome analysis of the vane shear test shall include the following contents:

1 To calculate the un-drained shear peak strength and residual strength of the soil, the strength of the remolded soil and the sensitivity at each testing spot;

2 To plot the curve of the un-drained shear peak strength, the residual strength, the strength of the remolded soil and the sensitivity verse the depth of the soil in single-hole vane shear testing. If necessary, plot the curve of the shear strength verse the torsion angle;

3 According to the soil conditions and the local experiences, to modify the measured vane un-drained shear strength.

10.6.5 The outcome of the vane shear test, according to the local experience, can be used to determine the subgrade bearing capacity, the bearing capacity of single pile, to calculate the stability of the side slope and to judge the consolidation history of the soft clay.

10.7 Pressuremeter Test

10.7.1 The pressuremeter test is applicable to the cohesive soil, silt, sandy soil, gravelly soil, residual soil, extremely soft rock, soft rock and so on.

10.7.2 The pressuremeter test shall be conducted at the representative place and the depth, and the measuring chamber of pressuremeter shall be in the same soil layer. The vertical interval of the test spot shall be determined according to the strata conditions and the engineering requirements, and not be less than 1m; the distance from the test

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hole to the existing borehole shall not be less than 1m.

10.7.3 The technical requirements of the pressuremeter test shall comply with the following specifications:

1 For the prebored type pressuremeter test, the hole quality shall be guaranteed, and the diameter of the borehole should be well matched with that of the pressuremeter to prevent the collapse of the hole wall; the self-drilling drill bit, the rotary speed, rotary rate, the blade distance, the mud fluid pressure, the flow and so on for the self-drilling pressuremeter test shall comply with the related specifications;

2 The loading increment shall be 1/5 to 1/7 of the predicted critical plastic pressure, and loading increment at the initial stage can be the minimum value; if necessary, the unloading and re-loading test can be conducted to measure the lateral pressure modulus;

3 The pressure of each increment shall maintain 1 min to 2 min, and then the next increment shall be applied and maintain for 1 min; the deformation amount shall be read at the intervals of 15s, 30s and 60s after applying each increment; after the pressure has lasted 2 min, the deformation shall be read at the intervals of 15s, 30s, 60s and 120s after applying the increment;

4 When the expanded volume of the measuring chamber is equivalent to the inherent volume of the measuring chamber or the pressure have reached the maximum allowable pressure of the apparatus, the test shall be terminated.

10.7.4 The outcome analysis of the pressuremeter test shall include the following contents:

1 The pressures of all steps of and the corresponding expanded volume (or converted into the radius increment) shall be corrected with the constraining force and the volume, and the pressure vs. the volume curve shall be plotted; if necessary, the creep curve can be plotted;

2 According to curve of the pressure vs. the volume curve and combining with the creep curve, the initial pressure, the critical plastic pressure and the ultimate pressure shall be determined;

3 According to the gradient of the straight line on the p-V curve, the lateral pressure modulus shall be calculated according to the following formula:

$$E_m = 2(1+\mu)\left(V_c + \frac{V_0+V_f}{2}\right)\frac{\Delta p}{\Delta V} \qquad (10.7.4)$$

Where E_m——Lateral pressure modulus (kPa);

μ——Poisson's ratio, which shall be determined according to formula 10.2.5;

V_c——Initial inherent volume of the measuring chamber in the pressuremeter (cm^3);

V_0——Volume corresponding with the initial pressure p_0 (cm^3);

V_f——Volume corresponding with the critical plastic pressure p_f(cm^3);

$\Delta p/\Delta V$——Gradient of the straight line on the lateral pressure curve (kPa/cm^3).

10.7.5 According to the initial pressure, critical plastic pressure, ultimate pressure and the lateral pressure modulus, and combining with the local experiences, the subgrade bearing capacity and the deformation parameters shall be assessed. Based on the lateral pressure curve of the self-drilling pressuremeter test, the in-situ horizontal stress, the static lateral pressure coefficient, the undrained shear strength and so on shall be obtained.

10.8 Dilatometer Test

10.8.1 The dilatometer test is applicable to the soft soil, common cohesive soil, silt, loess and loose to moderately dense sandy soil.

10.8.2 The technical requirements of the dilatometer test shall comply with the following specifications:

1 The probe for the dilatometer test is 230mm to 240mm in length, 94mm to 96mm in width, and 14mm to 16mm in thickness. The front blade angle of the probe is 12° to 16°, and the lateral steel diaphragm of the probe is 60mm in diameter;

2 The probe calibration shall be done before and after the test in each hole, and the average value of before and after the test shall be adopted as the correction value. The qualified standard for the diaphragm is:

During the calibration, when the steel diaphragm is expanded to 0.05mm, the measured air pressure $\Delta A=5\sim25$kPa,

During the calibration, when the steel diaphragm is expanded to 1.10mm, the measured air pressure $\Delta B=10\sim110$kPa.

3 During the test, the probe shall penetrate the soil at a constant speed under the static pressure, with the penetration speed of 2cm/s; the vertical interval of the testing spots shall be 20cm to 50cm;

4 When the probe has reach the pre-determined depth, increase and reduce the pressure at constant speed to measure the pressure of A, B and C corresponding to the pressure of the diaphragm expanding to 0.05mm, 1.10mm and constrict to 0.05mm.

5 The dilatometer dissipating test shall be conducted at the test depth; the time interval for readings shall be 1 min, 2 min, 4 min, 8 min, 15 min, 30 min, 90 min;and later on, the readings shall be observed every 90 min until the dissipating phenomenon have disappeared.

10.8.3 The test outcome analysis of the dilatometer test shall include the following contents:

1 To correct the measured data for the rigidity of the diaphragm from the test;

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$$p_0 = 1.05(A - z_m + \Delta A) - 0.05(B - z_m - \Delta B) \quad (10.8.3\text{-}1)$$

$$p_1 = B - z_m - \Delta B \quad (10.8.3\text{-}2)$$

$$p_2 = C - z_m + \Delta A \quad (10.8.3\text{-}3)$$

Where p_0——Contact pressure before the diaphragm expanding into the soil (kPa);

p_1——Pressure when the diaphragm expands to 1.10mm (kPa);

p_2——Pressure when the diaphragm returns to 0.05mm (kPa);

z_m——Readings of the pressure gauge before zeroing (kPa).

2 According to p_0, p_1 and p_2, calculate the following indexes:

$$E_D = 34.7(p_1 - p_0) \quad (10.8.3\text{-}4)$$

$$K_D = (p_0 - u_0)/\sigma_{vo} \quad (10.8.3\text{-}5)$$

$$I_D = (p_1 - P_0)/(p_0 - u_0) \quad (10.8.3\text{-}6)$$

$$U_D = (p_2 - u_0)/(p_0 - u_0) \quad (10.8.3\text{-}7)$$

Where E_D——Dilatometric modulus (kPa);

K_D——Dilatometric horizontal stress index of dilatometer test;

I_D——Dilatometric soil property index;

U_D——Pore pressure index of dilatometer test;

u_0——Hydrostatic pressur at the test depth (kPa);

σ_{vo}——Effective overlying pressure of the soil at the test depth (kPa).

3 To plot the curve of E_D, I_D, K_D and U_D v. s the depth.

10.8.4 According to the dilatometer test indexes and the local experience, to identify the soil types and determine the state of the clay, the static lateral pressure index, the horizontal bedding coefficient and so on.

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10.9 Field Direct Shear Test

10.9.1 The field direct shear test can be applicable to the shear tests for the rock and soil mass, the soft and weak structural plane of the rock and soil mass or the contact planes with other materials. The direct shear test can be classified into three types, the shear test that the rock and soil mass get failure along the shearing surface under the actions of the normal stress, the shear test (the friction test) that the rock and soil mass shall be sheared along the shearing plane continuously after it is sheared and the shear test that the rock and soil mass is under the action of the normal stress of zero.

10.9.2 The field direct shear test can be conducted in the test cave, test pit, trench or big-caliber borehole. If the shearing surface is horizontal or approximately horizontal, the horizontal pushing or inclined pushing method can be adopted. If the shearing surface is rather steep, the wedge pushing method can be adopted.

The rock properties of rock and soil in the same group test shall be basically the

same. The test stress state shall be close to the actual one in engineering.

10.9.3 In the field direct shear test, every group rock mash shall at least have 5 test blocks, with the shearing area of no less than 0.25m^2. The minimum side length of each test block shall not be less than 50cm, and the height shall not be less than 0.5 times of the minimum side length. The distance between the test blocks shall be greater than 1.5 times of the minimum side length.

Every group of soil test shall have at least 3 test blocks. The shearing area shall not be less than 0.3m^2, and the height shall not be less than 20cm or be 4 to 8 times of the maximum particle diameter. The open slot of the shearing surface shall be 1/3 to 1/4 of the minimum particle diameter.

10.9.4 The technical requirements of the field direct shear test shall comply with the following specifications:

1 During the excavation of the test pit, a disturbance to the test block and a marked change of the water content shall be avoided. If the test is conducted below the groundwater table, the influence of the water pressure and the seepage flow on the test shall be avoided;

2 The applied normal load and shearing load shall be set at the center of the shearing surface or the shearing split; or the combined force of the normal load and the shearing load shall pass through the center of the shearing surface and remain the normal force unchanged;

3 The maximum normal load shall be greater than the designed load, and be divided into several steps in constant increment. The load accuracy shall be ±2% of the maximum load;

4 The normal load on each test block can be divided into 4 to 5 steps to apply. When the normal deformation reaches to a relatively stable state, the shearing load can be applied then;

5 Each step of shearing load shall be applied at the constant increment of 8% to 10% of the predicted maximum load or at the constant increment of 5% to 10% of the normal load in steps. Each step of shearing load shall be applied every 5 min to 10 min for the rock mass and every 30s for the soil mass;

6 When the shear deformation increases sharply or reaches to 1/10 of the test block size, the test can be terminated;

7 The residual shear strength may be determined according to the test outcome that the shear displacement is greater than 10mm. If necessary, the friction test can be conducted along the shearing surface continually.

10.9.5 The analysis of the field direct shear outcome shall include the following contents:

1 To plot the curve of the shearing stress vs. the shearing displacement, and the

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curve of the shearing stress vs. the vertical displacement, and to determine the proportional strength, the yield strength, the peak strength, the shear swelling point and the shear swelling strength;

2 To plot the curve of the normal stress vs. the proportional strength, the yield strength, the peak strength, and the residual strength, and to determine the corresponding strength parameters.

10.10 Wave Velocity Test

10.10.1 The wave velocity test is applicable for measuring the velocity of the compressive wave, and shear wave or rayleigh wave in various rock and soil mass. According to the project requirement, the single hole method, the cross-hole method and the surface wave method can be adopted.

10.10.2 The technical requirements of single-hole wave velocity testing shall comply with the following specifications:

1 The test hole shall be vertical;

2 The three-component detector shall be fixed at the designed depth in the hole and closely touching the hole wall;

3 The shock can be excited on the ground or in the hole;

4 The measuring spots shall be set combining with the soil layers distribution, and the vertical interval of the measuring points shall be 1 to 3m. When stratum changes greatly, the measuring points shall be densified at varying section, and the measuring shall be done point by point from down to up.

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10.10.3 The technical requirements of cross-hole wave velocity test shall comply with the following specifications:

1 The vibration source holes and the test hole shall be set at the same line;

2 In the soil layer, the distance between the test holes shall be 2 to 5m and in the rock mass it shall be 8 to 15m. The vertical interval of the measuring points shall be 1 to 2m. The measuring point near the ground surface shall be set at the depth of 0.4 times of the borehole distance. The vibration source and the detector shall be set in the same stratum and at the same elevation;

3 When the test depth is greater than 15m, the inclination angle and the inclination orientation of the exciting hole and the test hole shall be measured, with 1m interval of the measuring points.

10.10.4 During measuring the wave velocity with the surface wave means, the transient method or the steady-state method can be adopted. The low-frequency detector should be adopted, and the track pitch may be determined through the trial test according to the site conditions.

10.10.5 The analysis of the wave velocity test outcome shall include the following contents:

1 To identify the initial arrival time of the compressive wave and the shear wave from the waveform recording;

2 To calculate the distance from the shock source to the measuring point;

3 To determine the wave velocity according to the propagation time and distance of the wave;

4 To calculate the dynamic elastic modulus, the dynamic shear modulus and the dynamic Poisson's ratio of the small strain of the rock and soil.

10.11 In-situ Stress Test of Rock Mass

10.11.1 The rock mass stress test is applicable to the anhydrous, integral or secondly integral rock mass. The hole-wall strain method, the aperture deformation method and the hole-bottom strain method can be adopted to measure the space stress and the plane stress of the rock mass.

10.11.2 During measuring the original stress of the rock mass, the depth of the measuring point shall be beyond the influence range of the stress disturbance. When testing in the underground chamber, that is the depth of the measuring point shall exceed two times of the chamber diameter.

10.11.3 The technical requirements of the rock mass stress testing shall comply with the following specifications:

1 In the test section of the measuring point, the lithology shall be uniform and intact;

2 The wall and bottom of the test hole shall be smooth, flat and dry;

3 The stability criterion is that the difference within the three continual readings (readings every 10 min) does not exceed $5\mu\varepsilon$;

4 The measuring readings in the same borehole shall be observed at least 3 times.

10.11.4 The confining pressure test shall be conducted in 24 hours after the stress on the core have been relieved. The pressure shall be divided into 5 to 10 steps and the maximum pressure shall be greater than the pre-estimated principal stress of the rock mass.

10.11.5 The processing of the measured outcome shall meet the following requirements:

1 To calculate the plane stress and space stress of the rock mass according to the testing outcome, and the calculation methods shall comply with the specifications of the national current standard "Standards for Test Method of Engineering Rock Massas" GB/T 50266;

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2 To plot the curve of the relieve process according to the relieved stress value and the relieved depth;

3 To plot the curve of the stress v. s the strain, and to calculate the elastic constant of rock according to the confining pressure test data.

10.12 Shock Excitation Test

10.12.1 The shock excitation test is applicable for determining the dynamic characteristics of the natural subgrade and the artificial subgrade to offer the subgrade rigidity, the damping ratio and the mass of vibration for the design of the foundations of the dynamic machines.

10.12.2 In the shock excitation test, the forced vibration means shall be adopted. If possible, the two measuring means, that is the forced vibration method and the free vibration method shall be adopted simultaneously.

10.12.3 Before the shock excitation test, such data as the performance of the machine, the type of the foundation, that is the elevation of the foundation base, the property and uniformity of the subsoil, the underground structures and the disturbance vibration source and so on shall be collected.

10.12.4 The technical requirements of the shock excitation test shall comply with the following specifications:

1 The minimum working frequency of the mechanical shock excitation equipment shall be 3 to 5Hz, and the maximum frequency should be greater than 60Hz. The disturbance force of the electromagnetic excitation equipment should not be less than 600N;

2 The dimension of the block foundation should be 2.0m×1.5m×1.0m. In the same stratum, the contrast test should be conducted on two block foundations with the same bottom area, and the height of 1.0m and 1.5m respectively. The pile foundation test shall be done for two piles, and the pile span shall be the design span. The distance from the edge of the pile cap to the pile axis may be 1/2 of the pile spacing, and the length-width ratio of the pile cap shall be 2 : 1, and the height of the pile cap shall not be less than 1.6m. When the pile number in the contrast test is different, the pile number and the area of pile cap shall be increased. The concrete strength grade of test foundation shall not be lower than C15;

3 The tested foundation shall be set near the designed foundation and in the soil layer with similar property; and the elevation of the bottom surface shall be the same as that of designed foundation;

4 The tests shall be conducted in two situations, that is, the open setting and the buried setting; and the fill for the buried foundation shall be compacted layer by layer;

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5 The accuracy, installation, testing method and requirement and so on of the equipment shall accord with the specifications of the current national "Code for Measurement Method of Dynamic Properties of Subsoil" GB/T 50269.

10.12.5 The analysis of the shock excitation test outcome shall include the followings:

1 For the forced vibration test, the following amplitude frequency response curves shall be plotted:

1) For the vertical vibration, the amplitude frequency response curve of the vertical amplitude varying with the frequency (the A_z-f curve);

2) For the horizontal rotary coupled vibration, the amplitude frequency response curve (the $A_{x\varphi}$-f curve) of the horizontal amplitude varying with the frequency and the amplitude frequency response curve (the $A_{z\varphi}$-f curve) of the vertical amplitude varying with the frequency;

3) For the torsion vibration, the amplitude frequency response curve (the $A_{x\varphi}$-f curve)of the horizontal amplitude varying with the frequency under the torsion disturbance moment.

2 For the free vibration test, the following oscillogram shall be plotted,

1) The oscillogram of the vertical free vibration;

2) The oscillogram of the horizontal rotary coupled vibration.

3 Based on the amplitude frequency response curve of the forced vibration test and the oscillogram of the free vibration test, the rigidity coeficient of the subgrade, damping ratio and the mass of vibration shall be calculated according to the current national, "Code for Measurement Method of Dynamic Properties of Subsoil" GB/T 50269.

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11 Laboratory Tests

11.1 General Provisions

11.1.1 The test item and method of the laboratory tests for rock and soil properties should comply with the specifications in this chapter of the code, and the concrete operations and test instruments for the tests should comply with the specifications in the current national "Standards for Soil Test Method" GB/T 50123 and the national "Standard for Test Methods of Engineering Rock Massas" GB/T 50266. The parameters value selected for the geotechnical engineering assessment should be determined after corrected through comparison with the outcome from the corresponding in-situ tests or the outcome from the back analysis of the prototype observation.

11.1.2 The test items and methods should be determined according to the engineering requirements and the characteristics of rock and soil properties. If it is necessary, the in-situ stress field and the stress history of the rock and soil mass, the new stress field, the new boundary conditions resulting from the engineering activities should be considered to make the test conditions close to the actual situation as possible; the non-uniformity, the anisotropism and the discontinuity and the corresponding differences in engineering property between the rock and soil mass and the rock and soil samples should be paid attention to.

11.1.3 For the specific test item, the special test scheme shall be established.

11.1.4 Prior to preparing the test specimen, the important properties of the rock and soil mass with naked eyes shall be identified and described briefly.

11.2 Tests for the Physical Properties of the Soil

11.2.1 The following soil classification indexes and the physical property indexes for all sorts of engineering should be measured:

Sandy soil: Grain size distribution, specific gravity, natural water content, natural density, the maximum and minimum density;

Silt: Grain size distribution, liquid limit, plastic limit, specific gravity, natural water content, natural density and organic content;

Clay: Liquid limit, plastic limit, specific gravity, natural water content, natural density and organic content;

Note: 1 For sandy soil, if it is hard to get the soil samples of Grade Ⅰ, Ⅱ and Ⅲ, it is allowable only to perform grain size distribution test;

2 If there is no organic matter in the soil through naked-eyes identification, the organic content test can be neglected.

11.2.2 For measuring liquid limit, the test methods specified in the current national "Standard for Test Methods of Soil" GB/T 50123 shall be selected based on the classification and assessment requirements, which shall be noted in the test report. In the areas with abundant experiences, the specific gravity may be determined according to the experiences.

11.2.3 As required the seepage flow analysis is necessary to be conducted to provide water permeability parameters of the soil for the design of lowering groundwater table for the foundation pit, the permeability test may be carried out. The constant water head test is applicable to sandy soil and gravelly soil; the variable water head test is applicable to silt and cohesive soil; for soft soil with very low permeability, consolidation coefficient, and volume compressive coefficient may be determined according to the consolidation test; and then the permeability coefficient can be calculated. The value of soil permeability coefficient shall be determined after being compared with the outcome from field water-pumping test or water-injection test.

11.2.4 Backfill soil mass and the quality of filling engineering is required to be controlled, the compaction test shall be done to determine the relation of the dry density to the water content, the maximum dry density and the optimum water content.

11.3 Compression and Consolidation Test of Soil

11.3.1 When compression modulus is adopted to calculate the settlement, the maximum pressure of consolidation test should be greater than the sum of effective self-weight pressure and additional pressure; and the test outcome can be represented by e-p curve; the calculation of compression coefficient and compression modulus should be corresponding to the pressure section from effective self-weight pressure of soil to the sum of effective self-weight pressure and additional pressure. When the influence of load release due to pit excavation and reloading have to been taken into account, the rebound test shall be taken, and the loading of the pressure should be similar to the actual loading and unloading state.

11.3.2 When calculating the settlement with consideration of the stress history, the test outcome can be represented by the e-lg$p$ curve to determine the pre-consolidation pressure and to calculate the compression indexes and the rebound index. The maximum applied pressure should satisfy drawing the complete e-lg$p$ curve. In order to determine the rebound index, after reaching the estimated pre-consolidation pressure, perform the unloading rebound, and then loading continually until finish the predicted the last step of the loading.

11.3.3 If it is required to analyze the relationship of the settlement duration, some soil samples under total pressure of effective self-weight pressure and additional pressure

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shall be selected, and detailed consolidation duration recordings shall be made to calculate consolidation coefficient.

11.3.4 For the engineering built on thick high-compressibility soft soil, if necessary, a certain amount of soil samples should be adopted to measure coefficient of secondary consolidation that can be used to determine the relation between secondary consolidation settlement and duration.

11.3.5 If it is required to analyze the relation between stress and strain of the soil and to offer parameters for non-linear elastic, elastic and plastic model, tri-axial compression test can be taken, which should meet the following requirements:

1 To adopt three or more different constant confining pressure to make samples consolidated separately, and then to increase axial pressure step by step until the sample has been destroyed; during the test, each sample for the confining pressure test should be let rebound one to three times, and the test outcome should be formed the relationships curve of the axial stress corresponding to various constant confining pressure v. s the axial strain;

2 To carry out equal-pressure consolidation test with same confining pressure and axial pressure, apply load step by step to get the relationships curve of the confining pressure v. s the volume strain.

11.4 Shear Test of the Soil

11.4.1 The test methods for tri-axial shear test shall be determined according to the following requirements:

1 For saturated clay, if loading speed is rather quick, the unconsolidated and undrained test (*UU*) should be adopted; for saturated soft soil, the soil samples should be pre-consolidated under the effective self-weight pressure, and then used in the test;

2 For the pre-treated subgrade, the subgrade with good drainage conditions, the project with low loading rate, the project with rather high loading rate but rather high over-consolidation subsoil and the project that requires to check the stability of soil slope when water table drops quickly, consolidated-undrained test (*CU*) can be adopted; when it is required to offer shear strength index of the effective stress, consolidated undrained test ($\overline{CU}$) measuring pore water pressure shall be adopted.

11.4.2 The test methods for the direct shear test shall be determined according to the load types, loading rate and the drainage conditions of the subgrade soil. For soft clay with the internal friction angle of $\varphi \approx 0$, unconfined compression test with the soil samples of Grade Ⅰ may be conducted.

11.4.3 In measuring the shear strength of such already exist shear fracture surfaces as landslide zone, the residual strength test should be taken. The calculation parameters

should be determined after comparing with the outcome from back analysis of the field observation.

11.4.4 When the geotechnical engineering assessment has special requirements, the K_0 consolidated un-drained test and the K_0 consolidated un-drained test measuring pore water pressure test, the special stress ratio consolidated un-drained test, the plane strain compression test, the plane strain tension test and so on should be taken.

11.5 Tests for the Dynamic Characteristics of the Soil

11.5.1 When the engineering design requires to test the dynamic characteristics of the soil, the dynamic tri-axial test or dynamic shear test or the resonant column test can be adopted. In selecting the test methods and instruments, application scope of the dynamic strain it shall be paid attention to.

11.5.2 The dynamic tri-axial and dynamic shear test can be used to measure the following dynamic characteristics of the soil:

1 The dynamic elastic modulus, dynamic damping ratio and their relationships to the dynamic strain;

2 The relationships of the dynamic stress to the dynamic strain under the specified cyclic load;

3 The relationships of the liquefied shear stress to the dynamic stress of saturated soil under cycle numbers.

11.5.3 The resonant column test can be used to determine the dynamic elastic modulus and the dynamic damping ratio at the small dynamic strain.

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11.6 Rock Test

11.6.1 The tests for the components and physical properties of the rock may adopt the following test items according to the engineering demand:

1 Identifying the minerals;

2 Grain density and Block density test;

3 Water absorption and saturated water absorption test;

4 Disintegration resistance test;

5 Swelling test;

6 Freezing-thawing test.

11.6.2 The uni-axial compressive strength test shall respectively measure the strength under dry state and saturated state, and offer ultimate compressive strength and softening coefficient. The elastic modulus and Poisson's ratio of rock should be measured according to uniaxial compression deformation test. For the markedly anisotropic rock, the strengths, parallel to bedding plane and perpendicular to the bedding plane, shall be

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respectively measured.

11.6.3 For rock tri-axial compression test, to select four confining pressures and to provide the relationships of the principal stress difference to the axial strain under the condition of different confining pressures, the shear strength envelope curve and the value of strength parameters, c, φ according to its stress state.

11.6.4 The rock direct shear test can measure the shear strength of rock and such discontinuity planes as the joint planes, sliding planes, fault planes or rock stratum planes, and provide the value of c, φ, the curve of the shear stress v. s the displacement under the various normal stresses.

11.6.5 For rock tensile strength test, to apply a pair of linear load on the diameter direction of test samples to destroy the test samples along the diameter and to measure tensile strength of the rock indirectly.

11.6.6 When determining the strength and modulus of rock indirectly, the point loading test or the sound wave velocity test can be adopted.

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12 Appraisal of Corrosivity of Water and Soil

12.1 Sampling and Test

12.1.1 When there are adequate experiences of sufficient data to confirm that soil or water (groundwater or surface water) of engineering site and its surroundings have no corrosiveness to constructional material, sample the soil and water to assess their corrosivity is not necessary. Otherwise, it is required to sample water or soil to make an test and assess their corrosiveness to constructional material according to this chapter.

The assessment of the soil to the steel structural corrosiveness may be made according to the mission requirements.

12.1.2 Sampling water and soil shall comply with the following requirements:

1 When concrete structure is above groundwater level, soil sample shall be taken to make the corrosion test of soil;

2 When concrete structure is in the underground water or surface water, water sample shall be taken to make corrosion test of water;

3 When concrete structure is above the underground water level and parts is under the underground water level, soil sample and water sample shall be taken respectively to make corrosion test;

4 Water and soil samples shall be taken from the concrete structure-located depth, and their sampling number shall be no less than two pieces at each site. When the salt composition and content in the soil are distributed unevenly, sampling shall be made by zoning and in layers, and that shall be no less than two pieces for each zone and each layer.

12.1.3 Items and test method for corrosivity test water and soil shall comply with the following requirements:

1 Test items of water corrosivity on the concrete structure include: pH value, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}, Aggressiveness CO_2, free CO_2, NH_4^+, OH^- and the total mineralized degree;

2 Test items of soil corrosivity on the concrete structure include: analysis on pH value, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, eutectic salt of CO_3^{2-} (soil-to-water ratio is 1:5);

3 Test items of soil corrosivity on the steel structure include: pH value, redox

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potential, polarization current density, resistivity and mass loss;

4 The test method of the corrosivity test items shall be in accordance with those specified in Table 12.1.3.

Table 12.1.3 Corrosivity Test Method

No.	Test items	Test method
1	pH value	Potential method or taper electrode method
2	Ca^{2+}	EDTA Volumetric method
3	Mg^{2+}	EDTA Volumetric method
4	Cl^-	Mohr's method
5	SO_4^{2-}	EDTA Volumetric method or mass method
6	HCO_3^-	Acidimetric method
7	CO_3^{2-}	Acidimetric method
8	Aggressiveness CO_2	Gayle method
9	Free CO_2	Alka limetric method
10	NH_4^+	Nesslerization
11	OH^-	Acidimetric method
12	Total salinity	Calculation method
13	Redox potential	Platinum electrode method
14	Polarization current density	In-situ polarization method
15	Resistivity	Quadrupole method
16	Mass loss	Tube and pot method

12.1.4 The corrosivity of water and soil on the constructional materials may be classified into four grades: micro, weak, moderate and strong, and they may be assessed according to Section 12.2 of this code.

12.2 Appraisal of Corrosivity

12.2.1 Affected by environmental type corrosivity of water and soil on concrete structure shall comply with those specified in Table 12.2.1; the classification of environmental type shall be implemented according to Appendix G of this code.

Table 12.2.1 Corrosivity Appraisal of Water and Soil on Concrete Structure According to Environmental Type

Corrosion grade	Corrosive media	Environmental type		
		Ⅰ	Ⅱ	Ⅲ
Micro	Sulfate Content SO_4^{2-} (mg/L)	≤200	≤300	≤500
Weak		200～500	300～1500	500～3000
Moderate		500～1500	1500～3000	3000～6000
Strong		>1500	>3000	>6000
Micro	Magnesium salt Content Mg^{2+} (mg/L)	≤1000	≤2000	≤3000
Weak		1000～2000	2000～3000	3000～4000
Moderate		2000～3000	3000～4000	4000～5000
Strong		>3000	>4000	>5000

Table 12.2.1 (continued)

Corrosion grade	Corrosive media	Environmental type		
		I	II	III
Micro	Ammonium salt Content NH_4^+ (mg/L)	≤100	≤500	≤800
Weak		100～500	500～800	800～1000
Moderate		500～800	800～1000	1000～1500
Strong		>800	>1000	>1500
Micro	Caustic alkali content OH^- (mg/L)	≤35000	≤43000	≤57000
Weak		35000～43000	43000～57000	57000～70000
Moderate		43000～57000	57000～70000	70000～100000
Strong		>57000	>70000	>100000
Micro	Total mineralization (mg/L)	≤10000	≤20000	≤50000
Weak		10000～20000	20000～50000	50000～60000
Moderate		20000～50000	50000～60000	60000～70000
Strong		>50000	>60000	>70000

Note: 1 Values listed in table are applicable to circumstance of alternation of wetting and drying; if without alternation of wetting and drying for I and II environment type, sulfate content SO_4^{2-} listed in table shall be multiplied by 1.3;

2 (This note is cancelled);

3 Valued listed in table are applicable to corrosivity appraisal of water; for corrosivity appraisal of soil, they shall be multiplied by 1.5; unit shall be expressed in mg/kg;

4 The (OH^-) content in caustic alkali (mg/L) as listed in the table shall be the OH^- content (mg/L) in NaOH and KOH.

12.2.2 Corrosivity appraisal of water and soil on concrete structure affected by the permeability of stratum shall comply with those specified in Table 12.2.2.

Table 12.2.2 Corrosivity Appraisal of Water and Soil on Concrete structure According to Penetrability of stratum

Corrosion grade	pH value		Corrosivity CO_2 (mg/L)		HCO_3^- (mmol/L)
	A	B	A	B	A
Micro	≥6.5	≥5.0	≤15	≤30	≥1.0
Weak	6.5～5.0	5.0～4.0	15～30	30～60	1.0～0.5
Moderate	5.0～4.0	4.0～3.0	30～60	60～100	<0.5
Srtong	<4.0	<3.5	>60	—	—

Note: 1 A refers to directly facing water the groundwater in strong permeable layer; B refers to groundwater in weak permeable layer; the strong permeable layer refers to gravel soil and sandy soil; the weak permeable layer refers to silty soil and cohesive soil;

2 HCO_3^- content refers to the corrosivity of for the soft water which degree of mineralization is lower than 0.1g/L;

3 Corrosivity appraisal of soil only consider pH index when assess its corrosiveness, A refers to strong permeable soil layer; B refers to weak permeable soil layer.

12.2.3 If the corrosion grades are not the same with each other according to Table

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12.2.1 and Table 12.2.2, we should assess them synthetically according to the following regulations:

1 In the corrosion grades, if there is only weak corrosion and no moderate corrosion or strong corrosion, we should appraise it as the weak corrosion synthetically;

2 In the corrosion grades, if there is no strong corrosion and the highest grade is moderate corrosion, we should appraise it as the moderate corrosion synthetically;

3 In the corrosion grades, if there are one or more than one strong corrosions, we should appraise it as the strong corrosion synthetically.

12.2.4 Corrosivity appraisal of water and soil to reinforced steel bar in reinforced concrete structure shall comply with those specified in Table 12.2.4.

Table 12.2.4 Corrosivity Appraisal of Reinforcing Steel Bar in Reinforced Concrete Structure

Corrosion grade	Cl^- content in water (mg/L)		Cl^- content in soil (mg/kg)	
	Long-term soaking	Alternation of wetting and drying	A	B
Micro	<10000	<100	<400	<250
Weak	10000~20000	100~500	400~750	250~500
Moderate	—	500~5000	750~7500	500~5000
Srtong	—	>5000	>7500	>5000

Note: A refers to gravel soil, sandy soil, hard and hard plastic cohesive soil above the underground water level; B refers to the wet, extremely wet silty soil, plastic, soft plastic and flow plastic cohesive soil.

12.2.5 Corrosivity appraisal of soil on steel structure shall comply with those specified in Table 12.2.5.

Table 12.2.5 Corrosivity Apprisal of Soil on steel Structure

Corrosion grade	pH	Oxidation-reduction potential (mV)	Apparent resistivity (Ω·m)	Polarization current density (mA/cm^2)	Mass loss (g)
Micro	>5.5	>400	>100	<0.02	<1
Weak	5.5~4.5	400~200	100~50	0.02~0.05	1~2
Medium	4.5~3.5	200~100	50~20	0.05~0.20	2~3
Srtong	<3.5	<100	<20	>0.20	>3

Note: Corrosivity appvisal of soil on the steel structure takes the highest one among all of the corrosion grades.

12.2.6 The protection from the corrosivity of water and soil to the building material should accord with the regulations in the current national "Code for Anticorrosion Design of Industrial Constructions" GB 50046.

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13 In-situ Inspection and Monitoring

13.1 General Provisions

13.1.1 In-situ inspection and monitoring should be conducted during the engineering construction period. For projects with special requirements, the necessary items should be determined in terms of the engineering features and carried out during the application period.

13.1.2 All of the records, data and drawings for in-situ inspection and monitoring should be kept well, and should be worked up and analyzed in terms of engineering requirements.

13.1.3 Documents for in-situ inspection and monitoring should be submitted to the relavant units promptly. If the monitored data approach the critical value that endangers the project, it is required to monitor the engineering more frequently and report timely.

13.1.4 When the in-situ inspection and monitoring are completed, result reports should be submitted. Monitoring curves and drawings should be attached to reports, analysis and assessment should be done and recommendations should be made.

13.2 Inspection and Monitoring for Subsoil and Foundation

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13.2.1 When the foundation pit of natural foundation is excavated, it is required to check whether the geotechnical conditions are in accordance with the investigation reports. If anomaly is found, treatment measures or recommendations on modifying design should be put forward. If great discrepancy is found, investigation during construction shall be recommended. The inspection shall include the following contents:

1 Distribution and properties of rock and soil;

2 Underground water status;

3 The soiled foundation may be inspected by means of light cone dynamic penetration test or other machines and tools.

13.2.2 For the pile foundation engineering, whether the rock and soil conditions are in accordance with investigation reports shall be inspected through trial drilling or trial driving. If anomaly is found, treatment measures shall be put forward. If great discrepancy is found, investigation during construction shall be recommended. The bearing capacity of single pile shall be inspected by means of the combination the static loading test and the non-destruction dynamic test. For the large-diameter manual dug piles, the pile

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toe size and rock and soil conditions of the piles shall be inspected one by one.

13.2.3 The foundation treatment effects also can be tested through the cone static penetration, cone dynamic penetration, standard penetration test, pressuremeter test and wave velocity test etc., besides static loading test, which should be performed as per Chapter 10 of this code.

13.2.4 The monitoring scheme of foundation excavation engineering should be determined according to the site conditions and the construction design of supportive structures, which should include the followings:

1 Deformation of bracing structures;

2 Deformation of ground surrounding the foundation pit;

3 Deformation of neighboring engineering and underground facilities;

4 Groundwater level;

5 Leakage, surge, washout and piping etc..

13.2.5 Settlement observation should be carried out for the following projects:

1 Buildings with Grade A foundation design;

2 Grade B buildings with uneven subgrade or soft subgrade;

3 Projects including floors-adding, construction, excavation and loading in neighboring areas that cause ground stress to change obviously;

4 Projects causes underground water level to change dramatically due to water suction and other factors;

5 Projects need observation settlement according to other relevant regulations.

13.2.6 Settlement observation should be performed in terms of the current standard "Code for Deformation Measurement of Buildings and Structurs" JGJ 8.

13.2.7 If necessary, the following monitoring of rock and soils would be conducted:

1 Convergence measurement of cavity or side slopes of rock;

2 Rebound measurement for deep foundation pit excavation;

3 Measurement of earth pressure or rock stress.

13.3 Monitoring for Adverse Geological Actions and Geological Disasters

13.3.1 Monitoring for adverse geological actions and geological disasters should be carried out in the following cases:

1 Adverse geological actions or geological disasters exist in the sites and neighboring areas, which likely endanger the safety or normal uses of projects;

2 Engineering construction and operation which likely accelerate the development of adverse geological actions or incur geological disasters;

3 Project construction and operation likely produce substantial adverse impacts on the neighboring environment.

13.3.2 For the monitoring of adverse geological actions and geological disasters, monitoring outlines shall be worked out based on the geological conditions and the actual engineering requirements of the sites and neighboring areas; and the monitoring shall be processed in line with the outlines. The outline includes: monitoring objectives and requirements, monitoring items, distribution of monitoring points, time interval and observation period, observation instrument, monitoring method and precision, data and drawings to be submitted. Suggestions on disaster forecast and corresponding measures should be provided timely.

13.3.3 Monitoring of karst cavity and soil cave should place monitoring emphasis on the following contents:

1 Ground deformation;

2 Dynamic changes of groundwater level;

3 Water pumping of the sites and neighboring areas;

4 Impacts of groundwater level changes on soil holes development and collapse occurrence.

13.3.4 Landslide monitoring should include the following contents:

1 Displacement of landslip mass;

2 Location and dislocation of sliding plane;

3 Occurrence and development of landslide crack;

4 The groundwater level, flow direction, flow rate of spring water and sliding zone pore water pressure inside and outside the sliding mass;

5 Occurrence and development of displacement, deformation, and cracks of retaining structures and other engineering facilities.

13.3.5 When the stability of collapse disintegrated mass and crags needs to be judged, the tensile cracks should be monitored. The collapse which likely cause serious hazard shall be systematically monitored, and its occurring time, scale, collapsing directions and access, and impacted scopes of collapse likely took place shall be forecasted according to the monitoring results.

13.3.6 For the existing goaf, the ground displacement and building deformation shall be observed in accordance with the following requirements:

1 The observation lines should be parallel and perpendicular to mining beds strike, and its length shall beyond the scopes of moving basins;

2 The interval of observation points may be determined according to the exploitation depth and equal proximately;

3 The observation period shall be determined according the ground deforming rate and exploitation depth.

13.3.7 For regional ground subsidence caused by water-pumping in cities or industrial

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zones, regional ground subsidence should be observed; the monitoring requirements and methods should be in accordance with relevant standards.

13.4 Monitoring of Groundwater

13.4.1 Monitoring of groundwater should be conducted in the following cases:

1 When the fluctuation of groundwater level has influence on the stability of rock and soils;

2 When the buoyancy force generated by the ascending of groundwater level has great impacts on the moisture-proof, water proof and stability of basements or underground structures;

3 When dewatering during construction creates great impacts on the projects to-be-built or neighboring projects;

4 When the variation in pore water pressure and groundwater pressure caused by the construction or environmental conditions changing has great impacts on the engineering design or construction;

5 When the descending of groundwater level causes regional ground sediment;

6 When the fluctuation of groundwater level makes rock and soils to softened, collapsed or swelled and shrunk;

7 When the impacts on the environment from the contaminant transportation need to be appraised.

13.4.2 The monitoring work should be designed according to the monitoring purposes, site conditions, engineering requirements and hydrological and geological conditions.

13.4.3 The monitoring method of groundwater should comply with the following requirements:

1 The groundwater level may be monitored by mean of setting up special observation holes of groundwater level, or by using water well and groundwater natural outcrops;

2 Pore water pressure and groundwater pressure can be monitored with pore water piezomete and piezometer;

3 When adopting chemical analysis method for the monitoring of water quality, the sampling should be not less than four times each year for the analysis of relevant items.

13.4.4 Monitoring time should satisfy with the following requirements:

1 The dynamic monitoring time should be not less than one hydrological year;

2 When the changes in pore water pressure likely impacts the engineering safety, the monitoring should not stop until the pore water pressure drops to the safety value;

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3 For projects influenced by groundwater buoyancy force, monitoring of groundwater pressure should continue until the engineering load is larger than buoyancy force.

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14 Geotechnical Engineering Analysis and Assessment and Invesitigation Report

14.1 General Provisions

14.1.1 Geotechnical engineering analysis and assessment should be conducted on the basis of engineering geological mapping, exploration, testing and collected existing documents, and combining with project features and requirements. Analysis and assessment of various projects, adverse geological actions, geological disaster and special rock and soils should be in accordance with the requirements in Chapter 4, 5 and 6 respectively.

14.1.2 Geotechnical engineering analysis and assessment should comply with the following requirements:

1 To completely acquaint with the styles, features, loads conditions and deformation control requirements of engineering structures;

2 To master the site's geological background, consider the nonuniform property, anisotropism and changes with time of rock and soil materials. To appraise the uncertainness of rock and soil parameters and determine the optimum estimated value;

3 To take local experiences and those of similar works into full consideration.

4 To for geotechniancal problems without sufficient theoretical basis and much practical experiments, the analysis and assessment can be carried out by in-situ model experiment or full scale test to gain actual data;

5 To if necessary, it is suggested to adjust design and construction programme by construction monitoring.

14.1.3 In geotechnical engineering analysis and assessment, quantitative analysis should be conducted on the basis of qualitative analysis. Deformation, strength and stability of rock and soils should be analyzed in a quantitative way. The suitability of the site and the stability of the site geological conditions can be only analyzed in a qualitative way.

14.1.4 Geotechniancal engineering calculations should comply with the following requirements:

1 Calculation based on limited status of bearing capacity may be used to appraise the bearing capacity of rock and soil subgrade and the stability of side slope, retained wall and stability of foundation according to the requirement of related design codes, with calculation method of the sub-item coefficient or total safety coefficient methods. If experiences are available, the allowable value of resistance with implicit safety coefficient can be used in calculation;

2 Verification based on the requirements of limited status under normal uses may be used to appraise the deforming, dynamic reaction, water permeability and water yield of rock and soils and so on.

14.1.5 Geotechnical engineering analysis and assessment should accord with geotechnical engineering investigation grades. For Grade C engineering, the geotechnical engineering investigation can be conducted according to the neighboring engineering experiences, combining with the datum from penetration test, drilling, sampling and testing. For grade B engineering, the geotechnical engineering investigation should be based on detailed exploration and testing work, combining with neighboring engineering experiences, and provide the strength and deforming index of rock and soils. For grade A engineering, besides the requirements for Grade B engineering, loading test results should also be provided. If necessary, special research should be conducted for some sophisticated problems and the assessment should be verified conclusions should be verified combining with monitoring datum.

14.1.6 If required, according to measuring results of rock and soil properties from the engineering prototypes or based on full scale test, the geotechnical parameters may be determined through the reverse analysis method, and the design calculation can be verified, and engineering effects or accident reasons can be checked.

14.2 Determination of Geotechnical Parameters

14.2.1 The rock and soil parameters should be selected based on the engineering features and geological conditions, whose reliability and applicability should be assessed in according to the following contents:

1 The influence of sampling methods and other factors on the testing results;

2 The test methods adopted and value determination standards;

3 Analysis and comparison of results from various test methods;

4 The discrete degree of test results;

5 The matching of the testing method with the used calculation model.

14.2.2 The statistics of geotechnical parameters should comply with the following requirements:

1 Statistics should be made for the physical and mechanical index of rock and soils separately in terms of site's engineering geological units and layers respectively;

2 The average value, standard tolerance and coefficient of variation should be calculated in terms of the following formula:

$$\phi_m = \frac{\sum_{i=1}^{n} \phi_i}{n} \tag{14.2.2-1}$$

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$$\sigma_f=\sqrt{\frac{1}{n-1}\left[\sum_{i=1}^{n}\phi_i^2-\frac{\left(\sum_{i=1}^{n}\phi_i\right)^2}{n}\right]} \qquad (14.2.2\text{-}2)$$

$$\delta=\frac{\sigma_f}{\phi_m} \qquad (14.2.2\text{-}3)$$

Where ϕ_m——Average value of rock and soil parameters;

σ_i——Standard tolerance of rock and soil parameters;

δ——Coefficient of variation of rock and soil parameters.

3 To analyze the distribution of the data and illustrate standards of data accepted or rejected.

14.2.3 Curves of major parameters v. s depth should be made and divided into relative type and irrelative type according to the variation features. If necessary, the variation discipline of parameters in the horizontal should be analyzed.

Combining with the experimental relations of rock and soil parameters with depth, the remaining standard tolerance of relative-type parameters can be determined according to the following formula, and the coefficient of variation can be determined by the remaining standard tolerance.

$$\sigma_r=\sigma_1\sqrt{1-r^2} \qquad (12.2.3\text{-}1)$$

$$\delta=\frac{\sigma_r}{\phi_m} \qquad (12.2.3\text{-}2)$$

Where σ_r——Remaining standard tolerance;

r——Relative coefficient; $r=0$ for the irrelative type.

14.2.4 The standard value ϕ_k of rock and soil parameters would be determined according to the following method:

$$\phi_k=\gamma_s\phi_m \qquad (14.2.4\text{-}1)$$

$$\gamma_s=1\pm\left\{\frac{1.704}{\sqrt{n}}+\frac{4.678}{n^2}\right\}\delta \qquad (14.2.4\text{-}2)$$

Where γ_s——Correction coefficient of statistics.

Note: The positive or minus in the formula should be selected with consideration of the adverse combination, for example, the correction coefficient of anti-shear strength index should be minus.

The correction coefficient of statistics γ_s also can be selected according to experiences based on the type and importance geotechnical engineering, variation of parameters and number of statistics data.

14.2.5 The geotechnical engineering investigation reports should provide rock and soil parameter value according to different situations as followings:

1 In general, geotechnical parameters such as the average value, standard tolerance, coefficient of variation, distribution scope of data and the number of data should be provided;

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2 The standard value of rock and soil parameters for the calculation of limited state bearing capacity shall be determined by formula (14.2.4.1). Unless there is special determination method of standard value specified in related norms.

14.3 Basic Requirements of Result Reports

14.3.1 The original documents, on which geotechncial investigation reports are based, should be complied, checked, and analyzed and it can be used only after it is confirmed that there is no errors.

14.3.2 Geotechnical engineering investigation reports shall be with completed information, true and accurate data without faults, clear tables and figures, reliable conclusions, reasonable recommendations, and convenient for use and long-term preservation. It should accord with actual conditions, high-light key points and has definite engineering objective.

14.3.3 The compilation of geotechnical engineering investigation reports shall comply with task requirements, investigation stages, project features and geological conditions, and shall include the following contents:

1 Investigation purposes, task requirements and technical standards referred to;

2 General description of the projects to-be-built;

3 Investigation methods and investigation work amount;

4 Topography, ground feature, stratum, geological configuration, rock and soil properties and uniformity of the site;

5 Index of rock and soil properties, the recommended value of strength parameters, deformation parameters and subsoil bearing capacity;

6 The embedded condition, types, water level and fluctuation of the underground water;

7 Corrosion of soil and water to building materials;

8 Description of adverse geological actions which possibly has influence on the engineering stability and assessment its hazard degree to the projects;

9 Assessment of stability and suitability of the site.

14.3.4 The geotechnical engineering investigation reports shall analyze and demonstrate the utilization, treatment and renovation methods of rock and soils and provide recommendations, predict geotechnical problems that may probably occurred during construction and using period, and put forward recommendations on monitoring and precaution measures.

14.3.5 The following figures shall be attached to the geotechnical engineering investigation reports:

1 The layout of exploration points;

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2 The engineering geological log;

3 The engineering geological profile;

4 Figure and table of in-situ tests results;

5 Figure and table of laboratory tests results.

Note: If necessary, such figures and tables as comprehensive engineering geological figures, comprehensive geological logs, underground water level contour map, sketch, pictures, comprehensive analysis figures and tables, related figures and tables of rock and soil utilization, treatment and renovation, rock and soil engineering calculation diagrams and calculation result figures and tables may be attached.

14.3.6 For the proposals to the utilization, treatment and renovations of rock and soils, technical and economical demonstration of various methods should be conducted, and recommendations on design, construction and in-situ monitoring requirements should be provided.

14.3.7 The following special reports may be submitted if required:

1 Geotechnical engineering inspection and testing reports;

2 Geotechnical engineering testing or monitoring reports;

3 Investigation and analysis reports of geotechnical engineering accident;

4 Rock and soil utilization, treatment or renovation reports;

5 Technical consultation reports of special geotechnical engineering problems.

14.3.8 The wordings, terminology, notations, symbols, digits, metric units and punctuation marks in investigation reports should comply with the requirements of related national standards.

14.3.9 The geotechnical engineering investigation reports for Grade C engineering may be properly simplified, and primarily in diagrams and charts with necessary literal explanation. For the geotechnical engineering investigation reports for Grade A engineering, besides the requirements of this section, special test reports, research reports or monitoring reports aiming at special geotechnical problems may be submitted.

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Appendix A Classification and Identification of Rock and Soil

A. 0. 1 The hardness degree of rocks can be qualitatively classified in terms of Table A. 0. 1.

Table A. 0. 1 Qualitative Classification of Rock Hardness

Hardness grade		Qualitative descriptions	Representative rocks
Stiff rock	Hard rock	Silvery knocking sound, rebounded, hand-shocked, hard to be crushed, basically no water absorbing reaction	Non-weathered or slightly weathered granite, diorite, dolerite, basalt, andesite, gneiss, quartzite, quartz gritstone, silicic conglomerate, silicon limestone
	Secondly hard rock	Relatively silvery knocking sound, small rebounded, slightly hand shocked, not easy to be crushed, slight water absorbing reaction	1 Slightly weathered hard rocks; 2 Non-weathered or slightly wea-thered marble, slate, limestone, dolomite rock, calcium gritstone
Soft rock	Secondly soft rock	Not silvery knocking sound, not rebounded, relatively easy to be crushed, can be scratched by fingers after dipped in water	1 Moderately weathered or highly weathered hard rocks or secondly hard rocks; 2 Non-weathered orslightly wea-thered tuff, phylite, marlite, sandy mudstone
	Soft rock	Muting knocking sound, not rebounded, easy to be crushed, may be broken off with fingers after dipped in water	1 Highly weathered hard rocks or secondly hard rocks; 2 Moderately weathered or highly weathered soft rocks; 3 Non-weathered or slightly weathered shale
Extremely soft rock		Muting knocking sound, not rebounded, with dint may be pinched to break by hands, and may be made agglomeration by hands after dipped in water	1 Various fully weathered rocks; 2 Various half formed rocks

A. 0. 2 The integrality degree of rock mass can be qualitatively classified in terms of Table A. 0. 2.

Table A. 0. 2 Qualitative Classification of Rock Integrality Degree

Integrality degree	Development degree of structural plane		Integrating degree of major structural plane	Types of major structural plane	Corresponding structural types
	Number of groups	Average intervals (m)			
Integral	1～2	>0. 1	Well or commonly integrated	Fissure, bedding plane	Monolithic or huge thick layer structure

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Table A. 0. 2 (continued)

Integrality degree	Development degree of structural plane		Integrating degree of major structural plane	Types of major structural plane	Corresponding structural types
	Number of groups	Average intervals (m)			
Secondly integral	1～2	>1. 0	Poorly integrated	Fissure, bedding plane	Chunk or thick layer structure
	2～3	1. 0～0. 4	Well or commonly integrated		Chunk structure
Secondly frangible	2～3	1. 0～0. 4	Poorly integrated	Fissure, bedding plane, small fault	Cracked chunk or moderately thick layer structure
	⩾3	0. 4～0. 2	Well integrated		Inlaid fracture structure
			Commonly integrated		Moderately thick or thin layer structure
Frangible	⩾3	0. 4～0. 2	Poorly integrated	Various structural plane	Cracked chunk structure
		⩽0. 2	Commonly or poorly integrated		Fracture structure
Extremely frangible	Out of order		Very poorly integrated		Fragmentary structure

Note: Average interval refers to the average value of intervals between major structural sections (1～2 groups).

A. 0. 3 Weathering degree of rocks can be classified in terms of Table A. 0. 3.

Table A. 0. 3 Weathering Degree Classification of Rocks

Weathering degree	Field characters	Indices of weathering degree parameters	
		Wave velocity ratio K_v	Weathering coefficient K_f
Non-weathered	Fresh texture, weathering trace occasionally seen	0. 9～1. 0	0. 9～1. 0
Slightly weathered	Structure basically kept unchanged, only color slightly changed at joint plane, small amount of weathered fissures	0. 8～0. 9	0. 8～0. 9
Moderately weathered	Structure partially destroyed, secondary minerals appeared along joint planes, weathered fissures developed, rock mass is cut into chunks, hard to be dug by shovel, can be drilled with core driller	0. 6～0. 8	0. 4～0. 8
Highly weathered	Majority of structural planes destroyed, mineral components changed obviously, weathered fissure well developed, rock mass crashed, may be dug by shovel, hard to be drilled in dry condition	0. 4～0. 6	<0. 4
Fully weathered	Structure basically destroyed, but still being recognizable, residual structural strength existing, may be dug by shovel, and drilled in dry condition	0. 2～0. 4	—
Residual soil	Structure fully destroyed, weathered to soils, easily dug by shovel, easily drilled in dry condition, with plasticity	<0. 2	—

Note: 1 Wave velocity ration K_v is the ratio of compressing wave rates of weathered rocks and fresh rocks;

2 Weathered coefficient K_f is the ratio of saturated uniaxial compressive strength of weathered rocks and fresh rocks;

3 Weathering degree of rocks can be classified according to the local experiences besides in terms of the field

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character and quantitative indices listed in the table;

4 Granite-type rocks can be classified in terms of standard penetration test, highly weathered in case of $N \geqslant 50$, fully weathered in case of $50 > N \geqslant 30$, and residual soils in case of $N < 30$;

5 Half formed rocks may not be divided in terms of weathering degree.

A. 0. 4 Rock mass can be classified in terms of structural types shown in Table A. 0. 4:

Table A. 0. 4 Rock Mass Classification in Terms of Structural Types

Structural types of rocks	Geological types of rock mass	Shapes of structures	Development of structural section	Rock and soil engineering properties	Likely rock and soil geotechnical engineering problems occurred
Monolithic structure	Huge chunk magma rocks and metamorphic rocks, huge thick sedimentary rock	Huge chunk	Primary in joint of bedding plane, original and structural joints, which mostly in closed type, with interval larger than 1. 5m. Generally one to two groups exists, with no dangerous structures	Stable rock mass, may be regarded as homogeneous, elastic and anisotropic mass	Locally slide or collapse, eboulement of deeply covered cavities
Chunk structure	Thick layer sedimentary rocks. Chunk magma rocks and metamorphic rocks	Chunk and column type	There are few interpenetrative joint fissures, interval of structural sections is 0. 7-1. 5m, there generally are two to three groups, and few disintegrated mass existing	Inter-restrained among the structural planes, which is basically stable rock mass is close to elastic and anisotropic mass	
Laminated structure	Multi-rhythm thin layer, medially thick layer sedimentary rocks and metamorphic rocks	Layer and plate type	There are beddings, schistosty, joints, layer dislocation commonly happened	Deformation and strength controlled by bedding surface, may be regarded as anisotropic, elastic plastic mass, with poor stability	Sliding collapsed along structural plane, soft rocks likely create plastic deformation
Cracked structure	Cracked rocky layers with seriously impacted by configuration	Cracked chunk	Fault, joint, schistosty, bedding are developed, interval of structural sections is 0. 25～0. 50m, generally over three groups, and many disintegrated mass exists	Low whole strength controlled by soft and weak structural plane, elastic and plastic, with poor stability	Large-scale rock mass instability easily happened, underground water intensifies the instability
Fragmentary structure	Fracture zone of fault, highly or fully weathered zone	Fragment	Dense structural and weathered fissures, sophisticated structural plane, fully filled with adhesive soils, out-of-order small chunks and fragments formed	Integrality seriously destroyed, poor stability, close to loose media	Rock stability failure easily took place in large scale, underground water intensifies the instability

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A. 0. 5 Soil can be classified in terms of organic matter contents shown in Table A. 0. 5.

Table A. 0. 5 Soil Classification in Terms of Organic Matter Contents

Category	Organic matter content W_u (%)	In-situ identifying character	Interpretation
Inorganic soil	$W_u<5\%$		
Organic soil	$5\%\leqslant W_u\leqslant 10\%$	Dark gray, lustrous, odor, containing some not completely decomposed animal and plant bodies besides humus, air bubble appeared at the water surface after immersed in water, volume shrank after dried.	1 If it can be identified on the spot or regional experiences are available, it is no need to measure the contents of organic matter; 2 It is called sledged soil when $w>w_L$, $1.0\leqslant e<1.5$; 3 It is called sludge when $w>w_L$, $e\geqslant 1.5$
Peaty soil	$10\%\leqslant W_u\leqslant 60\%$	Dark gray or black, fishy odor, not completely decomposed plant structures found, volume swelled when dipped in water, easily disintegrated, plant residues floated in water, obvious shrinking after dried	Wu can be undivided in terms of regional characters and demands: Weak peaty soil ($10\%\leqslant W_u\leqslant 25\%$); Medium peaty soil ($25\%\leqslant W_u\leqslant 40\%$); Strong peaty soil ($40\%\leqslant W_u\leqslant 60\%$)
Peat	$W_u>60\%$	Having the characters of peaty soil, loose structures, light soil weight, dark, no luster, extremely obvious shrinking after dried	

Note: The organic matter content W_u is determined in terms of weight losses by burning.

A. 0. 6 Field identification of compactness of gravelly soil can be performed in terms of Table A. 0. 6.

Table A. 0. 6 Field Identification of Compactness for Gravelly Soil

Compactness	Contents and arrangement of skeleton particles	Dug possibility	Drilled possibility
Loose	Mass of skeleton particles less than 60% of the total, disordered distribution, majority of them without contacts	May be dug by shovel, well walls easily collapse; well walls collapse as soon as big particles are taken out	Easily drilled, drill rod slightly shaken, hole walls easily collapse
Medium dense	Mass of skeleton particles equal to 60% of the total, crossbeding distribution, majority of them with contacts	May be dug by shovel, there is chunks fall from well walls. Well walls keep concave shapes when big particles are taken out	Relatively hard to be drilled, drill rod and hoisted hammer hopped not dramatically, hole walls likely collapse
Dense	Mass of skeleton particles greater than 70% of the total; crossbeding distribution, continuous contact	Hard to be dug by shovel, loosened only by crowbar, well wall relatively stable	Hard to be drilled, drill rod and hoisted hammer hopped dramatically, hole wall relatively stable

Note: Compactness should be determined by comprehensively considering all the characters listed in the table.

Appendix B Correction of Blows of Cone Dynamic Penetration

B. 0. 1 When the heavy cone dynamic penetration test is employed to determine the density of gravelly soil, the blows of $N_{63.5}$ shall be corrected according to the following formula:

$$N_{63.5}=\alpha_1 \cdot N'_{63.5} \tag{B. 0. 1}$$

Where $N_{63.5}$——The corrected blow number of heavy cone dynamic penetration;

α_1——The correction coefficient, which shall be selected from Table B. 0. 1 below;

$N'_{63.5}$——Blow number of cone dynamic penetration test recorded.

Table B. 0. 1 Correction Coefficient for Heavy Cone Dynamic Penetration Tests

$N'_{63.5}$ / L (m)	5	10	15	20	25	30	35	40	≥50
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
4	0.96	0.95	0.93	0.92	0.90	0.89	0.87	0.86	0.84
6	0.93	0.90	0.88	0.85	0.83	0.81	0.79	0.78	0.75
8	0.90	0.86	0.83	0.80	0.77	0.75	0.73	0.71	0.67
10	0.88	0.83	0.79	0.75	0.72	0.69	0.67	0.64	0.61
12	0.85	0.79	0.75	0.70	0.67	0.64	0.61	0.59	0.55
14	0.82	0.76	0.71	0.66	0.62	0.58	0.56	0.53	0.50
16	0.79	0.73	0.67	0.62	0.57	0.54	0.51	0.48	0.45
18	0.77	0.70	0.63	0.57	0.53	0.49	0.46	0.43	0.40
20	0.75	0.67	0.59	0.53	0.48	0.44	0.41	0.39	0.36

Note: In the table, "L" is the length of rod.

B. 0. 2 When super-heavy cone dynamic penetration test is employed in determining the density of gravelly soil, the blow number of N_{120} shall be corrected according to the following formula:

$$N_{120}=\alpha_2 \cdot N'_{120} \tag{B. 0. 2}$$

Where N_{120}——The corrected blow number of super-heavy dynamic cone penetration;

α_2——The correction coefficient, which shall be selected from Table B. 0. 2 below;

N'_{120}——Blow number of cone dynamic penetration test recorded.

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Table B. 0. 2 Correction Coefficient for Super-Heavy Cone Dynamic Penetration Tests

L (m) \ N'_{120}	1	3	5	7	9	10	15	20	25	30	35	40
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.96	0.92	0.91	0.90	0.90	0.90	0.90	0.89	0.89	0.88	0.88	0.88
3	0.94	0.88	0.86	0.85	0.84	0.84	0.84	0.83	0.82	0.82	0.81	0.81
5	0.92	0.82	0.79	0.78	0.77	0.77	0.76	0.75	0.74	0.73	0.72	0.72
7	0.90	0.78	0.75	0.74	0.73	0.72	0.71	0.70	0.68	0.68	0.67	0.66
9	0.88	0.75	0.72	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.62
11	0.87	0.73	0.69	0.67	0.66	0.66	0.64	0.62	0.61	0.60	0.59	0.58
13	0.86	0.71	0.67	0.65	0.64	0.63	0.61	0.60	0.58	0.57	0.56	0.55
15	0.86	0.69	0.65	0.63	0.62	0.61	0.59	0.58	0.56	0.55	0.54	0.53
17	0.85	0.68	0.63	0.61	0.60	0.60	0.57	0.56	0.54	0.53	0.52	0.50
19	0.84	0.66	0.62	0.60	0.58	0.58	0.56	0.54	0.52	0.51	0.50	0.48

Note: In the table, "L" is the length of rod.

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Appendix C Engineering Classification of Debris Flow

C. 0. 1 Engineering classification of debris flow shall be performed according to the following Table C. 0. 1.

Table C. 0. 1 Features and Engineering Classification of Debris Flow

Category	Features of debris flow	Features of debris flow area	Sub-category	Seriousness	Coverage of flow area (km^2)	Flush amount once of solid material ($\times 10^4 m^3$)	Flow amount (m^3/s)	Dumping area (km^2)
Valleys with high frequent occurrence of debris flow	Debris flows almost occur every year. Landslide and collapse from the valley are the main source of solid material. Storm intensity is weaker than 2~4 mm/10min. Besides rocky factors, large-scale sticky debris flow always occurs in valleys with serious slide and collapse. Other wise, the flow is usually thin and small	Mostly in strongly elevating area. Rock layers are crushed and seriously weathered and mountain body has bad stability. Debris is newly dumped with no vegetations or only sparse weeds. For viscous debris flow, the bed slope of the middle and lower reaches is larger than 4%	I_1	Very	>5	>5	>100	>1
			I_2	Medium	1~5	1~5	30~100	<1
			I_3	Slight	<1	<1	<30	—
Valleys with low frequent occurrence of debris flow	Debris flows generally occur less than once every 10 years. Valley bed is the main source of solid material. When flow occurs, there is apparent phenomenon of "bed-scouring". Shallow slide on slopes during storms is the main instigation of debris flows. Storm instigator is strong and of large scale, usually stronger than 4mm/10min. Sticky or thin	Mountain body is relatively stable with no large-scale active slide or collapse. Large gravels are distributed around the valley bed and fan area. Plants cover the ground well with dense bushes on bed. Fan area is mostly developed into agricultural sites. For sticky debris flow, the bed slope of the middle and lower reaches is smaller than 4%	II_1	Very	>10	>5	>100	>1
			II_2	Medium	1~10	1~5	30~100	<1
			II_3	Slight	<1	<1	<30	—

Note: 1 In the table, the flow amount for high frequent debris flow valley refers to the maximum amount once encountered within 100 years, for low frequent debris flow, it is the largest amount recorded in the previous;

2 Engineering classification of debris flow should be conducted by combination of field features with quantified indicators, and only one indicator is necessary to be satisfied.

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Appendix D Preliminary Determination of Expansive Soil

D. 0. 1 Soil with the following features can be preliminarily determined as expansive soil:

1 Mostly distributed in the second or higher terrace, hills in front of mountains and verge of basins;

2 Even topography with no apparent naturally-formed escarp;

3 Frequency appearance of shallow slides and ground crack. Collapses are easy to occur in newly excavated road cuts, slopes and trench;

4 Fissures is developed in irregular directions, frequently with smooth faces and scratch, and are usually filled with gray or pale green clay;

5 Hard when dry, softened when met with water, and when in natural condition, usually appears hard or non-plastic;

6 Free swelling rate generally larger than 40%;

7 Untreated building structures are destroyed in group, and of which low-rise buildings more seriously than multi-story ones and rigid ones than flexible ones;

8 Crevice of buildings occurs usually in dry seasons and the width of the crevices changes with season.

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Appendix E Determination Method for Hydrogeological Parameters

E. 0. 1 Hydrogeological parameters can be determined by means specified in Table E. 0. 1.

Table E. 0. 1 Determination Method for Hydrogeological Parameters

Parameters	Methods
Water level	Observed by means of drilling, exploratory well, or peizometer Permeability coefficient
Coefficient of conductivity	Water-pumping test, water injection test, water-pressing test, and lab permeability test
Coefficient of yield Coefficient of storage	Single-hole water-pumping test, unsteady flow water-pumping test, ground water level long-term monitoring, laboratory test
Run-over coefficient, leakage factor	Multi-hole water-pumping test (steady-flow or unsteady-flow)
Unit water absorption rate	Water injection test, water-pressing test
Capillary elevation	Testing pit monitoring, laboratory test

Note: Except for water level, when there are not too many restrictions on accuracy, empirical data can be employed.

E. 0. 2 Pore-water pressure can be observed by methods specified in Table E. 0. 2.

Table E. 0. 2 Pore-Water Pressure Observation Method and Applicability

Instruments Type		Applicability	Observation Methods
Type of piezometer	Standpipe piezometer	Suitable for aquifer with uniform porosity and its permeability coefficient larger than 10^{-4} cm/s	Drive a piezometric pipe with filter into the ground and observe it directly inside the pipe
	Hydrulic piezometer	In soil layers with low permeability coefficient, observe the pressure changes caused by tidal fluctuation and excavation	By a small piezometer probe installed on the wall of the hole, the ground water pressure can be observed, which is conducted to mercury meter by plastic duct
	Electrical piezometer (resistance strain type & steel chord strain type)	Various soil layers	The pore water pressure conducted through porous stone to diaphragm cause deflection changes and then induce changes in resistance piece(or steel chord), and then detected by receiver
	Pneumatic piezometer	Various soil layers	Keep the pressures constantly by 2 air-exhausted tubes. The conducted pore pressure causes pressure difference on hydraulic valve in porous element, which is to be measured
Static penetrometer of pore pressure		Various soil layers	Install porous pervious filter and pressure sensor on penetrometer probe and measuring during penetration

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Appendix F Technical Standards for Soil Sampler

F. 0. 1 Parameters of soil sampler should conform to regulations in Table F. 0. 1 below.

Table F. 0. 1 Parameters of Soil Sampler

Sampler Parameters	Thick-wall soil sampler	Thin-wall soil sampler		
		Free open piston	Water pressure fixed piston	Fixed piston
Area ratio $\frac{D_w^2-D_c^2}{D_c^2}\times 100$ (%)	13～20	⩽10	10～13	
Internal interspaces ratio $\frac{D_S-D_e}{D_e}\times 100$ (%)	0.5～1.5	0	0.5～1.0	
Outside interspaces ratio $\frac{D_w-D_t}{D_t}\times 100$ (%)	0～2.0	0		
Blade angle α (°)	＜10	5～10		
Length L (mm)	400, 500	SandY soil: (5～10) D_e Cohesive soil: (10～15) D_e		
Outer diameter D_t (mm)	75～89, 108	75, 100		
Liner pipe	Whole rounding or semi-closure pipe, plastic and phenolic laminated paper or galvanized sheet iron	No liner pipe. Ringed-line barrel sampler, liner pipe is the same as the left one.		

Note: 1 The inner wall of sampling pipe and liner pipe must be smooth, round and intact;

2 In special circumstances, the diameter of sampler can be enlarged to 150～250mm;

3 In the table;

D_e——The internal diameter of the blade of sampler;

D_s——The internal diameter of sampling pipe, or internal diameter of liner pipe when liner pipe is employed;

D_t——The outside diameter of sampling pipe;

D_w——The outside diameter of the sampler shoe, for thin-walled pipes, $D_w=D_t$.

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Appendix G Site Environement Type

G. 0. 1 The site environment classification shall meet the requirements of Table G. 0. 1.

Table G. 0. 1 Environment Classification

Environment classification	Geological condition of the site environment
Ⅰ	Hign cold region, dry region directly face water; the underground water in the strong permeable strata of high cold region, dry region
Ⅱ	The underground water in the poor permeable strata of high cold region, dry region Humid region directly face water; the underground water in the strong permeable strata of the humid region
Ⅲ	Slight-wet poor permeable strata of climatic areas; strong permeable strata above underground water level of climatic areas

Note: 1 The high cold region is referred to the area whose sea level is equal to or greater than 3000m, and the dry region is referred to the area 3000m lower than exhaustion and index of aridity is equal to or greater than 1.5; the humid region is referred to the area which index of aridity K value is less than 1.5;

2 The strong permeable strata refers to gravel soil and sandy soil; the poor permeable strata refers to silty soil and cohesive soil;

3 Soil layers with water content ω less than 3% can be taken as dry layers with no corrosive to the surroundings.

3A When the concrete structure has one side contact the surface of underground water, and another side expose to the air, water may be evaporated through seepage of capillary action in the exposed air, the environment type of concrete structure shall be classified as I-level;

4 When there is any local experience, the environment type can be classified according to the local experience; when the same site has two different environment types, it shall be classified according to specific circumstances.

G. 0. 2 (This clause is cancelled)

G. 0. 3 (This clause is cancelled)

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Appendix H Explanation of Wording in This Code

H. 0. 1 In order to treat different situations according to their individual conditions during the implementation of this code, Words denoting the different degrees of strictness of demands are explained as follows:

1 Words denoting a very strict or mandatory requirement:
"Must" is used for affirmation; "Must not" is used for negation.

2 Words denoting a strict requirement under normal conditions:
"Shall" is used for affirmation; "Shall not" is used for negation.

3 Words denoting a permission of slight choice or an indication of the most suitable choice when conditions allow:
"Should" or "may" are used for affirmation; "Should not" is used for negation.

H. 0. 2 "Be in accordance with be or in compliance with" are used to indicate that it is necessary to implement items in this code according to other relative standards and stipulations.

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中华人民共和国国家标准

岩土工程勘察规范

Code for Investigation of Geotechnical Engineering

GB 50021－2001

（2009 年版）

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关于发布国家标准《岩土工程勘察规范》局部修订的公告

第 314 号

现批准《岩土工程勘察规范》GB50021－2001 局部修订的条文，自 2009 年 7 月 1 日起实施。其中，1.0.3、4.1.18(1、2、3、4)、4.1.20(1、2、3)、4.8.5、5.7.2、7.2.2 条(款)为强制性条文，必须严格执行。经此次修改的原文条同时废止。

局部修订的条文及具体内容，将在近期出版的《工程建设标准化》刊物上登载。

中华人民共和国住房和城乡建设部

2009 年 5 月 19 日

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关于发布国家标准
《岩土工程勘察规范》的通知

建标[2002]7 号

根据我部《关于印发一九九八年工程建设国家标准制订、修订计划(第二批)的通知》(建标[1998]244 号)的要求,由建设部会同有关部门共同修订的《岩土工程勘察规范》,经有关部门会审,批准为国家标准,编号为 GB 50021－2001,自 2002 年 3 月 1 日起施行。其中,1.0.3、4.1.11、4.1.17、4.1.18、4.1.20、4.8.5、4.9.1、5.1.1、5.2.1、5.3.1、5.4.1、5.7.2、5.7.8、5.7.10、7.2.2、14.3.3 为强制性条文,必须严格执行。原《岩土工程勘察规范》GB 50021－94 于 2002 年 12 月 31 日废止。

本规范由建设部负责管理和对强制性条文的解释,建设部综合勘察研究设计院负责具体技术内容的解释,建设部标准定额研究所组织中国建筑工业出版社出版发行。

中华人民共和国建设部

2002 年 1 月 10 日

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前　言

本规范是根据建设部建标[1998]244号文的要求，对1994年发布的国标《岩土工程勘察规范》的修订。在修订过程中，主编单位建设部综合勘察研究设计院会同有关勘察、设计、科研、教学单位组成编制组，在全国范围内广泛征求意见，重点修改的部分编写了专题报告，并与正在实施和正在修订的有关国家标准进行了协调，经多次讨论，反复修改，先后形成了《初稿》、《征求意见稿》、《送审稿》，经审查，报批定稿。

本规范基本上保持了1994年发布的《规范》的适用范围、总体框架和主要内容，作了局部调整。现分为14章：1. 总则；2. 术语和符号；3. 勘察分级和岩土分类；4. 各类工程的勘察基本要求；5. 不良地质作用和地质灾害；6. 特殊性岩土；7. 地下水；8. 工程地质测绘和调查；9. 勘探和取样；10. 原位测试；11. 室内试验；12. 水和土腐蚀性的评价；13. 现场检验和监测；14. 岩土工程分析评价和成果报告。

本次修订的主要内容有：1. 适用范围增加了“核电厂”的勘察；2. 增加了“术语和符号”章；3. 增加了岩石坚硬程度分类、完整程度分类和岩体基本质量分级；4. 修订了“房屋建筑和构筑物”以及“桩基础”勘察的要求；5. 修订了“地下洞室”、“岸边工程”、“基坑工程”和“地基处理”勘察的规定；6. 将“尾矿坝和贮灰坝”节改为“废弃物处理工程”的勘察；7. 将“场地稳定性”章名改为“不良地质作用和地质灾害”；8. 将“强震区的场地和地基”、“地震液化”合为一节，取名“场地与地基的地震效应”；9. 对特殊性土中的“湿陷性土”和“红粘土”作了修订；10. 加强了对“地下水”勘察的要求；11. 增加了“深层载荷试验”和“扁铲侧胀试验”等。同时压缩了篇幅，突出勘察工作必须遵守的技术规则，以利作为工程质量检查的执法依据。

本规范将来可能进行局部修订，有关局部修订的信息和条文内容将刊登在《工程建设标准化》杂志上。

本规范以黑体字标志的条文为强制性条文。必须严格执行。

为了提高规范质量，请各单位在执行过程中，注意总结经验，积累资料。随时将有关意见反馈给建设部综合勘察研究设计院（北京东直门内大街177号，邮编100007），以供今后修订时参考。

参加本次修订的单位和人员名单如下：

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1 总　　则

1.0.1 为了在岩土工程勘察中贯彻执行国家有关的技术经济政策，做到技术先进，经济合理，确保工程质量，提高投资效益，制定本规范。

1.0.2 本规范适用于除水利工程、铁路、公路和桥隧工程以外的工程建设岩土工程勘察。

1.0.3 各项建设工程在设计和施工之前，必须按基本建设程序进行岩土工程勘察。

1.0.3A 岩土工程勘察应按工程建设各勘察阶段的要求，正确反映工程地质条件，查明不良地质作用和地质灾害，精心勘察、精心分析，提出资料完整、评价正确的勘察报告。

1.0.4 岩土工程勘察，除应符合本规范的规定外，尚应符合国家现行有关标准、规范的规定。

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2 术语和符号

2.1 术　　语

2.1.1 岩土工程勘察　geotechnical investigation

根据建设工程的要求，查明、分析、评价建设场地的地质、环境特征和岩土工程条件，编制勘察文件的活动。

2.1.2 工程地质测绘　engineering geological mapping

采用搜集资料、调查访问、地质测量、遥感解译等方法，查明场地的工程地质要素，并绘制相应的工程地质图件。

2.1.3 岩土工程勘探　geotechnical exploration

岩土工程勘察的一种手段，包括钻探、井探、槽探、坑探、洞探以及物探、触探等。

2.1.4 原位测试　in-situ tests

在岩土体所处的位置，基本保持岩土原来的结构、湿度和应力状态，对岩土体进行的测试。

2.1.5 岩土工程勘察报告　geotechnical investigation report

在原始资料的基础上进行整理、统计、归纳、分析、评价，提出工程建议，形成系统的为工程建设服务的勘察技术文件。

2.1.6 现场检验　in-situ inspection

在现场采用一定手段，对勘察成果或设计、施工措施的效果进行核查。

2.1.7 现场监测　in-situ monitoring

在现场对岩土性状和地下水的变化，岩土体和结构物的应力、位移进行系统监视和观测。

2.1.8 岩石质量指标(RQD)　rock quality designation

用直径为 75mm 的金刚石钻头和双层岩芯管在岩石中钻进，连续取芯，回次钻进所取岩芯中，长度大于 10cm 的岩芯段长度之和与该回次进尺的比值，以百分数表示。

2.1.9 土试样质量等级　quality classification of soil samples

按土试样受扰动程度不同划分的等级。

2.1.10 不良地质作用　adverse geologic actions

由地球内力或外力产生的对工程可能造成危害的地质作用。

2.1.11 地质灾害　geological disaster

由不良地质作用引发的，危及人身、财产、工程或环境安全的事件。

2.1.12 地面沉降　ground subsidence，land subsidence

大面积区域性的地面下沉，一般由地下水过量抽吸产生区域性降落漏斗引起。大面积地下采空和黄土自重湿陷也可引起地面沉降。

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2.1.13 岩土参数标准值 standard value of a geotechnical parameter

岩土参数的基本代表值，通常取概率分布的 0.05 分位数。

2.2 符　　号

2.2.1 岩土物理性质和颗粒组成

e——孔隙比；

I_L——液性指数；

I_P——塑性指数；

n——孔隙度，孔隙率；

S_r——饱和度；

w——含水量，含水率；

w_L——液限；

w_P——塑限；

W_u——有机质含量

γ——重力密度（重度）；

ρ——质量密度（密度）；

ρ_d——干密度。

2.2.2 岩土变形参数

a——压缩系数；

C_c——压缩指数；

C_c——再压缩指数；

C_s——回弹指数；

c_h——水平向固结系数；

c_v——垂直向固结系数；

E_0——变形模量；

E_D——侧胀模量；

E_m——旁压模量；

E_s——压缩模量；

G——剪切模量；

p_c——先期固结压力。

2.2.3 岩土强度参数

c——粘聚力；

p_0——载荷试验比例界限压力，旁压试验初始压力；

p_f——旁压试验临塑压力；

p_L——旁压试验极限压力；

p_u——载荷试验极限压力；

q_u——无侧限抗压强度；

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τ——抗剪强度；

φ——内摩擦角。

2.2.4 触探及标准贯入试验指标

R_f——静力触探摩阻比；

f_s——静力触探侧阻力；

N——标准贯入试验锤击数；

N_{10}——轻型圆锥动力触探锤击数；

$N_{63.5}$——重型圆锥动力触探锤击数；

N_{120}——超重型圆锥动力触探锤击数；

p_s——静力触探比贯入阻力；

q_c——静力触探锥头阻力。

2.2.5 水文地质参数

B——越流系数；

k——渗透系数；

Q——流量，涌水量；

R——影响半径；

S——释水系数；

T——导水系数；

u——孔隙水压力。

2.2.6 其他符号

F_s——边坡稳定系数；

I_D——侧胀土性指数；

K_D——侧胀水平应力指数；

p_e——膨胀力；

U_D——侧胀孔压指数；

ΔF_s——附加湿陷量；

s——基础沉降量，载荷试验沉降量；

S_t——灵敏度；

α_w——红粘土的含水比；

v_p——压缩波波速；

v_s——剪切波波速；

δ——变异系数；

Δ_s——总湿陷量；

μ——泊松比；

σ——标准差。

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3 勘察分级和岩土分类

3.1 岩土工程勘察分级

3.1.1 根据工程的规模和特征，以及由于岩土工程问题造成工程破坏或影响正常使用的后果，可分为三个工程重要性等级：

1 一级工程：重要工程，后果很严重；

2 二级工程：一般工程，后果严重；

3 三级工程：次要工程，后果不严重。

3.1.2 根据场地的复杂程度，可按下列规定分为三个场地等级：

1 符合下列条件之一者为一级场地（复杂场地）：

1）对建筑抗震危险的地段；

2）不良地质作用强烈发育；

3）地质环境已经或可能受到强烈破坏；

4）地形地貌复杂；

5）有影响工程的多层地下水、岩溶裂隙水或其他水文地质条件复杂，需专门研究的场地。

2 符合下列条件之一者为二级场地（中等复杂场地）：

1）对建筑抗震不利的地段；

2）不良地质作用一般发育；

3）地质环境已经或可能受到一般破坏；

4）地形地貌较复杂；

5）基础位于地下水位以下的场地。

3 符合下列条件者为三级场地（简单场地）：

1）抗震设防烈度等于或小于 6 度，或对建筑抗震有利的地段；

2）不良地质作用不发育；

3）地质环境基本未受破坏；

4）地形地貌简单；

5）地下水对工程无影响。

注：1 从一级开始，向二级、三级推定，以最先满足的为准；第 3.1.3 条亦按本方法确定地基等级；

2 对建筑抗震有利、不利和危险地段的划分，应按现行国家标准《建筑抗震设计规范》（GB 50011）的规定确定。

3.1.3 根据地基的复杂程度，可按下列规定分为三个地基等级：

1 符合下列条件之一者为一级地基（复杂地基）：

1）岩土种类多，很不均匀，性质变化大，需特殊处理；

2）严重湿陷、膨胀、盐渍、污染的特殊性岩土，以及其他情况复杂，需作专门处理的岩土。

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2　符合下列条件之一者为二级地基(中等复杂地基)：

1) 岩土种类较多，不均匀，性质变化较大；

2) 除本条第1款规定以外的特殊性岩土。

3　符合下列条件者为三级地基(简单地基)：

1) 岩土种类单一，均匀，性质变化不大；

2) 无特殊性岩土。

3.1.4　根据工程重要性等级、场地复杂程度等级和地基复杂程度等级，可按下列条件划分岩土工程勘察等级。

甲级　在工程重要性、场地复杂程度和地基复杂程度等级中，有一项或多项为一级；

乙级　除勘察等级为甲级和丙级以外的勘察项目；

丙级　工程重要性、场地复杂程度和地基复杂程度等级均为三级。

注：建筑在岩质地基上的一级工程，当场地复杂程度等级和地基复杂程度等级均为三级时，岩土工程勘察等级可定为乙级。

3.2　岩石的分类和鉴定

3.2.1　在进行岩土工程勘察时，应鉴定岩石的地质名称和风化程度，并进行岩石坚硬程度、岩体完整程度和岩体基本质量等级的划分。

3.2.2　岩石坚硬程度、岩体完整程度和岩体基本质量等级的划分，应分别按表3.2.2-1～表3.2.2-3执行。

表3.2.2-1　岩石坚硬程度分类

坚硬程度	坚硬岩	较硬岩	较软岩	软岩	极软岩
饱和单轴抗压强度(MPa)	$f_r>60$	$60\geqslant f_r>30$	$30\geqslant f_r>15$	$15\geqslant f_r>5$	$f_r\leqslant 5$

注：1　当无法取得饱和单轴抗压强度数据时，可用点荷载试验强度换算，换算方法按现行国家标准《工程岩体分级标准》(GB 50218)执行；

2　当岩体完整程度为极破碎时，可不进行坚硬程度分类。

表3.2.2-2　岩体完整程度分类

完整程度	完整	较完整	较破碎	破碎	极破碎
完整性指标	>0.75	0.75～0.55	0.55～0.35	0.35～0.15	<0.15

注：完整性指数为岩体压缩波速度与岩块压缩波速度之比的平方，选定岩体和岩块测定波速时，应注意其代表性。

表3.2.2-3　岩体基本质量等级分类

完整程度 / 坚硬程度	完整	较完整	较破碎	破碎	极破碎
坚硬岩	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ
较硬岩	Ⅱ	Ⅲ	Ⅳ	Ⅳ	Ⅴ
较软岩	Ⅲ	Ⅳ	Ⅳ	Ⅴ	Ⅴ
软　岩	Ⅳ	Ⅳ	Ⅴ	Ⅴ	Ⅴ
极软岩	Ⅴ	Ⅴ	Ⅴ	Ⅴ	Ⅴ

3.2.3 当缺乏有关试验数据时，可按本规范附录A表A.0.1和表A.0.2划分岩石的坚硬程度和岩体的完整程度。岩石风化程度的划分可按本规范附录A表A.0.3执行。

3.2.4 当软化系数等于或小于0.75时，应定为软化岩石；当岩石具有特殊成分、特殊结构或特殊性质时，应定为特殊性岩石，如易溶性岩石、膨胀性岩石、崩解性岩石、盐渍化岩石等。

3.2.5 岩石的描述应包括地质年代、地质名称、风化程度、颜色、主要矿物、结构、构造和岩石质量指标RQD。对沉积岩应着重描述沉积物的颗粒大小、形状、胶结物成分和胶结程度；对岩浆岩和变质岩应着重描述矿物结晶大小和结晶程度。

根据岩石质量指标RQD，可分为好的(RQD＞90)、较好的(RQD=75～90)、较差的(RQD=50～75)、差的(RQD=25～50)和极差的(RQD＜25)。

3.2.6 岩体的描述应包括结构面、结构体、岩层厚度和结构类型，并宜符合下列规定：

1 结构面的描述包括类型、性质、产状、组合形式、发育程度、延展情况、闭合程度、粗糙程度、充填情况和充填物性质以及充水性质等；

2 结构体的描述包括类型、形状、大小和结构体在围岩中的受力情况等；

3 岩层厚度分类应按表3.2.6执行。

表3.2.6 岩层厚度分类

层厚分类	单层厚度 h(m)	层厚分类	单层厚度 h(m)
巨厚层	$h>1.0$	中厚层	$0.5\geqslant h>0.1$
厚层	$1.0\geqslant h>0.5$	薄层	$h\leqslant 0.1$

3.2.7 对地下洞室和边坡工程，尚应确定岩体的结构类型。岩体结构类型的划分应按本规范附录A表A.0.4执行。

3.2.8 对岩体基本质量等级为Ⅳ级和Ⅴ级的岩体，鉴定和描述除按本规范第3.2.5条～第3.2.7条执行外，尚应符合下列规定：

1 对软岩和极软岩，应注意是否具有可软化性、膨胀性、崩解性等特殊性质；

2 对极破碎岩体，应说明破碎的原因，如断层、全风化等；

3 开挖后是否有进一步风化的特性。

3.3 土的分类和鉴定

3.3.1 晚更新世Q_3及其以前沉积的土，应定为老沉积土；第四纪全新世中近期沉积的土，应定为新近沉积土。根据地质成因，可划分为残积土、坡积土、洪积土、冲积土、淤积土、冰积土和风积土等。土根据有机质含量分类，应按本规范附录A表A.0.5执行。

3.3.2 粒径大于2mm的颗粒质量超过总质量50%的土，应定名为碎石土，并按表3.3.2进一步分类。

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表 3.3.2　碎石土分类

土的名称	颗粒形成	颗粒级配
漂　石	圆形及亚圆形为主	粒径大于 200mm 的颗粒质量超过总质量 50%
块　石	棱角形为主	
卵　石	圆形及亚圆形为主	粒径大于 20mm 的颗粒质量超过总质量 50%
碎　石	棱角形为主	
圆　砾	圆形及亚圆形为主	粒径大于 2mm 的颗粒质量超过总质量 50%
角　砾	棱角形为主	

注：定名时，应根据颗粒级配由大到小以最先符合者确定。

3.3.3　粒径大于 2mm 的颗粒质量不超过总质量的 50%，粒径大于 0.075mm 的颗粒质量超过总质量，50%的土，应定名为砂土，并按表 3.3.3 进一步分类。

表 3.3.3　砂土分类

土的名称	颗粒级配
砾　砂	粒径大于 2mm 的颗粒质量占总质量 25%～50%
粗　砾	粒径大于 0.5mm 的颗粒质量超过总质量 50%
中　砂	粒径大于 0.25mm 的颗粒质量超过总质量 50%
细　砂	粒径大于 0.075mm 的颗粒质量超过总质量 85%
粉　砂	粒径大于 0.075mm 的颗粒质量超过总质量 50%

注：定名时应根据颗粒级配由大到小以最先符合者确定。

3.3.4　粒径大于 0.075mm 的颗粒质量不超过总质量的 50%，且塑性指数等于或小于 10 的土，应定名为粉土。

3.3.5　塑性指数大于 10 的土应定名为粘性土。

粘性土应根据塑性指数分为粉质粘土和粘土。塑性指数大于 10，且小于或等于 17 的土，应定名为粉质粘土；塑性指数大于 17 的土应定名为粘土。

注：塑性指数应由相应于 76g 圆锥仪沉入土中深度为 10mm 时测定的液限计算而得。

3.3.6　除按颗粒级配或塑性指数定名外，土的综合定名应符合下列规定：

1　对特殊成因和年代的土类应结合其成因和年代特征定名；

2　对特殊性土，应结合颗粒级配或塑性指数定名；

3　对混合土，应冠以主要含有的土类定名；

4　对同一土层中相间呈韵律沉积，当薄层与厚层的厚度比大于 1/3 时，宜定为“互层”；厚度比为 1/10～1/3 时，宜定为“夹层”；厚度比小于 1/10 的土层，且多次出现时，宜定为“夹薄层”；

5　当土层厚度大于 0.5m 时，宜单独分层。

3.3.7　土的鉴定应在现场描述的基础上，结合室内试验的开土记录和试验结果综合确定。土的描述应符合下列规定：

1　碎石土宜描述颗粒级配、颗粒形状、颗粒排列、母岩成分、风化程度、充填物的性质和充填程度、密实度等；

2　砂土宜描述颜色、矿物组成、颗粒级配、颗粒形状、细粒含量、湿度、密实度等；

3　粉土宜描述颜色、包含物、湿度、密实度等；

4　粘性土宜描述颜色、状态、包含物、土的结构等；

5　特殊性土除应描述上述相应土类规定的内容外，尚应描述其特殊成分和特殊性质；如对淤泥尚应描述嗅味，对填土尚应描述物质成分、堆积年代、密实度和均匀性等；

6　对具有互层、夹层、夹薄层特征的土，尚应描述各层的厚度和层理特征；

7　需要时，可用目力鉴别描述土的光泽反应、摇振反应、干强度和韧性，按表 3.3.7 区分粉土和粘性土。

表 3.3.7　目力鉴别粉土和粘性土

鉴别项目	摇振反应	光泽反应	干强度	韧性
粉土	迅速、中等	无光泽反应	低	低
粘性土	无	有光泽、稍有光泽	高、中等	高、中等

3.3.8　碎石土的密实度可根据圆锥动力触探锤击数按表 3.3.8-1 或表 3.3.8-2 确定，表中的 $N_{63.5}$ 和 N_{120} 应按本规范附录 B 修正。定性描述可按本规范附录 A 表 A.0.6 的规定执行。

表 3.3.8-1　碎石土密实度按 $N_{63.5}$ 分类

重型动力触探锤击数 $N_{63.5}$	密实度	重型动力触探锤击数 $N_{63.5}$	密实度
$N_{63.5}\leqslant 5$	松　散	$10<N_{63.5}\leqslant 20$	中　密
$5<N_{63.5}\leqslant 10$	稍　密	$N_{63.5}>20$	密　实

注：本表适用于平均粒径等于或小于 50mm，且最大粒径小于 100mm. 的碎石土。对于平均粒径大于 50mm，或最大粒径大于 100mm 的碎石土，可用超重型动力触探或用野外观察鉴别。

表 3.3.8-2　碎石土密实度按 N_{120} 分类

超重型动力触探锤击数 N_{120}	密实度	超重型动力触探锤击数 N_{120}	密实度
$N_{120}\leqslant 3$	松　散	$11<N_{120}\leqslant 14$	密　实
$3<N_{120}\leqslant 6$	稍　密	$N_{120}>14$	很　密
$6<N_{120}\leqslant 11$	中　密		

3.3.9　砂土的密实度应根据标准贯入试验锤击数实测值 N 划分为密实、中密、稍密和松散，并应符合表 3.3.9 的规定。当用静力触探探头阻力划分砂土密实度时，可根据当地经验确定。

表 3.3.9　砂土密实度分类

标准贯入锤击数 N	密实度	标准贯入锤击数 N	密实度
$N\leqslant 10$	松　散	$15<N\leqslant 30$	中　密
$10<N\leqslant 15$	稍　密	$N>30$	密　实

3.3.10　粉土的密实度应根据孔隙比 e 划分为密实、中密和稍密；其湿度应根据含水量 w(%)划分为稍湿、湿、很湿。密实度和湿度的划分应分别符合表 3.3.10-1 和表 3.3.10-2的规定。

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表 3.3.10-1　粉土密实度分类

孔隙比 e	密实度
$e<0.75$	密　实
$0.75\leqslant e\leqslant 0.90$	中　密
$e>0.9$	稍　密

注：当有经验时，也可用原位测试或其他方法划分粉土的密实度。

表 3.3.10-2　粉土湿度分类

含水址 w	湿　度
$w<20$	稍　湿
$20\leqslant w\leqslant 30$	湿
$w>30$	很　湿

3.3.11　粘性土的状态应根据液性指数 I_L 划分为坚硬、硬塑、可塑料、软塑和流塑，并应符合表 3.3.11 的规定。

表 3.3.11　粘性土状态分类

液性指数	状　态	液性指数	状　态
$I_L\leqslant 0$	坚　硬	$0.75<I_L\leqslant 1$	软　塑
$0<I_L\leqslant 0.25$	硬　塑	$I_L>1$	流　塑
$0.25<I_L\leqslant 0.75$	可　塑		

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4 各类工程的勘察基本要求

4.1 房屋建筑和构筑物

4.1.1 房屋建筑和构筑物(以下简称建筑物)的岩土工程勘察,应在搜集建筑物上部荷载、功能特点、结构类型、基础形式、埋置深度和变形限制等方面资料的基础上进行。其主要工作内容应符合下列规定:

1 查明场地和地基的稳定性、地层结构、持力层和下卧层的工程特性、土的应力历史和地下水条件以及不良地质作用等;

2 提供满足设计、施工所需的岩土参数,确定地基承载力,预测地基变形性状;

3 提出地基基础、基坑支护、工程降水和地基处理设计与施工方案的建议;

4 提出对建筑物有影响的不良地质作用的防治方案建议;

5 对于抗震设防烈度等于或大于 6 度的场地,进行场地与地基的地震效应评价。

4.1.2 建筑物的岩土工程勘察宜分阶段进行,可行性研究勘察应符合选择场址方案的要求;初步勘察应符合初步设计的要求;详细勘察应符合施工图设计的要求;场地条件复杂或有特殊要求的工程,宜进行施工勘察。

场地较小且无特殊要求的工程可合并勘察阶段。当建筑物平面布置已经确定,且场地或其附近已有岩土工程资料时,可根据实际情况,直接进行详细勘察。

4.1.3 可行性研究勘察,应对拟建场地的稳定性和适宜性做出评价,并应符合下列要求:

1 搜集区域地质、地形地貌、地震、矿产、当地的工程地质、岩土工程和建筑经验等资料;

2 在充分搜集和分析已有资料的基础上,通过踏勘了解场地的地层、构造、岩性、不良地质作用和地下水等工程地质条件;

3 当拟建场地工程地质条件复杂,已有资料不能满足要求时,应根据具体情况进行工程地质测绘和必要的勘探工作;

4 当有两个或两个以上拟选场地时,应进行比选分析。

4.1.4 初步勘察应对场地内拟建建筑地段的稳定性做出评价,并进行下列主要工作:

1 搜集拟建工程的有关文件、工程地质和岩土工程资料以及工程场地范围的地形图;

2 初步查明地质构造、地层结构、岩土工程特性、地下水埋藏条件;

3 查明场地不良地质作用的成因、分布、规模、发展趋势,并对场地的稳定性做出评价;

4 对抗震设防烈度等于或大于 6 度的场地,应对场地和地基的地震效应做出初步评价;

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5　季节性冻土地区，应调查场地土的标准冻结深度；

6　初步判定水和土对建筑材料的腐蚀性；

7　高层建筑初步勘察时，应对可能采取的地基基础类型、基坑开挖与支护、工程降水方案进行初步分析评价。

4.1.5　初步勘察的勘探工作应符合下列要求：

1　勘探线应垂直地貌单元、地质构造和地层界线布置；

2　每个地貌单元均应布置勘探点，在地貌单元交接部位和地层变化较大的地段，勘探点应予加密；

3　在地形平坦地区，可按网格布置勘探点；

4　对岩质地基，勘探线和勘探点的布置，勘探孔的深度，应根据地质构造、岩体特性、风化情况等，按地方标准或当地经验确定；对土质地基，应符合本节第4.1.6条～第4.1.10条的规定。

4.1.6　初步勘察勘探线、勘探点间距可按表4.1.6确定，局部异常地段应予加密。

表4.1.6　初步勘察勘探线、勘探点间距(m)

地基复杂程度等级	勘探线间距	勘探点间距
一级(复杂)	50～100	30～50
二级(中等复杂)	75～150	40～100
三级(简单)	150～300	75～200

注：1　表中间距不适用于地球物理勘探；

2　控制性勘探点宜占勘探点总数的1/5～1/3，且每个地貌单元均应有控制性勘探点。

4.1.7　初步勘察勘探孔的深度可按表4.1.7确定。

表4.1.7　初步勘察勘探孔深度(m)

工程重要性等级	一般性勘探孔	控制性勘探孔
一级(重要工程)	≥15	≥30
二级(一般工程)	10～15	15～30
三级(次要工程)	6～10	10～20

注：1　勘探孔包括钻孔、探井和原位测试孔等；

2　特殊用途的钻孔除外。

4.1.8　当遇下列情形之一时，应适当增减勘探孔深度：

1　当勘探孔的地面标高与预计整平地面标高相差较大时，应按其差值调整勘探孔深度；

2　在预定深度内遇基岩时，除控制性勘探孔仍应钻入基岩适当深度外，其他勘探孔达到确认的基岩后即可终止钻进；

3　在预定深度内有厚度较大，且分布均匀的坚实土层(如碎石土、密实砂、老沉积土等)时，除控制性勘探孔应达到规定深度外，一般性勘探孔的深度可适当减小；

4　当预定深度内有软弱土层时，勘探孔深度应适当增加，部分控制性勘探孔应穿透软弱土层或达到预计控制深度；

5　对重型工业建筑应根据结构特点和荷载条件适当增加勘探孔深度。

4.1.9　初步勘察采取土试样和进行原位测试应符合下列要求：

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1　采取土试样和进行原位测试的勘探点应结合地貌单元、地层结构和土的工程性质布置，其数量可占勘探点总数的1/4～1/2；

2　采取土试样的数量和孔内原位测试的竖向间距，应按地层特点和土的均匀程度确定；每层土均应采取土试样或进行原位测试，其数量不宜少于6个。

4.1.10　初步勘察应进行下列水文地质工作：

1　调查含水层的埋藏条件，地下水类型、补给排泄条件，各层地下水位，调查其变化幅度，必要时应设置长期观测孔，监测水位变化；

2　当需绘制地下水等水位线图时，应根据地下水的埋藏条件和层位，统一量测地下水位；

3　当地下水可能浸湿基础时，应采取水试样进行腐蚀性评价。

4.1.11　详细勘察应按单体建筑物或建筑群提出详细的岩土工程资料和设计、施工所需的岩土参数；对建筑地基做出岩土工程评价，并对地基类型、基础形式、地基处理、基坑支护、工程降水和不良地质作用的防治等提出建议。主要应进行下列工作：

1　搜集附有坐标和地形的建筑总平面图．场区的地面整平标高，建筑物的性质、规模、荷载、结构特点，基础形式、埋置深度，地基允许变形等资料；

2　查明不良地质作用的类型、成因、分布范围、发展趋势和危害程度，提出整治方案的建议；

3　查明建筑范围内岩土层的类型、深度、分布、工程特性。分析和评价地基的稳定性、均匀性和承载力；

4　对需进行沉降计算的建筑物，提供地基变形计算参数，预测建筑物的变形特征；

5　查明埋藏的河道、沟浜、墓穴、防空洞、孤石等对工程不利的埋藏物；

6　查明地下水的埋藏条件，提供地下水位及其变化幅度；

7　在季节性冻土地区，提供场地土的标准冻结深度；

8　判定水和土对建筑材料的腐蚀性。

4.1.12　对抗震设防烈度等于或大于6度的场地，勘察工作应按本规范第5.7节执行；当建筑物采用桩基础时，应按本规范第4.9节执行；当需进行基坑开挖、支护和降水设计时，应按本规范第4.8节执行。

4.1.13　详细勘察应论证地下水在施工期间对工程和环境的影响。对情况复杂的重要工程，需论证使用期间水位变化和需提出抗浮设防水位时，应进行专门研究。

4.1.14　详细勘察勘探点布置和勘探孔深度，应根据建筑物特性和岩土工程条件确定。对岩质地基，应根据地质构造、岩体特性、风化情况等，结合建筑物对地基的要求，按地方标准或当地经验确定；对土质地基，应符合本节第4.1.15条～第4.1.19条的规定。

4.1.15　详细勘察勘探点的间距可按表4.1.15确定。

表4.1.15　详细勘察勘探点的间距(m)

地基复杂程度等级	勘探点间距	地基复杂程度等级	勘探点间距
一级(复杂)	10～15	三级(简单)	30～50
二级(中等复杂)	15～30		

4.1.16　详细勘察的勘探点布置，应符合下列规定：

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1　勘探点宜按建筑物周边线和角点布置，对无特殊要求的其他建筑物可按建筑物或建筑群的范围布置；

2　同一建筑范围内的主要受力层或有影响的下卧层起伏较大时，应加密勘探点，查明其变化；

3　重大设备基础应单独布置勘探点；重大的动力机器基础和高耸构筑物，勘探点不宜少于3个；

4　勘探手段宜采用钻探与触探相配合，在复杂地质条件、湿陷性土、膨胀岩土、风化岩和残积土地区，宜布置适量探井。

4.1.17　详细勘察的单栋高层建筑勘探点的布置.应满足对地基均匀性评价的要求，且不应少于4个；对密集的高层建筑群，勘探点可适当减少，但每栋建筑物至少应有1个控制性勘探点。

4.1.18　详细勘察的勘探深度自基础底面算起，应符合下列规定：

1　勘探孔深度应能控制地基主要受力层，当基础底面宽度不大于5m时，勘探孔的深度对条形基础不应小于基础底面宽度的3倍，对单独柱基不应小于1.5倍，且不应小于5m；

2　对高层建筑和需作变形计算的地基，控制性勘探孔的深度应超过地基变形计算深度；高层建筑的一般性勘探孔应达到基底下0.5～1.0倍的基础宽度，并深入稳定分布的地层；

3　对仅有地下室的建筑或高层建筑的裙房，当不能满足抗浮设计要求，需设置抗浮桩或锚杆时，勘探孔深度应满足抗拔承载力评价的要求；

4　当有大面积地面堆载或软弱下卧层时，应适当加深控制性勘探孔的深度；

5　在上述规定深度内当遇基岩或厚层碎石土等稳定地层时，勘探孔深度可适当调整。

4.1.19　详细勘察的勘探孔深度，除应符合4.1.18条的要求外，尚应符合下列规定：

1　地基变形计算深度，对中、低压缩性土可取附加压等等于上覆土层有效自重压力20%的深度；对于高压缩性土层可取附加压力等于上覆土层有效自重压力10%的深度；

2　建筑总平面内的裙房或仅有地下室部分（或当基底附加压力 $p_0 \leqslant 0$ 时）的控制性勘探孔的深度可适当减小，但应深入稳定分布地层，且根据荷载和土质条件不宜少于基底下0.5～1.0倍基础宽度；

3　当需进行地基整体稳定性验算时，控制性勘探孔深度应根据具体条件满足验算要求；

4　当需确定场地抗震类别而邻近无可靠的覆盖层厚度资料时，应布置波速测试孔，其深度应满足确定覆盖层厚度的要求；

5　大型设备基础勘探孔深度不宜小于基础底面宽度的2倍；

6　当需进行地基处理时，勘探孔的深度应满足地基处理设计与施工要求；当采用桩基时，勘探孔的深度应满足本规范第4.9节的要求。

4.1.20 详细勘察采取土试样和进行原位测试应满足岩土工程评价要求，并符合下列要求：

1 采取土试样和进行原位测试的勘探孔的数量，应根据地层结构、地基土的均匀性和工程特点确定，且不应少于勘探孔总数的1/2，钻探取土孔的数量不应少于勘探孔总数的1/3；

2 每个场地每一主要土层的原状土试样或原位测试数据不应少于6件(组)，当采用连续记录的静力触探或动力触探为主要勘察手段时，每个场地不应少于3个孔；

3 在地基主要受力层内，对厚度大于0.5m的夹层或透镜体，应采取土试样或进行原位测试；

4 当土层性质不均匀时，应增加取土试样或原位测试数量。

4.1.21 基坑或基槽开挖后，岩土条件与勘察资料不符或发现必须查明的异常情况时，应进行施工勘察；在工程施工或使用期间，当地基土、边坡体、地下水等发生未曾估计到的变化时，应进行监测，并对工程和环境的影响进行分析评价。

4.1.22 室内土工试验应符合本规范第11章的规定，为基坑工程设计进行的土的抗剪强度试验，应满足本规范第4.8.4条的规定。

4.1.23 地基变形计算应按现行国家标准《建筑地基基础设计规范》(GB 50007)或其他有关标准的规定执行。

4.1.24 地基承载力应结合地区经验按有关标准综合确定。有不良地质作用的场地，建在坡上或坡顶的建筑物，以及基础侧旁开挖的建筑物，应评价其稳定性。

4.2 地下洞室

4.2.1 本节适用于人工开挖的无压地下洞室的岩土工程勘察。

4.2.2 地下洞室勘察的围岩分级方法应与地下洞室设计采用的标准一致。

4.2.3 可行性研究勘察应通过搜集区域地质资料，现场踏勘和调查，了解拟选方案的地形地貌、地层岩性、地质构造、工程地质、水文地质和环境条件，做出可行性评价，选择合适的洞址和洞口。

4.2.4 初步勘察应采用工程地质测绘、勘探和测试等方法，初步查明选定方案的地质条件和环境条件，初步确定岩体质量等级(围岩类别)，对洞址和洞口的稳定性做出评价，为初步设计提供依据。

4.2.5 初步勘察时，工程地质测绘和调查应初步查明下列问题：

1 地貌形态和成因类型；

2 地层岩性、产状、厚度、风化程度；

3 断裂和主要裂隙的性质、产状、充填、胶结、贯通及组合关系；

4 不良地质作用的类型、规模和分布；

5 地震地质背景；

6 地应力的最大主应力作用方向；

7 地下水类型、埋藏条件、补给、排泄和动态变化；

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8　地表水体的分布及其与地下水的关系，淤积物的特征；

9　洞室穿越地面建筑物、地下构筑物、管道等既有工程时的相互影响。

4.2.6　初步勘察时，勘探与测试应符合下列要求：

1　采用浅层地震剖面法或其他有效方法圈定隐伏断裂、构造破碎带，查明基岩埋深、划分风化带；

2　勘探点宜沿洞室外侧交叉布置，勘探点间距宜为100～200m，采取试样和原位测试勘探孔不宜少于勘探孔总数的2/3；控制性勘探孔深度，对岩体基本质量等级为Ⅰ级和Ⅱ级的岩体宜钻入洞底设计标高下1～3m；对Ⅲ级岩体宜钻入3～5m，对Ⅳ级、Ⅴ级的岩体和土层，勘探孔深度应根据实际情况确定；

3　每一主要岩层和土层均应采取试样，当有地下水时应采取水试样；当洞区存在有害气体或地温异常时，应进行有害气体成分、含量或地温测定；对高地应力地区，应进行地应力量测；

4　必要时，可进行钻孔弹性波或声波测试，钻孔地震CT或钻孔电磁波CT测试；

5　室内岩石试验和土工试验项目，应按本规范第11章的规定执行。

4.2.7　详细勘察应采用钻探、钻孔物探和测试为主的勘察方法，必要时可结合施工导洞布置洞探，详细查明洞址、洞口、洞室穿越线路的工程地质和水文地质条件，分段划分岩体质量等级（围岩类别），评价洞体和围岩的稳定性，为设计支护结构和确定施工方案提供资料。

4.2.8　详细勘察应进行下列工作：

1　查明地层岩性及其分布，划分岩组和风化程度，进行岩石物理力学性质试验；

2　查明断裂构造和破碎带的位置、规模、产状和力学属性，划分岩体结构类型；

3　查明不良地质作用的类型、性质、分布，并提出防治措施的建议；

4　查明主要含水层的分布、厚度、埋深，地下水的类型、水位、补给排泄条件，预测开挖期间出水状态、涌水量和水质的腐蚀性；

5　城市地下洞室需降水施工时，应分段提出工程降水方案和有关参数；

6　查明洞室所在位置及邻近地段的地面建筑和地下构筑物、管线状况，预测洞室开挖可能产生的影响，提出防护措施。

4.2.9　详细勘察可采用浅层地震勘探和孔间地震CT或孔间电磁波CT测试等方法，详细查明基岩埋深、岩石风化程度，隐伏体（如溶洞、破碎带等）的位置，在钻孔中进行弹性波波速测试，为确定岩体质量等级（围岩类别），评价岩体完整性，计算动力参数提供资料。

4.2.10　详细勘察时，勘探点宜在洞室中线外侧6～8m交叉布置，山区地下洞室按地质构造布置，且勘探点间距不应大于50m；城市地下洞室的勘探点间距，岩土变化复杂的场地宜小于25m，中等复杂的宜为25～40m，简单的宜为40～80m。

采集试样和原位测试勘探孔数量不应少于勘探孔总数的1/2。

4.2.11　详细勘察时，第四系中的控制性勘探孔深度应根据工程地质、水文地质条件、洞室埋深、防护设计等需要确定；一般性勘探孔可钻至基底设计标高下6～10m。控制性勘

探孔深度，可按本节第 4.2.6 条第 2 款的规定执行。

4.2.12 详细勘察的室内试验和原位测试，除应满足初步勘察的要求外，对城市地下洞室尚应根据设计要求进行下列试验：

1 采用承压板边长为 30cm 的载荷试验测求地基基床系数；

2 采用面热源法或热线比较法进行热物理指标试验，计算热物理参数：导温系数、导热系数和比热容；

3 当需提供动力参数时，可用压缩波波速 v_p 和剪切波波速 v_s 计算求得，必要时，可采用室内动力性质试验，提供动力参数。

4.2.13 施工勘察应配合导洞或毛洞开挖进行，当发现与勘察资料有较大出入时，应提出修改设计和施工方案的建议。

4.2.14 地下洞室围岩的稳定性评价可采用工程地质分析与理论计算相结合的方法，可采用数值法或弹性有限元图谱法计算。

4.2.15 当洞室可能产生偏压、膨胀压力、岩爆和其他特殊情况时，应进行专门研究。

4.2.16 详细勘察阶段地下洞室岩土工程勘察报告，除按本规范第 14 章的要求执行外，尚应包括下列内容：

1 划分围岩类别；

2 提出洞址、洞口、洞轴线位置的建议；

3 对洞口、洞体的稳定性进行评价；

4 提出支护方案和施工方法的建议；

5 对地面变形和既有建筑的影响进行评价。

4.3 岸 边 工 程

4.3.1 本节适用于港口工程、造船和修船水工建筑物以及取水构筑物的岩土工程勘察。

4.3.2 岸边工程勘察应着重查明下列内容：

1 地貌特征和地貌单元交界处的复杂地层；

2 高灵敏软土、层状构造土、混合土等特殊土和基本质量等级为 V 级岩体的分布和工程特性；

3 岸边滑坡、崩塌、冲刷、淤积、潜蚀、沙丘等不良地质作用。

4.3.3 可行性研究勘察时，应进行工程地质测绘或踏勘调查，内容包括地层分布、构造特点、地貌特征、岸坡形态、冲刷淤积、水位升降、岸滩变迁、淹没范围等情况和发展趋势。必要时应布置一定数量的勘探工作，并应对岸坡的稳定性和场址的适宜性做出评价，提出最优场址方案的建议。

4.3.4 初步设计阶段勘察应符合下列规定：

1 工程地质测绘，应调查岸线变迁和动力地质作用对岸线变迁的影响；埋藏河、湖、沟谷的分布及其对工程的影响；潜蚀、沙丘等不良地质作用的成因、分布、发展趋势及其对场地稳定性的影响；

2 勘探线宜垂直岸向布置；勘探线和勘探点的间距，应根据工程要求、地貌特征、岩

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土分布、不良地质作用等确定；岸坡地段和岩石与土层组合地段宜适当加密；

3 勘探孔的深度应根据工程规模、设计要求和岩土条件确定；

4 水域地段可采用浅层地震剖面或其他物探方法；

5 对场地的稳定性应做出进一步评价，并对总平面布置、结构和基础形式、施工方法和不良地质作用的防治提出建议。

4.3.5 施工图设计阶段勘察时，勘探线和勘探点应结合地貌特征和地质条件，根据工程总平面布置确定，复杂地基地段应予加密。勘探孔深度应根据工程规模、设计要求和岩土条件确定，除建筑物和结构物特点与荷载外，应考虑岸坡稳定性、坡体开挖、支护结构、桩基等的分析计算需要。

根据勘察结果，应对地基基础的设计和施工及不良地质作用的防治提出建议。

4.3.6 原位测试除应符合本规范第 10 章的要求外，软土中可用静力触探或静力触探与旁压试验相结合，进行分层，测定土的模量、强度和地基承载力等；用十字板剪切试验，测定土的不排水抗剪强度。

4.3.7 测定土的抗剪强度选用剪切试验方法时，应考虑下列因素：

1 非饱和土在施工期间和竣工以后受水浸成为饱和土的可能性；

2 土的固结状态在施工和竣工后的变化；

3 挖方卸荷或填方增荷对土性的影响。

4.3.8 各勘察阶段勘探线和勘探点的间距、勘探孔的深度、原位测试和室内试验的数量等的具体要求，应符合现行有关标准的规定。

4.3.9 评价岸坡和地基稳定性时，应考虑下列因素：

1 正确选用设计水位；

2 出现较大水头差和水位骤降的可能性；

3 施工时的临时超载；

4 较陡的挖方边坡；

5 波浪作用；

6 打桩影响；

7 不良地质作用的影响。

4.3.10 岸边工程岩土工程勘察报告除应遵守本规范第 14 章的规定外，尚应根据相应勘察阶段的要求，包括下列内容：

1 分析评价岸坡稳定性和地基稳定性；

2 提出地基基础与支护设计方案的建议；

3 提出防治不良地质作用的建议；

4 提出岸边工程监测的建议。

4.4 管道和架空线路工程

（Ⅰ）管道工程

4.4.1 本节适用于长输油、气管道线路及其大型穿、跨越工程的岩土工程勘察。

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4.4.2 长输油、气管道工程可分选线勘察、初步勘察和详细勘察三个阶段。对岩土工程条件简单或有工程经验的地区，可适当简化勘察阶段。

4.4.3 选线勘察应通过搜集资料、测绘与调查，掌握各方案的主要岩土工程问题，对拟选穿、跨越河段的稳定性和适宜性做出评价，并应符合下列要求：

1 调查沿线地形地貌、地质构造、地层岩性、水文地质等条件，推荐线路越岭方案；

2 调查各方案通过地区的特殊性岩土和不良地质作用，评价其对修建管道的危害程度；

3 调查控制线路方案河流的河床和岸坡的稳定程度，提出穿、跨越方案比选的建议；

4 调查沿线水库的分布情况，近期和远期规划，水库水位、回水浸没和坍岸的范围及其对线路方案的影响；

5 调查沿线矿产、文物的分布概况；

6 调查沿线地震动参数或抗震设防烈度。

4.4.4 穿越和跨越河流的位置应选择河段顺直，河床与岸坡稳定，水流平缓，河床断面大致对称，河床岩土构成比较单一，两岸有足够施工场地等有利河段。宜避开下列河段：

1 河道异常弯曲，主流不固定，经常改道；

2 河床为粉细砂组成，冲淤变幅大；

3 岸坡岩土松软，不良地质作用发育，对工程稳定性有直接影响或潜在威胁；

4 断层河谷或发震断裂。

4.4.5 初步勘察应包括下列内容：

1 划分沿线的地貌单元；

2 初步查明管道埋设深度内岩土的成因、类型、厚度和工程特性；

3 调查对管道有影响的断裂的性质和分布；

4 调查沿线各种不良地质作用的分布、性质、发展趋势及其对管道的影响；

5 调查沿线井、泉的分布和地下水位情况；

6 调查沿线矿藏分布及开采和采空情况；

7 初步查明拟穿、跨越河流的洪水淹没范围，评价岸坡稳定性。

4.4.6 初步勘察应以搜集资料和调查为主。管道通过河流、冲沟等地段宜进行物探。地质条件复杂的大中型河流，应进行钻探。每个穿、跨越方案宜布置勘探点1～3个；勘探孔深度应按本节第4.4.8条的规定执行。

4.4.7 详细勘察应查明沿线的岩土工程条件和水、土对金属管道的腐蚀性，提出工程设计所需要的岩土特性参数。穿、跨越地段的勘察应符合下列规定：

1 穿越地段应查明地层结构、土的颗粒组成和特性；查明河床冲刷和稳定程度；评价岸坡稳定性，提出护坡建议；

2 跨越地段的勘探工作应按本节第4.4.15条和第4.4.16条的规定执行。

4.4.8 详细勘察勘探点的布置，应满足下列要求：

1 对管道线路工程，勘探点间距视地质条件复杂程度而定，且为200～1000m，包括

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地质点及原位测试点，并应根据地形、地质条件复杂程度适当增减；勘探孔深度宜为管道埋设深度以下 1～3m；

2 对管道穿越工程，勘探点应布置在穿越管道的中线上，偏离中线不应大于 3m，勘探点间距宜为 30～100m，并不应少于 3 个；当采用沟埋敷设方式穿越时，勘探孔深度宜钻至河床最大冲刷深度以下 3～5m；当采用顶管或定向钻方式穿越时，勘探孔深度应根据设计要求确定。

4.4.9 抗震设防烈度等于或大于 6 度地区的管道工程，勘察工作应满足本规范第 5.7 节的要求。

4.4.10 岩土工程勘察报告应包括下列内容：

1 选线勘察阶段，应简要说明线路各方案的岩土工程条件，提出各方案的比选推荐建议；

2 初步勘察阶段，应论述各方案的岩土工程条件，并推荐最优线路方案；对穿、跨越工程尚应评价河床及岸坡的稳定性，提出穿、跨越方案的建议；

3 详细勘察阶段，应分段评价岩土工程条件，提出岩土工程设计参数和设计、施工方案的建议；对穿越工程尚应论述河床和岸坡的稳定性，提出护岸措施的建议。

（Ⅱ）架空线路工程

4.4.11 本节适用于大型架空线路工程，包括 220kV 及其以上的高压架空送电线路、大型架空索道等的岩土工程勘察。

4.4.12 大型架空线路工程可分初步设计勘察和施工图设计勘察两阶段；小型架空线路可合并勘察阶段。

4.4.13 初步设计勘察应符合下列要求：

1 调查沿线地形地貌、地质构造、地层岩性和特殊性岩土的分布、地下水及不良地质作用，并分段进行分析评价；

2 调查沿线矿藏分布、开发计划与开采情况；线路宜避开可采矿层；对已开采区，应对采空区的稳定性进行评价；

3 对大跨越地段，应查明工程地质条件，进行岩土工程评价，推荐最优跨越方案。

4.4.14 初步设计勘察应以搜集和利用航测资料为主。大跨越地段应做详细的调查或工程地质测绘，必要时，辅以少量的勘探、测试工作。

4.4.15 施工图设计勘察应符合下列要求：

1 平原地区应查明塔基土层的分布、埋藏条件、物理力学性质，水文地质条件及环境水对混凝土和金属材料的腐蚀性；

2 丘陵和山区除查明本条第 1 款的内容外，尚应查明塔基近处的各种不良地质作用，提出防治措施建议；

3 大跨越地段尚应查明跨越河段的地形地貌，塔基范围内地层岩性、风化破碎程度、软弱夹层及其物理力学性质；查明对塔基有影响的不良地质作用，并提出防治措施建议；

4 对特殊设计的塔基和大跨越塔基，当抗震设防烈度等于或大于 6 度时，勘察工作

应满足本规范第 5.7 节的要求。

4.4.16 施工图设计勘察阶段，对架空线路工程的转角塔、耐张塔、终端塔、大跨越塔等重要塔基和地质条件复杂地段，应逐个进行塔基勘探。直线塔基地段宜每 3～4 个塔基布置一个勘探点；深度应根据杆塔受力性质和地质条件确定。

4.4.17 架空线路岩土工程勘察报告应包括下列内容：

1 初步设计勘察阶段，应论述沿线岩土工程条件和跨越主要河流地段的岸坡稳定性，选择最优线路方案；

2 施工图设计勘察阶段，应提出塔位明细表，论述塔位的岩土条件和稳定性，并提出设计参数和基础方案以及工程措施等建议。

4.5 废弃物处理工程

（Ⅰ）一般规定

4.5.1 本节适用于工业废渣堆场、垃圾填埋场等固体废弃物处理工程的岩土工程勘察。核废料处理场地的勘察尚应满足有关规范的要求。

4.5.2 废弃物处理工程的岩土工程勘察，应着重查明下列内容：

1 地形地貌特征和气象水文条件；

2 地质构造、岩土分布和不良地质作用；

3 岩土的物理力学性质；

4 水文地质条件、岩土和废弃物的渗透性；

5 场地、地基和边坡的稳定性；

6 污染物的运移，对水源和岩土的污染，对环境的影响；

7 筑坝材料和防渗覆盖用粘土的调查；

8 全新活动断裂、场地地基和堆积体的地震效应。

4.5.3 废弃物处理工程勘察的范围，应包括堆填场（库区）、初期坝、相关的管线、隧洞等构筑物和建筑物，以及邻近相关地段，并应进行地方建筑材料的勘察。

4.5.4 废弃物处理工程的勘察应配合工程建设分阶段进行。可分为可行性研究勘察、初步勘察和详细勘察，并应符合有关标准的规定。

可行性研究勘察应主要采用踏勘调查，必要时辅以少量勘探工作，对拟选场地的稳定性和适宜性做出评价。

初步勘察应以工程地质测绘为主，辅以勘探、原位测试、室内试验，对拟建工程的总平面布置、场地的稳定性、废弃物对环境的影响等进行初步评价，并提出建议。

详细勘察应采用勘探、原位测试和室内试验等手段进行，地质条件复杂地段应进行工程地质测绘，获取工程设计所需的参数，提出设计施工和监测工作的建议，并对不稳定地段和环境影响进行评价，提出治理建议。

4.5.5 废弃物处理工程勘察前，应搜集下列技术资料：

1 废弃物的成分、粒度、物理和化学性质，废弃物的日处理量、输送和排放方式；

2 堆场或填埋场的总容量、有效容量和使用年限；

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3　山谷型堆填场的流域面积、降水量、径流量、多年一遇洪峰流量；

4　初期坝的坝长和坝顶标高，加高坝的最终坝顶标高；

5　活动断裂和抗震设防烈度；

6　邻近的水源地保护带、水源开采情况和环境保护要求。

4.5.6　废弃物处理工程的工程地质测绘应包括场地的全部范围及其邻近有关地段，其比例尺，初步勘察宜为1：2000～1：5000.详细勘察的复杂地段不应小于1：1000，除应按本规范第8章的要求执行外，尚应着重调查下列内容：

1　地貌形态、地形条件和居民区的分布；

2　洪水、滑坡、泥石流、岩溶、断裂等与场地稳定性有关的不良地质作用；

3　有价值的自然景观、文物和矿产的分布，矿产的开采和采空情况；

4　与渗漏有关的水文地质问题；

5　生态环境。

4.5.7　废弃物处理工程应按本规范第7章的要求，进行专门的水文地质勘察。

4.5.8　在可溶岩分布区，应着重查明岩溶发育条件，溶洞、土洞、塌陷的分布，岩溶水的通道和流向，岩溶造成地下水和渗出液的渗漏，岩溶对工程稳定性的影响。

4.5.9　初期坝的筑坝材料勘察及防渗和覆盖用粘土材料的勘察，应包括材料的产地、储量、性能指标、开采和运输条件。可行性勘察时应确定产地，初步勘察时应基本完成。

（Ⅱ）工业废渣堆场

4.5.10　工业废渣堆场详细勘察时，勘探工作应符合下列规定：

1　勘探线宜平行于堆填场、坝、隧洞、管线等构筑物的轴线布置，勘探点间距应根据地质条件复杂程度确定；

2　对初期坝，勘探孔的深度应能满足分析稳定、变形和渗漏的要求；

3　与稳定、渗漏有关的关键性地段，应加密加深勘探孔或专门布置勘探工作；

4　可采用有效的物探方法辅助钻探和井探；

5　隧洞勘察应符合本规范第4.2节的规定。

4.5.11　废渣材料加高坝的勘察，应采用勘探、原位测试和室内试验的方法进行，并应着重查明下列内容：

1　已有堆积体的成分、颗粒组成、密实程度、堆积规律；

2　堆积材料的工程特性和化学性质；

3　堆积体内浸润线位置及其变化规律；

4　已运行坝体的稳定性，继续堆积至设计高度的适宜性和稳定性；

5　废渣堆积坝在地震作用下的稳定性和废渣材料的地震液化可能性；

6　加高坝运行可能产生的环境影响。

4.5.12　废渣材料加高坝的勘察，可按堆积规模垂直坝轴线布设不少于三条勘探线，勘探点间距在堆场内可适当增大；一般勘探孔深度应进入自然地面以下一定深度，控制性勘探孔深度应能查明可能存在的软弱层。

4.5.13　工业废渣堆场的岩土工程评价应包括下列内容：

1　洪水、滑坡、泥石流、岩溶、断裂等不良地质作用对工程的影响；

2　坝基、坝肩和库岸的稳定性，地震对稳定性的影响；

3　坝址和库区的渗漏及建库对环境的影响；

4　对地方建筑材料的质量、储量、开采和运输条件，进行技术经济分析。

4.5.14　工业废渣堆场的勘察报告，除应符合本规范第14章的规定外，尚应满足下列要求：

1　按本节第4.5.13条的要求，进行岩土工程分析评价，并提出防治措施的建议；

2　对废渣加高坝的勘察，应分析评价现状和达到最终高度时的稳定性，提出堆积方式和应采取措施的建议；

3　提出边坡稳定、地下水位、库区渗漏等方面监测工作的建议。

（Ⅲ）垃圾填埋场

4.5.15　垃圾填埋场勘察前搜集资料时，除应遵守本节第4.5.5条的规定外，尚应包括下列内容：

1　垃圾的种类、成分和主要特性以及填埋的卫生要求；

2　填埋方式和填埋程序以及防渗衬层和封盖层的结构，渗出液集排系统的布置；

3　防渗衬层、封盖层和渗出液集排系统对地基和废弃物的容许变形要求；

4　截污坝、污水池、排水井、输液输气管道和其他相关构筑物情况。

4.5.16　垃圾填埋场的勘探测试，除应遵守本节第4.5.10条的规定外，尚应符合下列要求：

1　需进行变形分析的地段，其勘探深度应满足变形分析的要求；

2　岩土和似土废弃物的测试，可按本规范第10章和第11章的规定执行，非土废弃物的测试，应根据其种类和特性采用合适的方法，并可根据现场监测资料，用反分析方法获取设计参数；

3　测定垃圾渗出液的化学成分，必要时进行专门试验，研究污染物的运移规律。

4.5.17　垃圾填埋场勘察的岩土工程评价除应按本节第4.5.13条的规定执行外，尚宜包括下列内容：

1　工程场地的整体稳定性以及废弃物堆积体的变形和稳定性；

2　地基和废弃物变形，导致防渗衬层、封盖层及其他设施失效的可能性；

3　坝基、坝肩、库区和其他有关部位的渗漏；

4　预测水位变化及其影响；

5　污染物的运移及其对水源、农业、岩土和生态环境的影响。

4.5.18　垃圾填埋场的岩土工程勘察报告，除应符合本规范第14章的规定外，尚应符合下列规定：

1　按本节第4.5.17条的要求进行岩土工程分析评价；

2　提出保证稳定、减少变形、防止渗漏和保护环境措施的建议；

3　提出筑坝材料、防渗和覆盖用粘土等地方材料的产地及相关事项的建议；

4　提出有关稳定、变形、水位、渗漏、水土和渗出液化学性质监测工作的建议。

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4.6 核 电 厂

4.6.1 本节适用于各种核反应堆型的陆地固定式商用核电厂的岩土工程勘察。核电厂勘察除按本节执行外，尚应符合有关核安全法规、导则和有关国家标准、行业标准的规定。

4.6.2 核电厂岩土工程勘察的安全分类，可分为与核安全有关建筑和常规建筑两类。

4.6.3 核电厂岩土工程勘察可划分为初步可行性研究、可行性研究、初步设计、施工图设计和工程建造等五个勘察阶段。

4.6.4 初步可行性研究勘察应以搜集资料为主，对各拟选厂址的区域地质、厂址工程地质和水文地质、地震动参数区划、历史地震及历史地震的影响烈度以及近期地震活动等方面资料加以研究分析，对厂址的场地稳定性、地基条件、环境水文地质和环境地质做出初步评价，提出建厂的适宜性意见。

4.6.5 初步可行性研究勘察，厂址工程地质测绘的比例尺应选用 1：10000～1：25000；范围应包括厂址及其周边地区，面积不宜小于 $4km^2$。

4.6.6 初步可行性研究勘察，应通过必要的勘探和测试，提出厂址的主要工程地质分层，提供岩土初步的物理力学性质指标，了解预选核岛区附近的岩土分布特征，并应符合下列要求：

1 每个厂址勘探孔不宜少于两个，深度应为预计设计地坪标高以下 30～60m；

2 应全断面连续取芯，回次岩芯采取率对一般岩石应大于 85%，对破碎岩石应大于 70%；

3 每一主要岩土层应采取 3 组以上试样；勘探孔内间隔 2～3m 应作标准贯入试验一次，直至连续的中等风化以上岩体为止；当钻进至岩石全风化层时，应增加标准贯入试验频次，试验间隔不应大于 0.5m；

4 岩石试验项目应包括密度、弹性模量、泊松比、抗压强度、软化系数、抗剪强度和压缩波速度等；土的试验项目应包括颗粒分析、天然含水量、密度、比重、塑限、液限、压缩系数、压缩模量和抗剪强度等。

4.6.7 初步可行性研究勘察，对岩土工程条件复杂的厂址，可选用物探辅助勘察，了解覆盖层的组成、厚度和基岩面的埋藏特征，了解隐伏岩体的构造特征，了解是否存在洞穴和隐伏的软弱带。

在河海岸坡和山丘边坡地区，应对岸坡和边坡的稳定性进行调查，并做出初步分析评价。

4.6.8 评价厂址适宜性应考虑下列因素：

1 有无能动断层，是否对厂址稳定性构成影响；

2 是否存在影响厂址稳定的全新世火山活动；

3 是否处于地震设防烈度大于 8 度的地区，是否存在与地震有关的潜在地质灾害；

4 厂址区及其附近有无可开采矿藏，有无影响地基稳定的人类历史活动、地下工程、采空区、洞穴等；

5　是否存在可造成地面塌陷、沉降、隆起和开裂等永久变形的地下洞穴、特殊地质体、不稳定边坡和岸坡、泥石流及其他不良地质作用；

6　有无可供核岛布置的场地和地基，并具有足够的承载力；

7　是否危及供水水源或对环境地质构成严重影响。

4.6.9　可行性研究勘察内容应符合下列规定：

1　查明厂址地区的地形地貌、地质构造、断裂的展布及其特征；

2　查明厂址范围内地层成因、时代、分布和各岩层的风化特征，提供初步的动静物理力学参数；对地基类型、地基处理方案进行论证，提出建议；

3　查明危害厂址的不良地质作用及其对场地稳定性的影响，对河岸、海岸、边坡稳定性做出初步评价，并提出初步的治理方案；

4　判断抗震设计场地类别，划分对建筑物有利、不利和危险地段，判断地震液化的可能性；

5　查明水文地质基本条件和环境水文地质的基本特征。

4.6.10　可行性研究勘察应进行工程地质测绘，测绘范围应包括厂址及其周边地区，测绘地形图比例尺为1∶1000～1∶2000，测绘要求按本规范第8章和其他有关规定执行。

本阶段厂址区的岩土工程勘察应以钻探和工程物探相结合的方式，查明基岩和覆盖层的组成、厚度和工程特性；基岩埋深、风化特征、风化层厚度等；并应查明工程区存在的隐伏软弱带、洞穴和重要的地质构造；对水域应结合水工建筑物布置方案，查明海(湖)积地层分布、特征和基岩面起伏状况。

4.6.11　可行性研究阶段的勘探和测试应符合下列规定：

1　厂区的勘探应结合地形、地质条件采用网格状布置，勘探点间距宜为150m。控制性勘探点应结合建筑物和地质条件布置，数量不宜少于勘探点总数的1/3，沿核岛和常规岛中轴线应布置勘探线，勘探点间距宜适当加密，并应满足主体工程布置要求，保证每个核岛和常规岛不少于1个；

2　勘探孔深度，对基岩场地宜进入基础底面以下基本质量等级为Ⅰ级、Ⅱ级的岩体不少于10m；对第四纪地层场地宜达到设计地坪标高以下40m，或进入Ⅰ级、Ⅱ级岩体不少于3m；核岛区控制性勘探孔深度，宜达到基础底面以下2倍反应堆厂房直径；常规岛区控制性勘探孔深度，不宜小于地基变形计算深度，或进入基础底面以下Ⅰ级、Ⅱ级、Ⅲ级岩体3m；对水工建筑物应结合水下地形布置，并考虑河岸、海岸的类型和最大冲刷深度；

3　岩石钻孔应全断面取芯，每回次岩芯采取率对一般岩石应大于85%，对破碎岩石应大于70%，并统计RQD、节理条数和倾角；每一主要岩层应采取3组以上的岩样；

4　根据岩土条件，选用适当的原位测试方法，测定岩土的特性指标，并可用声波测试方法，评价岩体的完整程度和划分风化等级；

5　在核岛位置，宜选1～2个勘探孔，采用单孔法或跨孔法，测定岩土的压缩波速和剪切波速，计算岩土的动力参数；

6　岩土室内试验项目除应符合本节第4.6.6条的要求外，增加每个岩体(层)代表

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试样的动弹性模量、动泊松比和动阻尼比等动态参数测试。

4.6.12 可行性研究阶段的地下水调查和评价应符合下列规定：

1 结合区域水文地质条件，查明厂区地下水类型，含水层特征，含水层数量、埋深、动态变化规律及其与周围水体的水力联系和地下水化学成分；

2 结合工程地质钻探对主要地层分别进行注水、抽水或压水试验，测求地层的渗透系数和单位吸水率，初步评价岩体的完整性和水文地质条件；

3 必要时，布置适当的长期观测孔，定期观测和记录水位，每季度定时取水样一次作水质分析，观测周期不应少于一个水文年。

4.6.13 可行性研究阶段应根据岩土工程条件和工程需要，进行边坡勘察、土石方工程和建筑材料的调查和勘察。具体要求按本规范第 4.7 节和有关标准执行。

4.6.14 初步设计勘察应分核岛、常规岛、附属建筑和水工建筑四个地段进行，并应符合下列要求：

1 查明各建筑地段的岩土成因、类别、物理性质和力学参数，并提出地基处理方案；

2 进一步查明勘察区内断层分布、性质及其对场地稳定性的影响，提出治理方案的建议；

3 对工程建设有影响的边坡进行勘察，并进行稳定性分析和评价，提出边坡设计参数和治理方案的建议；

4 查明建筑地段的水文地质条件；

5 查明对建筑物有影响的不良地质作用，并提出治理方案的建议。

4.6.15 初步设计核岛地段勘察应满足设计和施工的需要，勘探孔的布置、数量和深度应符合下列规定：

1 应布置在反应堆厂房周边和中部，当场地岩土工程条件较复杂时，可沿十字交叉线加密或扩大范围。勘探点间距宜为 10～30m；

2 勘探点数量应能控制核岛地段地层岩性分布，并能满足原位测试的要求。每个核岛勘探点总数不应少于 10 个，其中反应堆厂房不应少于 5 个，控制性勘探点不应少于勘探点总数的 1/2；

3 控制性勘探孔深度宜达到基础底面以下 2 倍反应堆厂房直径，一般性勘探孔深度宜进入基础底面以下Ⅰ、Ⅱ级岩体不少于 10m。波速测试孔深度不应小于控制性勘探孔深度。

4.6.16 初步设计常规岛地段勘察，除应符合本规范第 4.1 节的规定外，尚应符合下列要求：

1 勘探点应沿建筑物轮廓线、轴线或主要柱列线布置，每个常规岛勘探点总数不应少于 10 个，其中控制性勘探点不宜少于勘探点总数的 1/4；

2 控制性勘探孔深度对岩质地基应进入基础底面下Ⅰ级、Ⅱ级岩体不少于 3m，对土质地基应钻至压缩层以下 10～20m；一般性勘探孔深度，岩质地基应进入中等风化层 3～5m，土质地基应达到压缩层底部。

4.6.17 初步设计阶段水工建筑的勘察应符合下列规定：

1　泵房地段钻探工作应结合地层岩性特点和基础埋置深度，每个泵房勘探点数量不应少于2个，一般性勘探孔应达到基础底面以下1～2m，控制性勘探孔应进入中等风化岩石1.5～3.0m；土质地基中控制性勘探孔深度应达到压缩层以下5～10m；

2　位于土质场地的进水管线，勘探点间距不宜大于30m，一般性勘探孔深度应达到管线底标高以下5m，控制性勘探孔应进入中等风化岩石1.5～3.0m；

3　与核安全有关的海堤、防波堤，钻探工作应针对该地段所处的特殊地质环境布置，查明岩土物理力学性质和不良地质作用；勘探点宜沿堤轴线布置，一般性勘探孔深度应达到堤底设计标高以下10m，控制性勘探孔应穿透压缩层或进入中等风化岩石1.5～3.0m。

4.6.18　初步设计阶段勘察的测试，除应满足本规范第4.1节、第10章和第11章的要求外，尚应符合下列规定：

1　根据岩土性质和工程需要，选择合适的原位测试方法，包括波速测试、动力触探试验、抽水试验、注水试验、压水试验和岩体静载荷试验等；并对核反应堆厂房地基进行跨孔法波速测试和钻孔弹模测试，测求核反应堆厂房地基波速和岩石的应力应变特性；

2　室内试验除进行常规试验外，尚应测定岩土的动静弹性模量、动静泊松比、动阻尼比、动静剪切模量、动抗剪强度、波速等指标。

4.6.19　施工图设计阶段应完成附属建筑的勘察和主要水工建筑以外其他水工建筑的勘察，并根据需要进行核岛、常规岛和主要水工建筑的补充勘察。勘察内容和要求可按初步设计阶段有关规定执行，每个与核安全有关的附属建筑物不应少于一个控制性勘探孔。

4.6.20　工程建造阶段勘察主要是现场检验和监测，其内容和要求按本规范第13章和有关规定执行。

4.6.21　核电厂的液化判别应按现行国家标准《核电厂抗震设计规范》(GB 50267)执行。

4.7　边坡工程

4.7.1　边坡工程勘察应查明下列内容：

1　地貌形态，当存在滑坡、危岩和崩塌、泥石流等不良地质作用时，应符合本规范第5章的要求；

2　岩土的类型、成因、工程特性，覆盖层厚度，基岩面的形态和坡度；

3　岩体主要结构面的类型、产状、延展情况、闭合程度、充填状况、充水状况、力学属性和组合关系，主要结构面与临空面关系，是否存在外倾结构面；

4　地下水的类型、水位、水压、水量、补给和动态变化，岩土的透水性和地下水的出露情况；

5　地区气象条件(特别是雨期、暴雨强度)，汇水面积、坡面植被，地表水对坡面、坡脚的冲刷情况；

6　岩土的物理力学性质和软弱结构面的抗剪强度。

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4.7.2 大型边坡勘察宜分阶段进行，各阶段应符合下列要求：

1 初步勘察应搜集地质资料，进行工程地质测绘和少量的勘探和室内试验，初步评价边坡的稳定性；

2 详细勘察应对可能失稳的边坡及相邻地段进行工程地质测绘、勘探、试验、观测和分析计算，做出稳定性评价，对人工边坡提出最优开挖坡角；对可能失稳的边坡提出防护处理措施的建议；

3 施工勘察应配合施工开挖进行地质编录，核对、补充前阶段的勘察资料，必要时，进行施工安全预报，提出修改设计的建议。

4.7.3 边坡工程地质测绘除应符合本规范第8章的要求外，尚应着重查明天然边坡的形态和坡角，软弱结构面的产状和性质。测绘范围应包括可能对边坡稳定有影响的地段。

4.7.4 勘探线应垂直边坡走向布置，勘探点间距应根据地质条件确定。当遇有软弱夹层或不利结构面时，应适当加密。勘探孔深度应穿过潜在滑动面并深入稳定层2～5m。除常规钻探外，可根据需要，采用探洞、探槽、探井和斜孔。

4.7.5 主要岩土层和软弱层应采取试样。每层的试样对土层不应少于6件，对岩层不应少于9件，软弱层宜连续取样。

4.7.6 三轴剪切试验的最高围压和直剪试验的最大法向压力的选择，应与试样在坡体中的实际受力情况相近。对控制边坡稳定的软弱结构面，宜进行原位剪切试验。对大型边坡，必要时可进行岩体应力测试、波速测试、动力测试、孔隙水压力测试和模型试验。

抗剪强度指标，应根据实测结果结合当地经验确定，并宜采用反分析方法验证。对永久性边坡，尚应考虑强度可能随时间降低的效应。

4.7.7 边坡的稳定性评价，应在确定边坡破坏模式的基础上进行，可采用工程地质类比法、图解分析法、极限平衡法、有限单元法进行综合评价。各区段条件不一致时，应分区段分析。

边坡稳定系数 F_s 的取值，对新设计的边坡、重要工程宜取1.30～1.50，一般工程宜取1.15～1.30，次要工程宜取1.05～1.15。采用峰值强度时取大值，采取残余强度时取小值。验算已有边坡稳定时，F_s 取1.10～1.25。

4.7.8 大型边坡应进行监测，监测内容根据具体情况可包括边坡变形、地下水动态和易风化岩体的风化速度等。

4.7.9 边坡岩土工程勘察报告除应符合本规范第14章的规定外，尚应论述下列内容：

1 边坡的工程地质条件和岩土工程计算参数；

2 分析边坡和建在坡顶、坡上建筑物的稳定性，对坡下建筑物的影响；

3 提出最优坡形和坡角的建议；

4 提出不稳定边坡整治措施和监测方案的建议。

4.8 基坑工程

4.8.1 本节主要适用于土质基坑的勘察。对岩质基坑，应根据场地的地质构造、岩体特

征、风化情况、基坑开挖深度等，按当地标准或当地经验进行勘察。

4.8.2 需进行基坑设计的工程，勘察时应包括基坑工程勘察的内容。在初步勘察阶段，应根据岩土工程条件，初步判定开挖可能发生的问题和需要采取的支护措施；在详细勘察阶段，应针对基坑工程设计的要求进行勘察；在施工阶段，必要时尚应进行补充勘察。

4.8.3 基坑工程勘察的范围和深度应根据场地条件和设计要求确定。勘察深度宜为开挖深度的2～3倍，在此深度内遇到坚硬粘性土、碎石土和岩层，可根据岩土类别和支护设计要求减少深度。勘察的平面范围宜超出开挖边界外开挖深度的2～3倍。在深厚软土区，勘察深度和范围尚应适当扩大。在开挖边界外，勘察手段以调查研究、搜集已有资料为主，复杂场地和斜坡场地应布置适量的勘探点。

4.8.4 在受基坑开挖影响和可能设置支护结构的范围内，应查明岩土分布，分层提供支护设计所需的抗剪强度指标。土的抗剪强度试验方法，应与基坑工程设计要求一致，符合设计采用的标准，并应在勘察报告中说明。

4.8.5 **当场地水文地质条件复杂，在基坑开挖过程中需要对地下水进行控制（降水或隔渗），且已有资料不能满足要求时，应进行专门的水文地质勘察。**

4.8.6 当基坑开挖可能产生流砂、流土、管涌等渗透性破坏时，应有针对性地进行勘察，分析评价其产生的可能性及对工程的影响。当基坑开挖过程中有渗流时，地下水的渗流作用宜通过渗流计算确定。

4.8.7 基坑工程勘察，应进行环境状况的调查，查明邻近建筑物和地下设施的现状、结构特点以及对开挖变形的承受能力。在城市地下管网密集分布区，可通过地理信息系统或其他档案资料了解管线的类别、平面位置、埋深和规模，必要时应采用有效方法进行地下管线探测。

4.8.8 在特殊性岩土分布区进行基坑工程勘察时，可根据本规范第6章的规定进行勘察，对软土的蠕变和长期强度，软岩和极软岩的失水崩解，膨胀土的膨胀性和裂隙性以及非饱和土增湿软化等对基坑的影响进行分析评价。

4.8.9 基坑工程勘察，应根据开挖深度、岩土和地下水条件以及环境要求，对基坑边坡的处理方式提出建议。

4.8.10 基坑工程勘察应针对以下内容进行分析，提供有关计算参数和建议：

1 边坡的局部稳定性、整体稳定性和坑底抗隆起稳定性；

2 坑底和侧壁的渗透稳定性；

3 挡土结构和边坡可能发生的变形；

4 降水效果和降水对环境的影响；

5 开挖和降水对邻近建筑物和地下设施的影响。

4.8.11 岩土工程勘察报告中与基坑工程有关的部分应包括下列内容：

1 与基坑开挖有关的场地条件、土质条件和工程条件；

2 提出处理方式、计算参数和支护结构选型的建议；

3 提出地下水控制方法、计算参数和施工控制的建议；

4 提出施工方法和施工中可能遇到的问题的防治措施的建议；

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5　对施工阶段的环境保护和监测工作的建议。

4.9　桩　基　础

4.9.1　桩基岩土工程勘察应包括下列内容：

1　查明场地各层岩土的类型、深度、分布、工程特性和变化规律；

2　当采用基岩作为桩的持力层时，应查明基岩的岩性、构造、岩面变化、风化程度，确定其坚硬程度、完整程度和基本质量等级，判定有无洞穴、临空面、破碎岩体或软弱岩层；

3　查明水文地质条件，评价地下水对桩基设计和施工的影响，判定水质对建筑材料的腐蚀性；

4　查明不良地质作用，可液化土层和特殊性岩土的分布及其对桩基的危害程度，并提出防治措施的建议；

5　评价成桩可能性，论证桩的施工条件及其对环境的影响。

4.9.2　土质地基勘探点间距应符合下列规定：

1　对端承桩宜为 12～24m，相邻勘探孔揭露的持力层层面高差宜控制为 1～2m；

2　对摩擦桩宜为 20～35m；当地层条件复杂，影响成桩或设计有特殊要求时，勘探点应适当加密；

3　复杂地基的一柱一桩工程，宜每柱设置勘探点。

4.9.3　桩基岩土工程勘察宜采用钻探和触探以及其他原位测试相结合的方式进行，对软土、粘性土、粉土和砂土的测试手段，宜采用静力触探和标准贯入试验；对碎石土宜采用重型或超重型圆锥动力触探。

4.9.4　勘探孔的深度应符合下列规定：

1　一般性勘探孔的深度应达到预计桩长以下 $3\sim5d$（d 为桩径），且不得小于 3m；对大直径桩，不得小于 5m；

2　控制性勘探孔深度应满足下卧层验算要求；对需验算沉降的桩基，应超过地基变形计算深度；

3　钻至预计深度遇软弱层时，应予加深；在预计勘探孔深度内遇稳定坚实岩土时，可适当减小；

4　对嵌岩桩，应钻入预计嵌岩面以下 $3\sim5d$，并穿过溶洞、破碎带，到达稳定地层；

5　对可能有多种桩长方案时，应根据最长桩方案确定。

4.9.5　岩土室内试验应满足下列要求：

1　当需估算桩的侧阻力、端阻力和验算下卧层强度时，宜进行三轴剪切试验或无侧限抗压强度试验；三轴剪切试验的受力条件应模拟工程的实际情况；

2　对需估算沉降的桩基工程，应进行压缩试验，试验最大压力应大于上覆自重压力与附加压力之和；

3　当桩端持力层为基岩时，应采取岩样进行饱和单轴抗压强度试验，必要时尚应进行软化试验；对软岩和极软岩，可进行天然湿度的单轴抗压强度试验。对无法取样的

破碎和极破碎的岩石，宜进行原位测试。

4.9.6 单桩竖向和水平承载力，应根据工程等级、岩土性质和原位测试成果并结合当地经验确定。对地基基础设计等级为甲级的建筑物和缺乏经验的地区，应建议做静载荷试验。试验数量不宜少于工程桩数的1%，且每个场地不少于3个。对承受较大水平荷载的桩，应建议进行桩的水平载荷试验；对承受上拔力的桩，应建议进行抗拔试验。勘察报告应提出估算的有关岩土的基桩侧阻力和端阻力。必要时提出估算的竖向和水平承载力和抗拔承载力。

4.9.7 对需要进行沉降计算的桩基工程，应提供计算所需的各层岩土的变形参数，并宜根据任务要求，进行沉降估算。

4.9.8 桩基工程的岩土工程勘察报告除应符合本规范第14章的要求，并按第4.9.6条、第4.9.7条提供承载力和变形参数外，尚应包括下列内容：

1 提供可选的桩基类型和桩端持力层；提出桩长、桩径方案的建议；

2 当有软弱下卧层时，验算软弱下卧层强度；

3 对欠固结土和有大面积堆载的工程，应分析桩侧产生负摩阻力的可能性及其对桩基承载力的影响，并提供负摩阻力系数和减少负摩阻力措施的建议；

4 分析成桩的可能性，成桩和挤土效应的影响，并提出保护措施的建议；

5 持力层为倾斜地层，基岩面凹凸不平或岩土中有洞穴时，应评价桩的稳定性，并提出处理措施的建议。

4.10 地基处理

4.10.1 地基处理的岩土工程勘察应满足下列要求：

1 针对可能采用的地基处理方案，提供地基处理设计和施工所需的岩土特性参数；

2 预测所选地基处理方法对环境和邻近建筑物的影响；

3 提出地基处理方案的建议；

4 当场地条件复杂且缺乏成功经验时，应在施工现场对拟选方案进行试验或对比试验，检验方案的设计参数和处理效果；

5 在地基处理施工期间，应进行施工质量和施工对周围环境和邻近工程设施影响的监测。

4.10.2 换填垫层法的岩土工程勘察宜包括下列内容：

1 查明待换填的不良土层的分布范围和埋深；

2 测定换填材料的最优含水量、最大干密度；

3 评定垫层以下软弱下卧层的承载力和抗滑稳定性，估算建筑物的沉降；

4 评定换填材料对地下水的环境影响；

5 对换填施工过程应注意的事项提出建议；

6 对换填垫层的质量进行检验或现场试验。

4.10.3 预压法的岩土工程勘察宜包括下列内容：

1 查明土的成层条件，水平和垂直方向的分布，排水层和夹砂层的埋深和厚度，地

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下水的补给和排泄条件等；

2 提供待处理软土的先期固结压力、压缩性参数、固结特性参数和抗剪强度指标、软土在预压过程中强度的增长规律；

3 预估预压荷载的分级和大小、加荷速率、预压时间、强度的可能增长和可能的沉降；

4 对重要工程，建议选择代表性试验区进行预压试验；采用室内试验、原位测试、变形和孔压的现场监测等手段，推算软土的固结系数、固结度与时间的关系和最终沉降量，为预压处理的设计施工提供可靠依据；

5 检验预压处理效果，必要时进行现场载荷试验。

4.10.4 强夯法的岩土工程勘察宜包括下列内容：

1 查明强夯影响深度范围内土层的组成、分布、强度、压缩性、透水性和地下水条件；

2 查明施工场地和周围受影响范围内的地下管线和构筑物的位置、标高；查明有无对振动敏感的设施，是否需在强夯施工期间进行监测；

3 根据强夯设计，选择代表性试验区进行试夯，采用室内试验、原位测试、现场监测等手段，查明强夯有效加固深度，夯击能量、夯击遍数与夯沉量的关系，夯坑周围地面的振动和地面隆起，土中孔隙水压力的增长和消散规律。

4.10.5 桩土复合地基的岩土工程勘察宜包括下列内容：

1 查明暗塘、暗浜、暗沟、洞穴等的分布和埋深；

2 查明土的组成、分布和物理力学性质，软弱土的厚度和埋深，可作为桩基持力层的相对硬层的埋深；

3 预估成桩施工可能性（有无地下障碍、地下洞穴、地下管线、电缆等）和成桩工艺对周围土体、邻近建筑、工程设施和环境的影响（噪声、振动、侧向挤土、地面沉陷或隆起等），桩体与水土间的相互作用（地下水对桩材的腐蚀性，桩材对周围水土环境的污染等）；

4 评定桩间土承载力，预估单桩承载力和复合地基承载力；

5 评定桩间土、桩身、复合地基、桩端以下变形计算深度范围内土层的压缩性，任务需要时估算复合地基的沉降量；

6 对需验算复合地基稳定性的工程，提供桩间土、桩身的抗剪强度；

7 任务需要时应根据桩土复合地基的设计，进行桩间土、单桩和复合地基载荷试验，检验复合地基承载力。

4.10.6 注浆法的岩土工程勘察宜包括下列内容：

1 查明土的级配、孔隙性或岩石的裂隙宽度和分布规律，岩土渗透性，地下水埋深、流向和流速，岩土的化学成分和有机质含量；岩土的渗透性宜通过现场试验测定；

2 根据岩土性质和工程要求选择浆液和注浆方法（渗透注浆、劈裂注浆、压密注浆等），根据地区经验或通过现场试验确定浆液浓度、粘度、压力、凝结时间、有效加固半径或范围，评定加固后地基的承载力、压缩性、稳定性或抗渗性；

3 在加固施工过程中对地面、既有建筑物和地下管线等进行跟踪变形观测，以控

制灌注顺序、注浆压力、注浆速率等；

4 通过开挖、室内试验、动力触探或其他原位测试，对注浆加固效果进行检验；

5 注浆加固后，应对建筑物或构筑物进行沉降观测，直至沉降稳定为止，观测时间不宜少于半年。

4.11 既有建筑物的增载和保护

4.11.1 既有建筑物的增载和保护的岩土工程勘察应符合下列要求：

1 搜集建筑物的荷载、结构特点、功能特点和完好程度资料，基础类型、埋深、平面位置，基底压力和变形观测资料；场地及其所在地区的地下水开采历史，水位降深、降速，地面沉降、形变，地裂缝的发生、发展等资料；

2 评价建筑物的增层、增载和邻近场地大面积堆载对建筑物的影响时，应查明地基土的承载力，增载后可能产生的附加沉降和沉降差；对建造在斜坡上的建筑物尚应进行稳定性验算；

3 对建筑物接建或在其紧邻新建建筑物，应分析新建建筑物在既有建筑物地基土中引起的应力状态改变及其影响；

4 评价地下水抽降对建筑物的影响时，应分析抽降引起地基土的固结作用和地面下沉、倾斜、挠曲或破裂对既有建筑物的影响，并预测其发展趋势；

5 评价基坑开挖对邻近既有建筑物的影响时，应分析开挖卸载导致的基坑底部剪切隆起，因坑内外水头差引发管涌，坑壁土体的变形与位移、失稳等危险；同时还应分析基坑降水引起的地面不均匀沉降的不良环境效应；

6 评价地下工程施工对既有建筑物的影响时，应分析伴随岩土体内的应力重分布出现的地面下沉、挠曲等变形或破裂，施工降水的环境效应，过大的围岩变形或坍塌等对既有建筑物的影响。

4.11.2 建筑物的增层、增载和邻近场地大面积堆载的岩土工程勘察应包括下列内容：

1 分析地基土的实际受荷程度和既有建筑物结构、材料状况及其适应新增荷载和附加沉降的能力；

2 勘探点应紧靠基础外侧布置，有条件时宜在基础中心线布置，每栋单独建筑物的勘探点不宜少于3个；在基础外侧适当距离处，宜布置一定数量勘探点；

3 勘探方法除钻探外，宜包括探井和静力触探或旁压试验；取土和旁压试验的间距，在基底以下一倍基宽的深度范围内宜为0.5m，超过该深度时可为1m；必要时，应专门布置探井查明基础类型、尺寸、材料和地基处理等情况；

4 压缩试验成果中应有 e-lg$p$ 曲线，并提供先期固结压力、压缩指数、回弹指数和与增荷后土中垂直有效压力相应的固结系数，以及三轴不固结不排水剪切试验成果；当拟增层数较多或增载量较大时，应作载荷试验，提供主要受力层的比例界限荷载、极限荷载、变形模量和回弹模量；

5 岩土工程勘察报告应着重对增载后的地基土承载力进行分析评价，预测可能的附加沉降和差异沉降，提出关于设计方案、施工措施和变形监测的建议。

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4.11.3 建筑物接建、邻建的岩土工程勘察应符合下列要求：

1 除应符合本规范第 4.11.2 条第 1 款的要求外，尚应评价建筑物的结构和材料适应局部挠曲的能力；

2 除按本规范第 4.1 节的有关要求对新建建筑物布置勘探点外，尚应为研究接建、邻建部位的地基土、基础结构和材料现状布置勘探点，其中应有探井或静力触探孔，其数量不宜少于 3 个，取土间距宜为 1m；

3 压缩试验成果中应有 e-lg$p$ 曲线，并提供先期固结压力、压缩指数、回弹指数和与增荷后土中垂直有效压力相应的固结系数，以及三轴不固结不排水剪切试验成果；

4 岩土工程勘察报告应评价由新建部分的荷载在既有建筑物地基土中引起的新的压缩和相应的沉降差；评价新基坑的开挖、降水、设桩等对既有建筑物的影响，提出设计方案、施工措施和变形监测的建议。

4.11.4 评价地下水抽降影响的岩土工程勘察应符合下列要求：

1 研究地下水抽降与含水层埋藏条件、可压缩土层厚度、土的压缩性和应力历史等的关系，做出评价和预测；

2 勘探孔深度应超过可压缩地层的下限，并应取土试验或进行原位测试；

3 压缩试验成果中应有 e-lg$p$ 曲线，并提供先期固结压力、压缩指数、回弹指数和与增荷后土中垂直有效压力相应的固结系数，以及三轴不固结不排水剪切试验成果；

4 岩土工程勘察报告应分析预测场地可能产生地面沉降、形变、破裂及其影响，提出保护既有建筑物的措施。

4.11.5 评价基坑开挖对邻近建筑物影响的岩土工程勘察应符合下列要求：

1 搜集分析既有建筑物适应附加沉降和差异沉降的能力，与拟挖基坑在平面与深度上的位置关系和可能采用的降水、开挖与支护措施等资料；

2 查明降水、开挖等影响所及范围内的地层结构，含水层的性质、水位和渗透系数，土的抗剪强度、变形参数等工程特性；

3 岩土工程勘察报告除应符合本规范第 4.8 节的要求外，尚应着重分析预测坑底和坑外地面的卸荷回弹，坑周土体的变形位移和坑底发生剪切隆起或管涌的危险，分析施工降水导致的地面沉降的幅度、范围和对邻近建筑物的影响，并就安全合理的开挖、支护、降水方案和监测工作提出建议。

4.11.6 评价地下开挖对建筑物影响的岩土工程勘察应符合下列要求：

1 分析已有勘察资料，必要时应做补充勘探测试工作；

2 分析沿地下工程主轴线出现槽形地面沉降和在其两侧或四周的地面倾斜、挠曲的可能性及其对两侧既有建筑物的影响，并就安全合理的施工方案和保护既有建筑物的措施提出建议；

3 提出对施工过程中地面变形、围岩应力状态、围岩或建筑物地基失稳的前兆现象等进行监测的建议。

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5 不良地质作用和地质灾害

5.1 岩　　溶

5.1.1 拟建工程场地或其附近存在对工程安全有影响的岩溶时，应进行岩溶勘察。

5.1.2 岩溶勘察宜采用工程地质测绘和调查、物探、钻探等多种手段结合的方法进行，并应符合下列要求：

1 可行性研究勘察应查明岩溶洞隙、土洞的发育条件，并对其危害程度和发展趋势作出判断，对场地的稳定性和工程建设的适宜性做出初步评价；

2 初步勘察应查明岩溶洞隙及其伴生土洞、塌陷的分布、发育程度和发育规律，并按场地的稳定性和适宜性进行分区。

3 详细勘察应查明拟建工程范围及有影响地段的各种岩溶洞隙和土洞的位置、规模、埋深，岩溶堆填物性状和地下水特征，对地基基础的设计和岩溶的治理提出建议。

4 施工勘察应针对某一地段或尚待查明的专门问题进行补充勘察。当采用大直径嵌岩桩时，尚应进行专门的桩基勘察。

5.1.3 岩溶场地的工程地质测绘和调查，除应遵守本规范第 8 章的规定外，尚应调查下列内容：

1 岩溶洞隙的分布、形态和发育规律；

2 岩面起伏、形态和覆盖层厚度；

3 地下水赋存条件、水位变化和运动规律；

4 岩溶发育与地貌、构造、岩性、地下水的关系；

5 土洞和塌陷的分布、形态和发育规律；

6 土洞和塌陷的成因及其发展趋势；

7 当地治理岩溶、土洞和塌陷的经验。

5.1.4 可行性研究和初步勘察宜采用工程地质测绘和综合物探为主，勘探点的间距不应大于本规范第 4 章的规定，岩溶发育地段应予加密。测绘和物探发现的异常地段，应选择有代表性的部位布置验证性钻孔。控制性勘探孔的深度应穿过表层岩溶发育带。

5.1.5 详细勘察的勘探工作应符合下列规定：

1 勘探线应沿建筑物轴线布置，勘探点间距不应大于本规范第 4 章的规定，条件复杂时每个独立基础均应布置勘探点；

2 勘探孔深度除应符合本规范第 4 章的规定外，当基础底面下的土层厚度不符合本节第 5.1.10 条第 1 款的条件时，应有部分或全部勘探孔钻入基岩；

3 当预定深度内有洞体存在，且可能影响地基稳定时，应钻入洞底基岩面下不少于 2m，必要时应圈定洞体范围；

4 对一柱一桩的基础，宜逐柱布置勘探孔；

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5　在土洞和塌陷发育地段，可采用静力触探、轻型动力触探、小口径钻探等手段，详细查明其分布；

6　当需查明断层、岩组分界、洞隙和土洞形态、塌陷等情况时，应布置适当的探槽或探井；

7　物探应根据物性条件采用有效方法，对异常点应采用钻探验证，当发现或可能存在危害工程的洞体时，应加密勘探点；

8　凡人员可以进入的洞体，均应入洞勘查，人员不能进入的洞体，宜用井下电视等手段探测。

5.1.6　施工勘察工作量应根据岩溶地基设计和施工要求布置。在土洞、塌陷地段，可在已开挖的基槽内布置触探或钎探。对重要或荷载较大的工程，可在槽底采用小口径钻探，进行检测。对大直径嵌岩桩，勘探点应逐桩布置，勘探深度应不小于底面以下桩径的3倍并不小于5m，当相邻桩底的基岩面起伏较大时应适当加深。

5.1.7　岩溶发育地区的下列部位宜查明土洞和土洞群的位置：

1　土层较薄、土中裂隙及其下岩体洞隙发育部位；

2　岩面张开裂隙发育，石芽或外露的岩体与土体交接部位；

3　两组构造裂隙交汇处和宽大裂隙带；

4　隐伏溶沟、溶槽、漏斗等，其上有软弱土分布的负岩面地段；

5　地下水强烈活动于岩土交界面的地段和大幅度人工降水地段；

6　低洼地段和地表水体近旁。

5.1.8　岩溶勘察的测试和观测宜符合下列要求：

1　当追索隐伏洞隙的联系时，可进行连通试验；

2　评价洞隙稳定性时，可采取洞体顶板岩样和充填物土样作物理力学性质试验，必要时可进行现场顶板岩体的载荷试验；

3　当需查明土的性状与土洞形成的关系时，可进行湿化、胀缩、可溶性和剪切试验；

4　当需查明地下水动力条件、潜蚀作用，地表水与地下水联系，预测土洞和塌陷的发生、发展时，可进行流速、流向测定和水位、水质的长期观测。

5.1.9　当场地存在下列情况之一时，可判定为未经处理不宜作为地基的不利地段：

1　浅层洞体或溶洞群，洞径大，且不稳定的地段；

2　埋藏的漏斗、槽谷等，并覆盖有软弱土体的地段；

3　土洞或塌陷成群发育地段；

4　岩溶水排泄不畅，可能暂时淹没的地段。

5.1.10　当地基属下列条件之一时，对二级和三级工程可不考虑岩溶稳定性的不利影响：

1　基础底面以下土层厚度大于独立基础宽度的3倍或条形基础宽度的6倍，且不具备形成土洞或其他地面变形的条件；

2　基础底面与洞体顶板间岩土厚度虽小于本条第1款的规定，但符合下列条件之一时：

1）洞隙或岩溶漏斗被密实的沉积物填满且无被水冲蚀的可能；

2）洞体为基本质量等级为Ⅰ级或Ⅱ级岩体，顶板岩石厚度大于或等于洞跨；

3）洞体较小，基础底面大于洞的平面尺寸，并有足够的支承长度；

4）宽度或直径小于 1.0m 的竖向洞隙、落水洞近旁地段。

5.1.11 当不符合本规范第 5.1.10 条的条件时，应进行洞体地基稳定性分析，并符合下列规定：

1 顶板不稳定，但洞内为密实堆积物充填且无流水活动时，可认为堆填物受力，按不均匀地基进行评价；

2 当能取得计算参数时，可将洞体顶板视为结构自承重体系进行力学分析；

3 有工程经验的地区，可按类比法进行稳定性评价；

4 在基础近旁有洞隙和临空面时，应验算向临空面倾覆或沿裂面滑移的可能；

5 当地基为石膏、岩盐等易溶岩时，应考虑溶蚀继续作用的不利影响；

6 对不稳定的岩溶洞隙可建议采用地基处理或桩基础。

5.1.12 岩溶勘察报告除应符合本规范第 14 章的规定外，尚应包括下列内容：

1 岩溶发育的地质背景和形成条件；

2 洞隙、土洞、塌陷的形态、平面位置和顶底标高；

3 岩溶稳定性分析；

4 岩溶治理和监测的建议。

5.2 滑　　坡

5.2.1 拟建工程场地或其附近存在对工程安全有影响的滑坡或有滑坡可能时，应进行专门的滑坡勘察。

5.2.2 滑坡勘察应进行工程地质测绘和调查，调查范围应包括滑坡及其邻近地段。比例尺可选用 1：200～1：1000。用于整治设计时，比例尺应选用 1：200～1：500。

5.2.3 滑坡区的工程地质测绘和调查，除应遵守本规范第 8 章的规定外，尚应调查下列内容：

1 搜集地质、水文、气象、地震和人类活动等相关资料；

2 滑坡的形态要素和演化过程，圈定滑坡周界；

3 地表水、地下水、泉和湿地等的分布；

4 树木的异态、工程设施的变形等；

5 当地治理滑坡的经验。

对滑坡的重点部位应摄影或录像。

5.2.4 勘探线和勘探点的布置应根据工程地质条件、地下水情况和滑坡形态确定。除沿主滑方向应布置勘探线外，在其两侧滑坡体外也应布置一定数量勘探线。勘探点间距不宜大于 40m，在滑坡体转折处和预计采取工程措施的地段，也应布置勘探点。

勘探方法除钻探和触探外，应有一定数量的探井。

5.2.5 勘探孔的深度应穿过最下一层滑面，进入稳定地层，控制性勘探孔应深入稳定地

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层一定深度，满足滑坡治理需要。

5.2.6 滑坡勘察应进行下列工作：

1 查明各层滑坡面(带)的位置；

2 查明各层地下水的位置、流向和性质；

3 在滑坡体、滑坡面(带)和稳定地层中采取土试样进行试验。

5.2.7 滑坡勘察时，土的强度试验宜符合下列要求：

1 采用室内、野外滑面重合剪，滑带宜作重塑土或原状土多次剪试验，并求出多次剪和残余剪的抗剪强度；

2 采用与滑动受力条件相似的方法；

3 采用反分析方法检验滑动面的抗剪强度指标。

5.2.8 滑坡的稳定性计算应符合下列要求：

1 正确选择有代表性的分析断面，正确划分牵引段、主滑段和抗滑段；

2 正确选用强度指标，宜根据测试成果、反分析和当地经验综合确定；

3 有地下水时，应计入浮托力和水压力；

4 根据滑面(滑带)条件，按平面、圆弧或折线，选用正确的计算模型；

5 当有局部滑动可能时，除验算整体稳定外，尚应验算局部稳定；

6 当有地震、冲刷、人类活动等影响因素时，应计及这些因素对稳定的影响。

5.2.9 滑坡稳定性的综合评价，应根据滑坡的规模、主导因素、滑坡前兆、滑坡区的工程地质和水文地质条件，以及稳定性验算结果进行，并应分析发展趋势和危害程度，提出治理方案的建议。

5.2.10 滑坡勘察报告除应符合本规范第 14 章的规定外，尚应包括下列内容：

1 滑坡的地质背景和形成条件；

2 滑坡的形态要素、性质和演化；

3 提供滑坡的平面图、剖面图和岩土工程特性指标；

4 滑坡稳定分析；

5 滑坡防治和监测的建议。

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5.3 危岩和崩塌

5.3.1 拟建工程场地或其附近存在对工程安全有影响的危岩或崩塌时，应进行危岩和崩塌勘察。

5.3.2 危岩和崩塌勘察宜在可行性研究或初步勘察阶段进行，应查明产生崩塌的条件及其规模、类型、范围，并对工程建设适宜性进行评价，提出防治方案的建议。

5.3.3 危岩和崩塌地区工程地质测绘的比例尺宜采用 1∶500～1∶1000；崩塌方向主剖面的比例尺宜采用 1∶200。除应符合本规范第 8 章的规定外，尚应查明下列内容：

1 地形地貌及崩塌类型、规模、范围，崩塌体的大小和崩落方向；

2 岩体基本质量等级、岩性特征和风化程度；

3 地质构造，岩体结构类型，结构面的产状、组合关系、闭合程度、力学属性、延展及

贯穿情况；

4　气象（重点是大气降水）、水文、地震和地下水的活动；

5　崩塌前的迹象和崩塌原因；

6　当地防治崩塌的经验。

5.3.4　当需判定危岩的稳定性时，宜对张裂缝进行监测。对有较大危害的大型危岩，应结合监测结果，对可能发生崩塌的时间、规模、滚落方向、途径、危害范围等做出预报。

5.3.5　各类危岩和崩塌的岩土工程评价应符合下列规定：

1　规模大，破坏后果很严重，难于治理的，不宜作为工程场地，线路应绕避；

2　规模较大，破坏后果严重的，应对可能产生崩塌的危岩进行加固处理，线路应采取防护措施；

3　规模小，破坏后果不严重的，可作为工程场地，但应对不稳定危岩采取治理措施。

5.3.6　危岩和崩塌区的岩土工程勘察报告除应遵守本规范第14章的规定外，尚应阐明危岩和崩塌区的范围、类型，作为工程场地的适宜性，并提出防治方案的建议。

5.4　泥　石　流

5.4.1　拟建工程场地或其附近有发生泥石流的条件并对工程安全有影响时，应进行专门的泥石流勘察。

5.4.2　泥石流勘察应在可行性研究或初步勘察阶段进行，应查明泥石流的形成条件和泥石流的类型、规模、发育阶段、活动规律，并对工程场地做出适宜性评价，提出防治方案的建议。

5.4.3　泥石流勘察应以工程地质测绘和调查为主。测绘范围应包括沟谷至分水岭的全部地段和可能受泥石流影响的地段。测绘比例尺，对全流域宜采用1：50000；对中下游可采用1：2000～1：10000除应符合本规范第8章的规定外，尚应调查下列内容：

1　冰雪融化和暴雨强度、一次最大降雨量，平均及最大流量，地下水活动等情况；

2　地形地貌特征，包括沟谷的发育程度、切割情况，坡度、弯曲、粗糙程度，并划分泥石流的形成区、流通区和堆积区，圈绘整个沟谷的汇水面积；

3　形成区的水源类型、水量、汇水条件、山坡坡度，岩层性质和风化程度；查明断裂、滑坡、崩塌、岩堆等不良地质作用的发育情况及可能形成泥石流固体物质的分布范围、储量；

4　流通区的沟床纵横坡度、跌水、急湾等特征；查明沟床两侧山坡坡度、稳定程度，沟床的冲淤变化和泥石流的痕迹；

5　堆积区的堆积扇分布范围，表面形态，纵坡，植被，沟道变迁和冲淤情况；查明堆积物的性质、层次、厚度、一般粒径和最大粒径；判定堆积区的形成历史、堆积速度，估算一次最大堆积量；

6　泥石流沟谷的历史，历次泥石流的发生时间、频数、规模、形成过程、暴发前的降雨情况和暴发后产生的灾害情况；

7　开矿弃渣、修路切坡、砍伐森林、陡坡开荒和过度放牧等人类活动情况；

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8 当地防治泥石流的经验。

5.4.4 当需要对泥石流采取防治措施时，应进行勘探测试，进一步查明泥石流堆积物的性质、结构、厚度，固体物质含量、最大粒径，流速、流量，冲出量和淤积量。

5.4.5 泥石流的工程分类，宜遵守本规范附录C的规定。

5.4.6 泥石流地区工程建设适宜性的评价，应符合下列要求：

1 I_1类和II_1类泥石流沟谷不应作为工程场地，各类线路宜避开；

2 I_2类和II_2类泥石流沟谷不宜作为工程场地，当必须利用时应采取治理措施；线路应避免直穿堆积扇，可在沟口设桥(墩)通过；

3 I_3类和II_3类泥石流沟谷可利用其堆积区作为工程场地，但应避开沟口；线路可在堆积扇通过，可分段设桥和采取排洪、导流措施，不宜改沟、并沟；

4 当上游大量弃渣或进行工程建设，改变了原有供排平衡条件时，应重新判定产生新的泥石流的可能性。

5.4.7 泥石流岩土工程勘察报告，除应遵守本规范第14章的规定外，尚应包括下列内容：

1 泥石流的地质背景和形成条件；

2 形成区、流通区、堆积区的分布和特征，绘制专门工程地质图；

3 划分泥石流类型，评价其对工程建设的适宜性；

4 泥石流防治和监测的建议。

5.5 采 空 区

5.5.1 本节适用于老采空区、现采空区和未来采空区的岩土工程勘察。采空区勘察应查明老采空区上覆岩层的稳定性，预测现采空区和未来采空区的地表移动、变形的特征和规律性；判定其作为工程场地的适宜性。

5.5.2 采空区的勘察宜以搜集资料、调查访问为主，并应查明下列内容：

1 矿层的分布、层数、厚度、深度、埋藏特征和上覆岩层的岩性、构造等；

2 矿层开采的范围、深度、厚度、时间、方法和顶板管理，采空区的塌落、密实程度、空隙和积水等；

3 地表变形特征和分布，包括地表陷坑、台阶、裂缝的位置、形状、大小、深度、延伸方向及其与地质构造、开采边界、工作面推进方向等的关系；

4 地表移动盆地的特征，划分中间区、内边缘区和外边缘区，确定地表移动和变形的特征值；

5 采空区附近的抽水和排水情况及其对采空区稳定的影响；

6 搜集建筑物变形和防治措施的经验。

5.5.3 对老采空区和现采空区，当工程地质调查不能查明采空区的特征时，应进行物探和钻探。

5.5.4 对现采空区和未来采空区，应通过计算预测地表移动和变形的特征值，计算方法可按现行标准《建筑物、水体、铁路及主要井巷煤柱留设与压煤开采规程》执行。

5.5.5 采空区宜根据开采情况，地表移动盆地特征和变形大小，划分为不宜建筑的场地和相对稳定的场地，并宜符合下列规定：

1 下列地段不宜作为建筑场地：

1）在开采过程中可能出现非连续变形的地段；

2）地表移动活跃的地段；

3）特厚矿层和倾角大于55°的厚矿层露头地段；

4）由于地表移动和变形引起边坡失稳和山崖崩塌的地段；

5）地表倾斜大于10mm/m，地表曲率大于0.6mm/m^{2}或地表水平变形大于6mm/m的地段。

2 下列地段作为建筑场地时，应评价其适宜性：

1）采空区采深采厚比小于30的地段；

2）采深小，上覆岩层极坚硬，并采用非正规开采方法的地段；

3）地表倾斜为3～10mm/m，地表曲率为0.2～0.6mm/m^{2}或地表水平变形为2～6mm/m的地段。

5.5.6 采深小、地表变形剧烈且为非连续变形的小窑采空区，应通过搜集资料、调查、物探和钻探等工作，查明采空区和巷道的位置、大小、埋藏深度、开采时间、开采方式、回填塌落和充水等情况；并查明地表裂缝、陷坑的位置、形状、大小、深度、延伸方向及其与采空区的关系；

5.5.7 小窑采空区的建筑物应避开地表裂缝和陷坑地段。对次要建筑且采空区采深采厚比大于30，地表已经稳定时可不进行稳定性评价；当采深采厚比小于30时，可根据建筑物的基底压力、采空区的埋深、范围和上覆岩层的性质等评价地基的稳定性，并根据矿区经验提出处理措施的建议。

5.6 地面沉降

5.6.1 本节适用于抽吸地下水引起水位或水压下降而造成大面积地面沉降的岩土工程勘察。

5.6.2 对已发生地面沉降的地区，地面沉降勘察应查明其原因和现状，并预测其发展趋势，提出控制和治理方案。

对可能发生地面沉降的地区，应预测发生的可能性，并对可能的沉降层位做出估计，对沉降量进行估算，提出预防和控制地面沉降的建议。

5.6.3 对地面沉降原因，应调查下列内容：

1 场地的地貌和微地貌；

2 第四纪堆积物的年代、成因、厚度、埋藏条件和土性特征，硬土层和软弱压缩层的分布；

3 地下水位以下可压缩层的固结状态和变形参数；

4 含水层和隔水层的埋藏条件和承压性质，含水层的渗透系数、单位涌水量等水文地质参数；

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5　地下水的补给、径流、排泄条件，含水层间或地下水与地面水的水力联系；

6　历年地下水位、水头的变化幅度和速率；

7　历年地下水的开采量和回灌量，开采或回灌的层段；

8　地下水位下降漏斗及回灌时地下水反漏斗的形成和发展过程。

5.6.4　对地面沉降现状的调查，应符合下列要求：

1　按精密水准测量要求进行长期观测，并按不同的结构单元设置高程基准标、地面沉降标和分层沉降标；

2　对地下水的水位升降，开采量和回灌量，化学成分，污染情况和孔隙水压力消散、增长情况进行观测；

3　调查地面沉降对建筑物的影响，包括建筑物的沉降、倾斜、裂缝及其发生时间和发展过程；

4　绘制不同时间的地面沉降等值线图，并分析地面沉降中心与地下水位下降漏斗的关系及地面回弹与地下水位反漏斗的关系；

5　绘制以地面沉降为特征的工程地质分区图。

5.6.5　对已发生地面沉降的地区，可根据工程地质和水文地质条件，建议采取下列控制和治理方案：

1　减少地下水开采量和水位降深，调整开采层次，合理开发，当地面沉降发展剧烈时，应暂时停止开采地下水；

2　对地下水进行人工补给，回灌时应控制回灌水源的水质标准，以防止地下水被污染；

3　限制工程建设中的人工降低地下水位。

5.6.6　对可能发生地面沉降的地区应预测地面沉降的可能性和估算沉降量，并可采取下列预测和防治措施：

1　根据场地工程地质、水文地质条件，预测可压缩层的分布；

2　根据抽水压密试验、渗透试验、先期固结压力试验、流变试验、载荷试验等的测试成果和沉降观测资料，计算分析地面沉降量和发展趋势；

3　提出合理开采地下水资源，限制人工降低地下水位及在地面沉降区内进行工程建设应采取措施的建议。

5.7　场地和地基的地震效应

5.7.1　抗震设防烈度等于或大于6度的地区，应进行场地和地基地震效应的岩土工程勘察，并应根据国家批准的地震动参数区划和有关的规范，提出勘察场地的抗震设防烈度、设计基本地震加速度和设计地震分组。

5.7.2　在抗震设防烈度等于或大于6度的地区进行勘察时，应确定场地类别。当场地位于抗震危险地段时，应根据现行国家标准《建筑抗震设计规范》GB 50011的要求，提出专门研究的建议。

5.7.3　对需要采用时程分析的工程，应根据设计要求，提供土层剖面、覆盖层厚度和剪

切波速度等有关参数。任务需要时，可进行地震安全性评估或抗震设防区划。

5.7.4 为划分场地类别布置的勘探孔，当缺乏资料时，其深度应大于覆盖层厚度。当覆盖层厚度大于80m时，勘探孔深度应大于80m，并分层测定剪切波速。10层和高度30m以下的丙类和丁类建筑，无实测剪切波速时，可按现行国家标准《建筑抗震设计规范》(GB 50011)的规定，按土的名称和性状估计土的剪切波速。

5.7.5 抗震设防烈度为6度时，可不考虑液化的影响，但对沉陷敏感的乙类建筑，可按7度进行液化判别。甲类建筑应进行专门的液化勘察。

5.7.6 场地地震液化判别应先进行初步判别，当初步判别认为有液化可能时，应再作进一步判别。液化的判别宜采用多种方法，综合判定液化可能性和液化等级。

5.7.7 液化初步判别除按现行国家有关抗震规范进行外，尚宜包括下列内容进行综合判别：

1 分析场地地形、地貌、地层、地下水等与液化有关的场地条件；

2 当场地及其附近存在历史地震液化遗迹时，宜分析液化重复发生的可能性；

3 倾斜场地或液化层倾向水面或临空面时，应评价液化引起土体滑移的可能性。

5.7.8 地震液化的进一步判别应在地面以下15m的范围内进行；对于桩基和基础埋深大于5m的天然地基，判别深度应加深至20m。对判别液化而布置的勘探点不应少于3个，勘探孔深度应大于液化判别深度。

5.7.9 地震液化的进一步判别，除应按现行国家标准《建筑抗震设计规范》(GB 50011)的规定执行外，尚可采用其他成熟方法进行综合判别。

当采用标准贯入试验判别液化时，应按每个试验孔的实测击数进行。在需作判定的土层中，试验点的竖向间距宜为1.0～1.5m，每层土的试验点数不宜少于6个。

5.7.10 凡判别为可液化的场地，应按现行国家标准《建筑抗震设计规范》(GB 50011)的规定确定其液化指数和液化等级。

勘察报告除应阐明可液化的土层、各孔的液化指数外，尚应根据各孔液化指数综合确定场地液化等级。

5.7.11 抗震设防烈度等于或大于7度的厚层软土分布区，宜判别软土震陷的可能性和估算震陷量。

5.7.12 场地或场地附近有滑坡、滑移、崩塌、塌陷、泥石流、采空区等不良地质作用时，应进行专门勘察，分析评价在地震作用时的稳定性。

5.8 活动断裂

5.8.1 抗震设防烈度等于或大于7度的重大工程场地应进行活动断裂(以下简称断裂)勘察。断裂勘察应查明断裂的位置和类型，分析其活动性和地震效应，评价断裂对工程建设可能产生的影响，并提出处理方案。

对核电厂的断裂勘察，应按核安全法规和导则进行专门研究。

5.8.2 断裂的地震工程分类应符合下列规定：

1 全新活动断裂为在全新地质时期(一万年)内有过地震活动或近期正在活动，在

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今后一百年可能继续活动的断裂；全新活动断裂中、近期（近500年来）发生过地震震级$M\geqslant5$级的断裂，或在今后100年内，可能发生$M\geqslant5$级的断裂，可定为发震断裂：

2 非全新活动断裂：一万年以前活动过，一万年以来没有发生过活动的断裂。

5.8.3 全新活动断裂可按表5.8.3分级。

表5.8.3 全新活动断裂分级

断裂分级 \ 指标		活动性	平均活动速率 v（mm/a）	历史地震震级（M）
Ⅰ	强烈全新活动断裂	中晚更新世以来有活动，全新世活动强烈	$v>1$	$M\geqslant7$
Ⅱ	中等全新活动断裂	中晚更新世以来有活动，全新世活动较强烈	$1\geqslant v\geqslant0.1$	$7>M\geqslant6$
Ⅲ	微弱全新活动断裂	全新世有微弱活动	$v<0.1$	$M<6$

5.8.4 断裂勘察，应搜集和分析有关文献档案资料，包括卫星航空相片，区域构造地质，强震震中分布，地应力和地形变，历史和近期地震等。

5.8.5 断裂勘察工程地质测绘，除应符合本规范第8章的要求外，尚应包括下列内容的调查：

1 地形地貌特征：山区或高原不断上升剥蚀或有长距离的平滑分界线；非岩性影响的陡坡、峭壁，深切的直线形河谷，一系列滑坡、崩塌和山前叠置的洪积扇；定向断续线形分布的残丘、洼地、沼泽、芦苇地、盐碱地、湖泊、跌水、泉、温泉等；水系定向展布或同向扭曲错动等。

2 地质特征：近期断裂活动留下的第四系错动，地下水和植被的特征；断层带的破碎和胶结特征等；深色物质宜采用放射性碳14（C^{14}）法，非深色物质宜采用热释光法或铀系法，测定已错断层位和未错断层位的地质年龄，并确定断裂活动的最新时限。

3 地震特征：与地震有关的断层、地裂缝、崩塌、滑坡、地震湖、河流改道和砂土液化等。

5.8.6 大型工业建设场地，在可行性研究勘察时，应建议避让全新活动断裂和发震断裂。避让距离应根据断裂的等级、规模、性质、覆盖层厚度、地震烈度等因素，按有关标准综合确定。非全新活动断裂可不采取避让措施，但当浅埋且破碎带发育时，可按不均匀地基处理。

6 特殊性岩土

6.1 湿陷性土

6.1.1 本节适用于干旱和半干旱地区除黄土以外的湿陷性碎石土、湿陷性砂土和其他湿陷性土的岩土工程勘察。对湿陷性黄土的勘察应按现行国家标准《湿陷性黄土地区建筑规范》(GB 50025)执行。

6.1.2 当不能取试样做室内湿陷性试验时，应采用现场载荷试验确定湿陷性。在200kPa压力下浸水载荷试验的附加湿陷量与承压板宽度之比等于或大于0.023的土，应判定为湿陷性土。

6.1.3 湿陷性土场地勘察，除应遵守本规范第4章的规定外，尚应符合下列要求：

1 勘探点的间距应按本规范第4章的规定取小值。对湿陷性土分布极不均匀的场地应加密勘探点；

2 控制性勘探孔深度应穿透湿陷性土层；

3 应查明湿陷性土的年代、成因、分布和其中的夹层、包含物、胶结物的成分和性质；

4 湿陷性碎石土和砂土，宜采用动力触探试验和标准贯入试验确定力学特性；

5 不扰动土试样应在探井中采取；

6 不扰动土试样除测定一般物理力学性质外，尚应作土的湿陷性和湿化试验；

7 对不能取得不扰动土试样的湿陷性土，应在探井中采用大体积法测定密度和含水量；

8 对于厚度超过2m的湿陷性土，应在不同深度处分别进行浸水载荷试验，并应不受相邻试验的浸水影响。

6.1.4 湿陷性土的岩土工程评价应符合下列规定：

1 湿陷性土的湿陷程度划分应符合表6.1.4的规定；

2 湿陷性土的地基承载力宜采用载荷试验或其他原位测试确定；

3 对湿陷性土边坡，当浸水因素引起湿陷性土本身或其与下伏地层接触面的强度降低时，应进行稳定性评价。

6.1.5 湿陷性土地基受水浸湿至下沉稳定为止的总湿陷量Δ_s(cm)，应按下式计算：

$$\Delta_s=\sum_{i=1}^{n}\beta\Delta F_{si}h_i \tag{6.1.5}$$

式中 ΔF_{si}——第i层土浸水载荷试验的附加湿陷量(cm)；

h_i——第i层土的厚度(cm)，从基础底面(初步勘察时自地面下1.5m)算起，$\Delta F_{si}/b<0.023$的不计入；

β——修正系数(cm^{-1})。承压板面积为0.50m^2时，$\beta=0.014$；承压板面积为0.25m^2时，$\beta=0.020$。

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表 6.1.4　湿陷程度分类

湿陷湿度 \ 试验条件	附加湿陷量 ΔF_s（cm）	
	承压板面积 0.50m²	承压板面积 0.25m²
轻　微	$1.6<\Delta F_s\leqslant 3.2$	$1.1<\Delta F_s\leqslant 2.3$
中　等	$3.2<\Delta F_s\leqslant 7.4$	$2.3<\Delta F_s\leqslant 5.3$
强　烈	$\Delta F_s>7.4$	$\Delta F_s>5.3$

注：对能用取土器取得不扰动试样的湿陷性粉砂，其试验方法和评定标准按现行国家标准《湿陷性黄土地区建筑规范》(GB 50025)执行。

6.1.6　湿陷性土地基的湿陷等级应按表 6.1.6 判定。

6.1.7　湿陷性土地基的处理应根据土质特征、湿陷等级和当地建筑经验等因素综合确定。

表 6.1.6　湿陷性土地基的湿陷等级

总湿陷量 Δ_s(cm)	湿陷性土总厚度(m)	湿陷等级
$5<\Delta_s\leqslant 30$	>3	Ⅰ
	≤3	Ⅱ
$30<\Delta_s\leqslant 60$	>3	
	≤3	Ⅲ
$\Delta_s>60$	>3	
	≤3	Ⅳ

6.2　红　粘　土

6.2.1　本节适用于红粘土(含原生与次生红粘土)的岩土工程勘察。颜色为棕红或褐黄，覆盖于碳酸盐岩系之上，其液限大于或等于 50% 的高塑性粘土，应判定为原生红粘土。原生红粘土经搬运、沉积后仍保留其基本特征，且其液限大于 45% 的粘土，可判定为次生红粘土。

6.2.2　红粘土地区的岩土工程勘察，应着重查明其状态分布、裂隙发育特征及地基的均匀性。

1　红粘土的状态除按液性指数判定外，尚可按表 6.2.2-1 判定；

表 6.2.2-1　红粘土的状态分类

状　态	含水比 α_w
坚　硬	$\alpha_w\leqslant 0.55$
硬　塑	$0.55<\alpha_w\leqslant 0.70$
可　塑	$0.70<\alpha_w\leqslant 0.85$
软　塑	$0.85<\alpha_w\leqslant 1.00$
流　塑	$\alpha_w>1.00$

注：$\alpha_w=w/w_L$。

2　红粘土的结构可根据其裂隙发育特征按表 6.2.2-2 分类；

3　红粘土的复浸水特性可按表 6.2.2-3 分类；

4　红粘土的地基均匀性可按表 6.2.2-4 分类。

表 6.2.2-2　红粘土的结构分类

土体结构	裂隙发育特征
致密状的	偶见裂隙（<1 条/m）
巨块状的	较多裂隙（1～2 条/m）
碎块状的	富裂隙（>5 条/m）

表 6.2.2-3　红粘土的复浸水性分类

地基均匀性	I_r 与 I'_r 关系	复浸水特性
Ⅰ	$I_r \geqslant I'_r$	收缩后复浸水膨胀，能恢复到原位
Ⅱ	$I_r < I'_r$	收缩后复浸水膨胀，不能恢复到原位

注：$I_r = w_L / w_p$，$I'_r = 1.4 + 0.0066 w_L$。

表 6.2.2-4　红粘土的地基均匀性分类

地基均匀性	地基压缩层范围内岩土组成
均匀地基	全部由红粘土组成
不均匀地基	由红粘土和岩石组成

6.2.3　红粘土地区的工程地质测绘和调查应按本规范第 8 章的规定进行，并着重查明下列内容：

1　不同地貌单元红粘土的分布、厚度、物质组成、土性等特征及其差异；

2　下伏基岩岩性、岩溶发育特征及其与红粘土土性、厚度变化的关系；

3　地裂分布、发育特征及其成因，土体结构特征，土体中裂隙的密度、深度、延展方向及其发育规律；

4　地表水体和地下水的分布、动态及其与红粘土状态垂向分带的关系；

5　现有建筑物开裂原因分析，当地勘察、设计、施工经验等。

6.2.4　红粘土地区勘探点的布置，应取较密的间距，查明红粘土厚度和状态的变化。初步勘察勘探点间距宜取 30～50m；详细勘察勘探点间距，对均匀地基宜取 12～24m，对不均匀地基宜取 6～12m。厚度和状态变化大的地段，勘探点间距还可加密。各阶段勘探孔的深度可按本规范第 4.1 节的有关规定执行。对不均匀地基，勘探孔深度应达到基岩。

对不均匀地基、有土洞发育或采用岩面端承桩时，宜进行施工勘察，其勘探点间距和勘探孔深度根据需要确定。

6.2.5　当岩土工程评价需要详细了解地下水埋藏条件、运动规律和季节变化时，应在测绘调查的基础上补充进行地下水的勘察、试验和观测工作。有关要求按本规范第 7 章的规定执行。

6.2.6　红粘土的室内试验除应满足本规范第 11 章的规定外，对裂隙发育的红粘土应进行三轴剪切试验或无侧限抗压强度试验。必要时，可进行收缩试验和复浸水试验。当需评价边坡稳定性时，宜进行重复剪切试验。

6.2.7　红粘土的地基承载力应按本规范第 4.1.24 条的规定确定。当基础浅埋、外侧地面倾斜、有临空面或承受较大水平荷载时，应结合以下因素综合考虑确定红粘土的承

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载力：

1　土体结构和裂隙对承载力的影响；

2　开挖面长时间暴露，裂隙发展和复浸水对土质的影响。

6.2.8　红粘土的岩土工程评价应符合下列要求：

1　建筑物应避免跨越地裂密集带或深长地裂地段；

2　轻型建筑物的基础埋深应大于大气影响急剧层的深度；炉窑等高温设备的基础应考虑地基土的不均匀收缩变形；开挖明渠时应考虑土体干湿循环的影响；在石芽出露的地段，应考虑地表水下渗形成的地面变形；

3　选择适宜的持力层和基础形式，在满足本条第2款要求的前提下，基础宜浅埋，利用浅部硬壳层，并进行下卧层承载力的验算；不能满足承载力和变形要求时，应建议进行地基处理或采用桩基础；

4　基坑开挖时宜采取保湿措施，边坡应及时维护，防止失水干缩。

6.3　软　　土

6.3.1　天然孔隙比大于或等于1.0，且天然含水量大于液限的细粒土应判定为软土，包括淤泥、淤泥质土、泥炭、泥炭质土等。

6.3.2　软土勘察除应符合常规要求外，尚应查明下列内容：

1　成因类型、成层条件、分布规律、层理特征、水平向和垂直向的均匀性；

2　地表硬壳层的分布与厚度、下伏硬土层或基岩的埋深和起伏；

3　固结历史、应力水平和结构破坏对强度和变形的影响；

4　微地貌形态和暗埋的塘、浜、沟、坑、穴的分布、埋深及其填土的情况；

5　开挖、回填、支护、工程降水、打桩、沉井等对软土应力状态、强度和压缩性的影响；

6　当地的工程经验。

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6.3.3　软土地区勘察宜采用钻探取样与静力触探结合的手段。勘探点布置应根据土的成因类型和地基复杂程度确定。当土层变化较大或有暗埋的塘、浜、沟、坑、穴时应予加密。

6.3.4　软土取样应采用薄壁取土器，其规格应符合本规范第9章的要求。

6.3.5　软土原位测试宜采用静力触探试验、旁压试验、十字板剪切试验、扁铲侧胀试验和螺旋板载荷试验。

6.3.6　软土的力学参数宜采用室内试验、原位测试，结合当地经验确定。有条件时，可根据堆载试验、原型监测反分析确定。抗剪强度指标室内宜采用三轴试验，原位测试宜采用十字板剪切试验。

压缩系数、先期固结压力、压缩指数、回弹指数、固结系数，可分别采用常规固结试验、高压固结试验等方法确定。

6.3.7　软土的岩土工程评价应包括下列内容：

1　判定地基产生失稳和不均匀变形的可能性；当工程位于池塘、河岸、边坡附近时，

应验算其稳定性；

2 软土地基承载力应根据室内试验、原位测试和当地经验，并结合下列因素综合确定：

1）软土成层条件、应力历史、结构性、灵敏度等力学特性和排水条件；

2）上部结构的类型、刚度、荷载性质和分布，对不均匀沉降的敏感性；

3）基础的类型、尺寸、埋深和刚度等；

4）施工方法和程序。

3 当建筑物相邻高低层荷载相差较大时，应分析其变形差异和相互影响；当地面有大面积堆载时，应分析对相邻建筑物的不利影响；

4 地基沉降计算可采用分层总和法或土的应力历史法，并应根据当地经验进行修正，必要时，应考虑软土的次固结效应；

5 提出基础形式和持力层的建议；对于上为硬层，下为软土的双层土地基应进行下卧层验算。

6.4 混 合 土

6.4.1 由细粒土和粗粒土混杂且缺乏中间粒径的土应定名为混合土。

当碎石土中粒径小于 0.075mm 的细粒土质量超过总质量的 25%时，应定名为粗粒混合土；当粉土或粘性土中粒径大于 2mm 的粗粒土质量超过总质量的 25%对，应定名为细粒混合土。

6.4.2 混合土的勘察应符合下列要求：

1 查明地形和地貌特征，混合土的成因、分布，下卧土层或基岩的埋藏条件；

2 查明混合土的组成、均匀性及其在水平方向和垂直方向上的变化规律；

3 勘探点的间距和勘探孔的深度除应满足本规范第 4 章的要求外，尚应适当加密加深；

4 应有一定数量的探井，并应采取大体积土试样进行颗粒分析和物理力学性质测定；

5 对粗粒混合土宜采用动力触探试验，并应有一定数量的钻孔或探井检验；

6 现场载荷试验的承压板直径和现场直剪试验的剪切面直径都应大于试验土层最大粒径的 5 倍，载荷试验的承压板面积不应小于 $0.5m^2$，直剪试验的剪切面面积不宜小于 $0.25m^2$。

6.4.3 混合土的岩土工程评价应包括下列内容：

1 混合土的承载力应采用载荷试验、动力触探试验并结合当地经验确定；

2 混合土边坡的容许坡度值可根据现场调查和当地经验确定。对重要工程应进行专门试验研究。

6.5 填 土

6.5.1 填土根据物质组成和堆填方式，可分为下列四类：

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1　素填土：由碎石土、砂土、粉土和粘性土等一种或几种材料组成，不含杂物或含杂物很少；

2　杂填土：含有大量建筑垃圾、工业废料或生活垃圾等杂物；

3　冲填土：由水力冲填泥砂形成；

4　压实填土：按一定标准控制材料成分、密度、含水量，分层压实或夯实而成。

6.5.2　填土勘察应包括下列内容：

1　搜集资料，调查地形和地物的变迁，填土的来源、堆积年限和堆积方式；

2　查明填土的分布、厚度、物质成分、颗粒级配、均匀性、密实性、压缩性和湿陷性；

3　判定地下水对建筑材料的腐蚀性。

6.5.3　填土勘察应在本规范第4章规定的基础上加密勘探点，确定暗埋的塘、浜、坑的范围。勘探孔的深度应穿透填土层。

勘探方法应根据填土性质确定。对由粉土或粘性土组成的素填土，可采用钻探取样、轻型钻具与原位测试相结合的方法；对含较多粗粒成分的素填土和杂填土宜采用动力触探、钻探，并应有一定数量的探井。

6.5.4　填土的工程特性指标宜采用下列测试方法确定：

1　填土的均匀性和密实度宜采用触探法，并辅以室内试验；

2　填土的压缩性、湿陷性宜采用室内固结试验或现场载荷试验；

3　杂填土的密度试验宜采用大容积法；

4　对压实填土，在压实前应测定填料的最优含水量和最大干密度，压实后应测定其干密度，计算压实系数。

6.5.5　填土的岩土工程评价应符合下列要求：

1　阐明填土的成分、分布和堆积年代，判定地基的均匀性、压缩性和密实度；必要时应按厚度、强度和变形特性分层或分区评价；

2　对堆积年限较长的素填土、冲填土和由建筑垃圾或性能稳定的工业废料组成的杂填土，当较均匀和较密实时可作为天然地基；由有机质含量较高的生活垃圾和对基础有腐蚀性的工业废料组成的杂填土，不宜作为天然地基；

3　填土地基承载力应按本规范第4.1.24条的规定综合确定；

4　当填土底面的天然坡度大于20%时，应验算其稳定性。

6.5.6　填土地基基坑开挖后应进行施工验槽。处理后的填土地基应进行质量检验。对复合地基，宜进行大面积载荷试验。

6.6　多年冻土

6.6.1　含有固态水，且冻结状态持续二年或二年以上的土，应判定为多年冻土。

6.6.2　根据融化下沉系数 δ_0 的大小，多年冻土可分为不融沉、弱融沉、融沉、强融沉和融陷五级，并应符合表6.6.2的规定。冻土的平均融化下沉系数 δ_0 可按下式计算：

$$\delta_0 = \frac{h_1 - h_2}{h_1} = \frac{e_1 - e_2}{1 + e_1} \times 100(\%) \tag{6.6.2}$$

式中　h_1、e_1——冻土试样融化前的高度(mm)和孔隙比；

h_2、e_2——冻土试样融化后的高度(mm)和孔隙比。

表 6.6.2　多年冻土的融沉性分类

土的名称	总含水量 w_0(%)	平均融沉系数 δ_0	融沉等级	融沉类别	冻土类型
碎石土，砾、粗、中砂(粒径小于0.075mm的颗粒含量不大于15%)	$w_0<10$	$\delta_0\leqslant 1$	Ⅰ	不融沉	少冰冻土
	$w_0\geqslant 10$	$1<\delta_0\leqslant 3$	Ⅱ	弱融沉	多冰冻土
碎石土，砾、粗、中砂(粒径小于0.075mm的颗粒含量大于15%)	$w_0<12$	$\delta_0\leqslant 1$	Ⅰ	不融沉	少冰冻土
	$12\leqslant w_0<15$	$1<\delta_0\leqslant 3$	Ⅱ	弱融沉	多冰冻土
	$15\leqslant w_0<25$	$3<\delta_0\leqslant 10$	Ⅲ	融沉	富冰冻土
	$w_0\geqslant 25$	$10<\delta_0\leqslant 25$	Ⅳ	强融沉	饱冰冻土
粉砂、细砂	$w_0<14$	$\delta_0\leqslant 1$	Ⅰ	不融沉	少冰冻土
	$14\leqslant w_0<18$	$1<\delta_0\leqslant 3$	Ⅱ	弱融沉	多冰冻土
	$18\leqslant w_0<28$	$3<\delta_0\leqslant 10$	Ⅲ	融沉	富冰冻土
	$w_0\geqslant 28$	$10<\delta_0\leqslant 25$	Ⅳ	强融沉	饱冰冻土
粉土	$w_0<17$	$\delta_0\leqslant 1$	Ⅰ	不融沉	少冰冻土
	$17\leqslant w_0<21$	$1<\delta_0\leqslant 3$	Ⅱ	弱融沉	多冰冻土
	$21\leqslant w_0<32$	$3<\delta_0\leqslant 10$	Ⅲ	融沉	富冰冻土
	$w_0\geqslant 32$	$10<\delta_0\leqslant 25$	Ⅳ	强融沉	饱冰冻土
粘性土	$w_0<w_p$	$\delta_0\leqslant 1$	Ⅰ	不融沉	少冰冻土
	$w_p\leqslant w_0<w_p+4$	$1<\delta_0\leqslant 3$	Ⅱ	弱融沉	多冰冻土
	$w_p+4\leqslant w_0<w_p+15$	$3<\delta_0\leqslant 10$	Ⅲ	融沉	富冰冻土
	$w_p+15\leqslant w_0<w_p+35$	$10<\delta_0\leqslant 25$	Ⅳ	强融沉	饱冰冻土
含土冰层	$w_0>w_p+35$	$\delta_0>25$	Ⅴ	融陷	含土冰层

注：1　总含水量 w_0 包未冰和未冻水；

2　本表不包括盐渍化冻土、冻结泥炭化土、腐殖土、高塑性粘土。

6.6.3　多年冻土勘察应根据多年冻土的设计原则、多年冻土的类型和特征进行，并应查明下列内容：

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1　多年冻土的分布范围及上限深度；

2　多年冻土的类型、厚度、总含水量、构造特征、物理力学和热学性质；

3　多年冻土层上水、层间水和层下水的赋存形式、相互关系及其对工程的影响；

4　多年冻土的融沉性分级和季节融化层土的冻胀性分级；

5　厚层地下冰、冰椎、冰丘、冻土沼泽、热融滑塌、热融湖塘、融冻泥流等不良地质作用的形态特征、形成条件、分布范围、发生发展规律及其对工程的危害程度。

6.6.4　多年冻土地区勘探点的间距，除应满足本规范第4章的要求外，尚应适当加密。勘探孔的深度应满足下列要求：

1　对保持冻结状态设计的地基，不应小于基底以下2倍基础宽度，对桩基应超过桩端以下3～5m；

2　对逐渐融化状态和预先融化状态设计的地基，应符合非冻土地基的要求；

3　无论何种设计原则，勘探孔的深度均宜超过多年冻土上限深度的1.5倍；

4　在多年冻土的不稳定地带，应查明多年冻土下限深度；当地基为饱冰冻土或含土冰层时，应穿透该层。

6.6.5　多年冻土的勘探测试应满足下列要求：

1　多年冻土地区钻探宜缩短施工时间，宜采用大口径低速钻进，终孔直径不宜小于108mm，必要时可采用低温泥浆，并避免在钻孔周围造成人工融区或孔内冻结；

2　应分层测定地下水位；

3　保持冻结状态设计地段的钻孔，孔内测温工作结束后应及时回填；

4　取样的竖向间隔，除应满足本规范第4章的要求外，在季节融化层应适当加密，试样在采取、搬运、贮存、试验过程中应避免融化；

5　试验项目除按常规要求外，尚应根据需要，进行总含水量、体积含冰量、相对含冰量、未冻水含量、冻结温度、导热系数、冻胀量、融化压缩等项目的试验；对盐渍化多年冻土和泥炭化多年冻土，尚应分别测定易溶盐含量和有机质含量；

6　工程需要时，可建立地温观测点，进行地温观测；

7　当需查明与冻土融化有关的不良地质作用时，调查工作宜在二月至五月份进行；多年冻土上限深度的勘察时间宜在九、十月份。

6.6.6　多年冻土的岩土工程评价应符合下列要求：

1　多年冻土的地基承载力，应区别保持冻结地基和容许融化地基，结合当地经验用载荷试验或其他原位测试方法综合确定，对次要建筑物可根据邻近工程经验确定；

2　除次要工程外，建筑物宜避开饱冰冻土、含土冰层地段和冰椎、冰丘、热融湖、厚层地下冰，融区与多年冻土区之间的过渡带，宜选择坚硬岩层、少冰冻土和多冰冻土地段以及地下水位或冻土层上水位低的地段和地形平缓的高地。

6.7　膨胀岩土

6.7.1　含有大量亲水矿物，湿度变化时有较大体积变化，变形受约束时产生较大内应力的岩土，应判定为膨胀岩土。膨胀土的初判应符合本规范附录D的规定；终判应在初判

的基础上按本节第 6.7.7 条进行。

6.7.2 膨胀岩土场地，按地形地貌条件可分为平坦场地和坡地场地。符合下列条件之一者应划为平坦场地：

1 地形坡度小于 5°，且同一建筑物范围内局部高差不超过 1m；

2 地形坡度大于 5°小于 14°，与坡肩水平距离大于 10m 的坡顶地带。

不符合以上条件的应划为坡地场地。

6.7.3 膨胀岩土地区的工程地质测绘和调查应包括下列内容：

1 查明膨胀岩土的岩性、地质年代、成因、产状、分布以及颜色、节理、裂缝等外观特征；

2 划分地貌单元和场地类型，查明有无浅层滑坡、地裂、冲沟以及微地貌形态和植被情况；

3 调查地表水的排泄和积聚情况以及地下水类型、水位和变化规律；

4 搜集当地降水量、蒸发力、气温、地温、干湿季节、干旱持续时间等气象资料，查明大气影响深度；

5 调查当地建筑经验。

6.7.4 膨胀岩土的勘察应遵守下列规定：

1 勘探点宜结合地貌单元和微地貌形态布置；其数量应比非膨胀岩土地区适当增加，其中采取试样的勘探点不应少于全部勘探点的 1/2；

2 勘探孔的深度，除应满足基础埋深和附加应力的影响深度外，尚应超过大气影响深度；控制性勘探孔不应小于 8m，一般性勘探孔不应小于 5m；

3 在大气影响深度内，每个控制性勘探孔均应采取Ⅰ、Ⅱ级土试样，取样间距不应大于 1.0m，在大气影响深度以下，取样间距可为 1.5～2.0m；一般性勘探孔从地表下 1m 开始至 5m 深度内，可取Ⅲ级土试样，测定天然含水量。

6.7.5 膨胀岩土的室内试验，除应遵守本规范第 11 章的规定外，尚应测定下列指标：

1 自由膨胀率；

2 一定压力下的膨胀率；

3 收缩系数；

4 膨胀力。

6.7.6 重要的和有特殊要求的工程场地，宜进行现场浸水载荷试验、剪切试验或旁压试验。对膨胀岩应进行粘土矿物成分、体膨胀量和无侧限抗压强度试验。对各向异性的膨胀岩土，应测定其不同方向的膨胀率、膨胀力和收缩系数。

6.7.7 对初判为膨胀土的地区，应计算土的膨胀变形量、收缩变形量和胀缩变形量，并划分胀缩等级。计算和划分方法应符合现行国家标准《膨胀土地区建筑技术规范》(GBJ 112)的规定。有地区经验时，亦可根据地区经验分级。

当拟建场地或其邻近有膨胀岩土损坏的工程时，应判定为膨胀岩土，并进行详细调查，分析膨胀岩土对工程的破坏机制，估计膨胀力的大小和胀缩等级。

6.7.8 膨胀岩土的岩土工程评价应符合下列规定：

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1 对建在膨胀岩土上的建筑物，其基础埋深、地基处理、桩基设计、总平面布置、建筑和结构措施、施工和维护，应符合现行国家标准《膨胀土地区建筑技术规范》(GBJ 112)的规定；

2 一级工程的地基承载力应采用浸水载荷试验方法确定；二级工程宜采用浸水载荷试验；三级工程可采用饱和状态下不固结不排水三轴剪切试验计算或根据已有经验确定；

3 对边坡及位于边坡上的工程，应进行稳定性验算；验算时应考虑坡体内含水量变化的影响；均质土可采用圆弧滑动法，有软弱夹层及层状膨胀岩土应按最不利的滑动面验算；具有胀缩裂缝和地裂缝的膨胀土边坡，应进行沿裂缝滑动的验算。

6.8 盐渍岩土

6.8.1 岩土中易溶盐含量大于0.3%，并具有溶陷、盐胀、腐蚀等工程特性时，应判定为盐渍岩土。

6.8.2 盐渍岩按主要含盐矿物成分可分为石膏盐渍岩、芒硝盐渍岩等。盐渍土根据其含盐化学成分和含盐量可按表6.8.2-1和6.8.2-2分类。

表6.8.2-1 盐渍土按含盐化学成分分类

盐渍土名称	$\frac{c(Cl^-)}{2c(SO_4^{2-})}$	$\frac{2c(CO_3^{2-})+c(HCO_3^-)}{c(Cl^-)+2c(SO_4^{2-})}$
氯盐渍土	>2	—
亚氯盐渍土	2～1	—
亚硫酸盐渍土	1～0.3	—
硫酸盐渍土	<0.3	—
碱性盐渍土	—	>0.3

注：表中$c(Cl^-)$为氯离子在100g土中所含毫摩数，其他离子同。

表6.8.2-2 盐渍土按含盐量分类

盐渍土名称	平均含盐量(%)		
	氯及亚氯盐	硫酸及亚硫酸盐	碱性盐
弱盐渍土	0.3～1.0	—	—
中盐渍土	1～5	0.3～2.0	0.3～1.0
强盐渍土	5～8	2～5	1～2
超盐渍土	>8	>5	>2

6.8.3 盐渍岩土地区的调查工作，应包括下列内容：

1 盐渍岩土的成因、分布和特点；

2 含盐化学成分、含盐量及其在岩土中的分布；

3 溶蚀洞穴发育程度和分布；

4 搜集气象和水文资料；

5 地下水的类型、埋藏条件、水质、水位及其季节变化；

6 植物生长状况；

7　含石膏为主的盐渍岩石膏的水化深度，含芒硝较多的盐渍岩，在隧道通过地段的地温情况；

8　调查当地工程经验。

6.8.4　盐渍岩土的勘探测试应符合下列规定：

1　除应遵守本规范第4章规定外，勘探点布置尚应满足查明盐渍岩土分布特征的要求；

2　采取岩土试样宜在干旱季节进行，对用于测定含盐离子的扰动土取样，宜符合表6.8.4的规定；

表6.8.4　盐渍土扰动土试样取样要求

勘察阶段	深度范围（m）	取土试样间距（m）	取样孔占勘探孔总数的百分数（%）
初步勘察	<5	1.0	100
	5～10	2.0	50
	>10	3.0～5.0	20
详细勘察	<5	0.5	100
	5～10	1.0	50
	>10	2.0～3.0	30

注：浅基取样深度到10m即可。

3　工程需要时，应测定有害毛细水上升的高度；

4　应根据盐渍土的岩性特征，选用载荷试验等适宜的原位测试方法，对于溶陷性盐渍土尚应进行浸水载荷试验确定其溶陷性；

5　对盐胀性盐渍土宜现场测定有效盐胀厚度和总盐胀量，当土中硫酸钠含量不超过1%时，可不考虑盐胀性；

6　除进行常规室内试验外，尚应进行溶陷性试验和化学成分分析，必要时可对岩土的结构进行显微结构鉴定；

7　溶陷性指标的测定可按湿陷性土的湿陷试验方法进行。

6.8.5　盐渍岩土的岩土工程评价应包括下列内容：

1　岩土中含盐类型、含盐量及主要含盐矿物对岩土工程特性的影响；

2　岩土的溶陷性、盐胀性、腐蚀性和场地工程建设的适宜性；

3　盐渍土地基的承载力宜采用载荷试验确定，当采用其他原位测试方法时，应与载荷试验结果进行对比；

4　确定盐渍岩地基的承载力时，应考虑盐渍岩的水溶性影响；

5　盐渍岩边坡的坡度宜比非盐渍岩的软质岩石边坡适当放缓，对软弱夹层、破碎带应部分或全部加以防护；

6　盐渍岩土对建筑材料的腐蚀性评价应按本规范第12章执行。

6.9　风化岩和残积土

6.9.1　岩石在风化营力作用下，其结构、成分和性质已产生不同程度的变异，应定名为风化岩。已完全风化成土而未经搬运的应定名为残积土。

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6.9.2 风化岩和残积土的勘察应着重查明下列内容：

1 母岩地质年代和岩石名称；

2 按本规范附录 A 表 A.0.3 划分岩石的风化程度；

3 岩脉和风化花岗岩中球状风化体(孤石)的分布；

4 岩土的均匀性、破碎带和软弱夹层的分布；

5 地下水赋存条件。

6.9.3 风化岩和残积土的勘探测试应符合下列要求：

1 勘探点间距应取本规范第 4 章规定的小值；

2 应有一定数量的探井；

3 宜在探井中或用双重管、三重管采取试样，每一风化带不应少于 3 组；

4 宜采用原位测试与室内试验相结合，原位测试可采用圆锥动力触探、标准贯入试验、波速测试和载荷试验；

5 室内试验除应按本规范第 11 章的规定执行外，对相当于极软岩和极破碎的岩体，可按土工试验要求进行，对残积土，必要时应进行湿陷性和湿化试验。

6.9.4 对花岗岩残积土，应测定其中细粒土的天然含水量 w、塑限 w_P、液限 w_L。

6.9.5 花岗岩类残积土的地基承载力和变形模量应采用载荷试验确定。有成熟地方经验时，对于地基基础设计等级为乙级、丙级的工程，可根据标准贯入试验等原位测试资料，结合当地经验综合确定。

6.9.6 风化岩和残积土的岩土工程评价应符合下列要求：

1 对于厚层的强风化和全风化岩石，宜结合当地经验进一步划分为碎块状、碎屑状和土状；厚层残积土可进一步划分为硬塑残积土和可塑残积土，也可根据含砾或含砂量划分为粘性土、砂质粘性土和砾质粘性土；

2 建在软硬互层或风化程度不同地基上的工程，应分析不均匀沉降对工程的影响；

3 基坑开挖后应及时检验，对于易风化的岩类，应及时砌筑基础或采取其他措施，防止风化发展；

4 对岩脉和球状风化体(孤石)，应分析评价其对地基(包括桩基)的影响，并提出相应的建议。

6.10 污 染 土

6.10.1 由于致污物质的侵入，使土的成分、结构和性质发生了显著变异的土，应判定为污染土。污染土的定名可在原分类名称前冠以“污染”二字。

6.10.2 本节适用于工业污染土、尾矿污染土和垃圾填埋场渗滤液污染土的勘察，不适用于核污染土的勘察。污染土对环境影响的的评价可根据任务要求进行。

6.10.3 污染土场地和地基可分为下列类型，不同类型场地和地基勘察应突出重点：

1 已受污染的已建场地和地基；

2 已受污染的拟建场地和地基；

3 可能受污染的已建场地和地基；

4 可能受污染的拟建场地和地基。

6.10.4 污染土场地和地基的勘察，应根据工程特点和设计要求选择适宜的勘察手段，并应符合下列要求：

1 以现场调查为主，对工业污染应着重调查污染源、污染史、污染途径、污染物成分，污染场地已有建筑物受影响程度、周边环境等。对尾矿污染应重点调查不同的矿物种类和化学成分，了解选矿所采用工艺、添加剂及其化学性质和成分等。对垃圾填埋场应着重调查垃圾成分、日处理量、堆积容量、使用年限、防渗结构、变形要求及周边环境等；

2 采用钻探或坑探采取土试样，现场观察污染土颜色、状态、气味和外观结构等，并与正常土比较，查明污染土分布范围和深度；

3 直接接触试验样品的取样设备应严格保持清洁，每次取样后均应用清洁水冲洗后再进行下一个样品的采取；对易分解或易挥发等不稳定组分的样品，装样时应尽量减少土样与空气的接触时间，防止挥发性物质流失并防止发生氧化；土样采集后宜采取适宜的保存方法并在规定时间内运送实验室；

4 对需要确定地基土工程性能的污染土，宜采用以原位测试为主的多种手段；当需要确定污染土地基承载力时，宜进行载荷试验。

6.10.5 对污染土的勘探测试，当污染物对人体健康有害或对机具仪器有腐蚀性时，应采取必要的防护措施。

6.10.6 拟建场地污染土勘察宜分为初步勘察和详细勘察两个阶段。条件简单时，可直接进行详细勘察。

初步勘察应以现场调查为主，配合少量勘探测试，查明污染源性质、污染途径，并初步查明污染土分布和污染程度；详细勘察应在初步勘察的基础上，结合工程特点、可能采用的处理措施，有针对性地布置勘察工作量，查明污染土的分布范围、污染程度、物理力学和化学指标，为污染土处理提供参数。

6.10.7 勘探测试工作量的布置应结合污染源和污染途径的分布进行，近污染源处勘探点间距宜密，远污染源处勘探点间距宜疏。为查明污染土分布的勘探孔深度应穿透污染土。详细勘察时，采取污染土试样的间距应根据其厚度及可能采取的处理措施等综合确定。确定污染土与非污染土界限时，取土间距不宜大于1m。

6.10.8 有地下水的勘探孔应采取不同深度地下水试样，查明污染物在地下水中的空间分布。同一钻孔内采取不同深度的地下水试样时，应采用严格的隔离措施，防止因采取混合水样面而影响判别结论。

6.10.9 污染土和水的室内试验，应根据污染情况和任务求进行下列试验：

1 污染土和水的化学成分；

2 污染土的物理力学性质；

3 对建筑材料腐蚀性的评价指标；

4 对环境影响的评价指标；

5 力学试验项目和试验方法应充分考虑污染土的特殊性质，进行相应的试验，如

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膨胀、湿化、湿陷性试验等；

6 必要时进行专门的试验研究。

6.10.10 污染土评价应根据任务要求进行，对场地和建筑物地基的评价应符合下列要求：

1 污染源的位置、成分、性质、污染史及对周边的影响；

2 污染土分布的平面范围和深度、地下水受污染的空间范围；

3 污染土的物理力学性质，评价污染对土的工程特性指标的影响程度；

4 工程需要时，提供地基承载力和变形参数，预测地基变形特征；

5 污染土和水对建筑材料的腐蚀性；

6 污染土和水对环境的影响；

7 分析污染发展趋势；

8 对已建项目的危害性或拟建项目适宜性的综合评价。

6.10.11 污染土和水对建筑材料的腐蚀性评价和腐蚀性等级的划分，应符合本规范第12章的有关规定。

6.10.12 污染对土的工程特性的影响程度可按表6.10.12划分。根据工程具体情况，可采用强度、变形、渗透等工程特性指标进行综合评价。

表6.10.12 污染对土的工程特性的影响程度

影响程度	轻微	中等	大
工程特性指标变化率(%)	<10	10～30	>30

注：工程特性指标变化率是指污染前后工程特性指标的差值与污染前指标之比。

6.10.13 污染土和水对环境影响的评价应结合工程具体要求进行，无明确要求时可按现行国家标准《土壤环境质量标准》GB15618、《地下水质量标准》GB/T14848和《地表水环境质量标准》GB3838进行评价。

6.10.14 污染土的处置与修复应根据污染程度、分布范围、土的性质、修复标准、处理工期和处理成本等综合考虑。

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7 地 下 水

7.1 地下水的勘察要求

7.1.1 岩土工程勘察应根据工程要求，通过搜集资料和勘察工作，掌握下列水文地质条件：

1 地下水的类型和赋存状态；

2 主要含水层的分布规律；

3 区域性气候资料，如年降水量、蒸发量及其变化和对地下水位的影响；

4 地下水的补给排泄条件、地表水与地下水的补排关系及其对地下水位的影响；

5 勘察时的地下水位、历史最高地下水位、近3～5年最高地下水位、水位变化趋势和主要影响因素；

6 是否存在对地下水和地表水的污染源及其可能的污染程度。

7.1.2 对缺乏常年地下水位监测资料的地区，在高层建筑或重大工程的初步勘察时，宜设置长期观测孔，对有关层位的地下水进行长期观测。

7.1.3 对高层建筑或重大工程，当水文地质条件对地基评价、基础抗浮和工程降水有重大影响时，宜进行专门的水文地质勘察。

7.1.4 专门的水文地质勘察应符合下列要求：

1 查明含水层和隔水层的埋藏条件，地下水类型、流向、水位及其变化幅度，当场地有多层对工程有影响的地下水时，应分层量测地下水位，并查明互相之间的补给关系；

2 查明场地地质条件对地下水赋存和渗流状态的影响；必要时应设置观测孔，或在不同深度处埋设孔隙水压力计，量测压力水头随深度的变化；

3 通过现场试验，测定地层渗透系数等水文地质参数。

7.1.5 水试样的采取和试验应符合下列规定：

1 水试样应能代表天然条件下的水质情况；

2 水试样的采取和试验项目应符合本规范第12章的规定；

3 水试样应及时试验，清洁水放置时间不宜超过72小时，稍受污染的水不宜超过48小时，受污染的水不宜超过12小时。

7.2 水文地质参数的测定

7.2.1 水文地质参数的测定方法应符合本规范附录E的规定。

7.2.2 地下水位的量测应符合下列规定：

1 遇地下水时应量测水位；

2 （此款取消）

3 对工程有影响的多层含水层的水位量测，应采取止水措施，将被测含水层与其

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他含水层隔开。

7.2.3 初见水位和稳定水位可在钻孔、探井或测压管内直接量测，稳定水位的间隔时间按地层的渗透性确定，对砂土和碎石土不得少于 0.5h，对粉土和粘性土不得少于 8h，并宜在勘察结束后统一量测稳定水位。量测读数至厘米，精度不得低于±2cm。

7.2.4 测定地下水流向可用几何法，量测点不应少于呈三角形分布的 3 个测孔(井)。测点间距按岩土的渗透性、水力梯度和地形坡度确定，宜为 50～100m。应同时量测各孔(井)内水位，确定地下水的流向。

地下水流速的测定可采用指示剂法或充电法。

7.2.5 抽水试验应符合下列规定：

1 抽水试验方法可按表 7.2.5 选用；

2 抽水试验宜三次降深，最大降深应接近工程设计所需的地下水位降深的标高；

3 水位量测应采用同一方法和仪器，读数对抽水孔为厘米，对观测孔为毫米；

4 当涌水量与时间关系曲线和动水位与时间的关系曲线，在一定范围内波动，而没有持续上升和下降时，可认为已经稳定；

5 抽水结束后应量测恢复水位。

表 7.2.5 抽水试验方法和应用范围

试验方法	应用范围
钻孔或探井简易抽水	粗略估算弱透水层的渗透系数
不带观测孔抽水	初步测定含水层的渗透性参数
带观测孔抽水	较准确测定含水层的各种参数

7.2.6 渗水试验和注水试验可在试坑或钻孔中进行。对砂土和粉土，可采用试坑单环法；对粘性土可采用试坑双环法；试验深度较大时可采用钻孔法。

7.2.7 压水试验应根据工程要求，结合工程地质测绘和钻探资料，确定试验孔位，按岩层的渗透特性划分试验段，按需要确定试验的起始压力、最大压力和压力级数，及时绘制压力与压入水量的关系曲线，计算试段的透水率，确定 p-Q 曲线的类型。

7.2.8 孔隙水压力的测定应符合下列规定：

1 测定方法可按本规范附录 E 表 E.0.2 确定；

2 测试点应根据地质条件和分析需要布置；

3 测压计的安装和埋设应符合有关安装技术规定；

4 测试数据应及时分析整理，出现异常时应分析原因，并采取相应措施。

7.3 地下水作用的评价

7.3.1 岩土工程勘察应评价地下水的作用和影响，并提出预防措施的建议。

7.3.2 地下水力学作用的评价应包括下列内容：

1 对基础、地下结构物和挡土墙，应考虑在最不利组合情况下，地下水对结构物的上浮作用；对节理不发育的岩石和粘土且有地方经验或实测数据时，可根据经验确定；

有渗流时，地下水的水头和作用宜通过渗流计算进行分析评价；

2 验算边坡稳定时，应考虑地下水对边坡稳定的不利影响；

3　在地下水位下降的影响范围内，应考虑地面沉降及其对工程的影响；当地下水位回升时，应考虑可能引起的回弹和附加的浮托力；

4　当墙背填土为粉砂、粉土或粘性土，验算支挡结构物的稳定时，应根据不同排水条件评价地下水压力对支挡结构物的作用；

5　因水头压差而产生自下向上的渗流时，应评价产生潜蚀、流土、管涌的可能性；

6　在地下水位下开挖基坑或地下工程时，应根据岩土的渗透性、地下水补给条件，分析评价降水或隔水措施的可行性及其对基坑稳定和邻近工程的影响。

7.3.3　地下水的物理、化学作用的评价应包括下列内容：

1　对地下水位以下的工程结构，应评价地下水对混凝土、金属材料的腐蚀性，评价方法按本规范第 12 章执行；

2　对软质岩石、强风化岩石、残积土、湿陷性土、膨胀岩土和盐渍岩土，应评价地下水的聚集和散失所产生的软化、崩解、湿陷、胀缩和潜蚀等有害作用；

3　在冻土地区，应评价地下水对土的冻胀和融陷的影响。

7.3.4　对地下水采取降低水位措施时，应符合下列规定：

1　施工中地下水位应保持在基坑底面以下 0.5～1.5m；

2　降水过程中应采取有效措施，防止土颗粒的流失；

3　防止深层承压水引起的突涌，必要时应采取措施降低基坑下的承压水头。

7.3.5　当需要进行工程降水时，应根据含水层渗透性和降深要求，选用适当的降低水位方法。当几种方法有互补性时，亦可组合使用。

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8 工程地质测绘和调查

8.0.1 岩石出露或地貌、地质条件较复杂的场地应进行工程地质测绘。对地质条件简单的场地，可用调查代替工程地质测绘。

8.0.2 工程地质测绘和调查宜在可行性研究或初步勘察阶段进行。在可行性研究阶段搜集资料时，宜包括航空相片、卫星相片的解译结果。在详细勘察阶段可对某些专门地质问题作补充调查。

8.0.3 工程地质测绘和调查的范围，应包括场地及其附近地段。测绘的比例尺和精度应符合下列要求：

1 测绘的比例尺，可行性研究勘察可选用 1∶5000～1∶50000；初步勘察可选用 1∶2000～1∶10000；详细勘察可选用 1∶500～1∶2000；条件复杂时，比例尺可适当放大；

2 对工程有重要影响的地质单元体（滑坡、断层、软弱夹层、洞穴等），可采用扩大比例尺表示；

3 地质界线和地质观测点的测绘精度，在图上不应低于 3mm。

8.0.4 地质观测点的布置、密度和定位应满足下列要求：

1 在地质构造线、地层接触线、岩性分界线、标准层位和每个地质单元体应有地质观测点；

2 地质观测点的密度应根据场地的地貌、地质条件、成图比例尺和工程要求等确定，并应具代表性；

3 地质观测点应充分利用天然和已有的人工露头，当露头少时，应根据具体情况布置一定数量的探坑或探槽；

4 地质观测点的定位应根据精度要求选用适当方法；地质构造线、地层接触线、岩性分界线、软弱夹层、地下水露头和不良地质作用等特殊地质观测点，宜用仪器定位。

8.0.5 工程地质测绘和调查，宜包括下列内容：

1 查明地形、地貌特征及其与地层、构造、不良地质作用的关系，划分地貌单元；

2 岩土的年代、成因、性质、厚度和分布；对岩层应鉴定其风化程度，对土层应区分新近沉积土、各种特殊性土；

3 查明岩体结构类型，各类结构面（尤其是软弱结构面）的产状和性质，岩、土接触面和软弱夹层的特性等，新构造活动的形迹及其与地震活动的关系；

4 查明地下水的类型、补给来源、排泄条件，井泉位置，含水层的岩性特征、埋藏深度、水位变化、污染情况及其与地表水体的关系；

5 搜集气象、水文、植被、土的标准冻结深度等资料；调查最高洪水位及其发生时间、淹没范围；

6　查明岩溶、土洞、滑坡、崩塌、泥石流、冲沟、地面沉降、断裂、地震震害、地裂缝、岸边冲刷等不良地质作用的形成、分布、形态、规模、发育程度及其对工程建设的影响；

7　调查人类活动对场地稳定性的影响，包括人工洞穴、地下采空、大挖大填、抽水排水和水库诱发地震等；

8　建筑物的变形和工程经验。

8.0.6　工程地质测绘和调查的成果资料宜包括实际材料图、综合工程地质图、工程地质分区图、综合地质柱状图、工程地质剖面图以及各种素描图、照片和文字说明等。

8.0.7　利用遥感影像资料解译进行工程地质测绘时，现场检验地质观测点数宜为工程地质测绘点数的30%～50%。野外工作应包括下列内容：

1　检查解译标志；

2　检查解译结果；

3　检查外推结果；

4　对室内解译难以获得的资料进行野外补充。

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9 勘探和取样

9.1 一般规定

9.1.1 当需查明岩土的性质和分布，采取岩土试样或进行原位测试时，可采用钻探、井探、槽探、洞探和地球物理勘探等。

勘探方法的选取应符合勘察目的和岩土的特性。

9.1.2 布置勘探工作时应考虑勘探对工程自然环境的影响，防止对地下管线、地下工程和自然环境的破坏。钻孔、探井和探槽完工后应妥善回填。

9.1.3 静力触探、动力触探作为勘探手段时，应与钻探等其他勘探方法配合使用。

9.1.4 进行钻探、井探、槽探和洞探时，应采取有效措施，确保施工安全。

9.2 钻　探

9.2.1 钻探方法可根据岩土类别和勘察要求按表 9.2.1 选用。

表 9.2.1 钻探方法的适用范围

钻探方法		钻进地层					勘察要求	
		粘性土	粉土	砂土	碎石土	岩石	直接鉴别、采取不扰动试样	直接鉴别、采取扰动试样
回转	螺旋钻探	++	+	+	—	—	++	++
	无岩芯钻探	++	++	++	+	++	—	—
	岩芯钻探	++	++	++	+	++	++	++
冲击	冲击钻探	—	+	++	++	—	—	—
	锤击钻探	++	++	++	+	—	++	++
振动钻探		++	++	++	+	—	+	++
冲洗钻探		+	++	++	—	—	—	—

注：++：适用；+：部分适用；—：不适用。

9.2.2 勘探浅部土层可采用下列钻探方法：

1 小口径麻花钻（或提土钻）钻进；

2 小口径勺形钻钻进；

3 洛阳铲钻进。

9.2.3 钻探口径和钻具规格应符合现行国家标准的规定。成孔口径应满足取样、测试和钻进工艺的要求。

9.2.4 钻探应符合下列规定：

1 钻进深度和岩土分层深度的量测精度，不应低于±5cm；

2 应严格控制非连续取芯钻进的回次进尺，使分层精度符合要求；

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3　对鉴别地层天然湿度的钻孔，在地下水位以上应进行干钻；当必须加水或使用循环液时，应采用双层岩芯管钻进；

4　岩芯钻探的岩芯采取率，对完整和较完整岩体不应低于80%，较破碎和破碎岩体不应低于65%；对需重点查明的部位（滑动带、软弱夹层等）应采用双层岩芯管连续取芯；

5　当需确定岩石质量指标RQD时，应采用75mm口径（N型）双层岩芯管和金刚石钻头；

6　（此款取消）

9.2.5　钻探操作的具体方法，应按现行标准《建筑工程地质钻探技术标准》（JGJ 87）执行。

9.2.6　钻孔的记录和编录应符合下列要求：

1　野外记录应由经过专业训练的人员承担；记录应真实及时，按钻进回次逐段填写，严禁事后追记；

2　钻探现场可采用肉眼鉴别和手触方法，有条件或勘察工作有明确要求时，可采用微型贯入仪等定量化、标准化的方法；

3　钻探成果可用钻孔野外柱状图或分层记录表示；岩土芯样可根据工程要求保存一定期限或长期保存，亦可拍摄岩芯、土芯彩照纳入勘察成果资料。

9.3　井探、槽探和洞探

9.3.1　当钻探方法难以准确查明地下情况时，可采用探井、探槽进行勘探。在坝址、地下工程、大型边坡等勘察中，当需详细查明深部岩层性质、构造特征时，可采用竖井或平洞。

9.3.2　探井的深度不宜超过地下水位。竖井和平洞的深度、长度、断面按工程要求确定。

9.3.3　对探井、探槽和探洞除文字描述记录外，尚应以剖面图、展示图等反映井、槽、洞壁和底部的岩性、地层分界、构造特征、取样和原位试验位置，并辅以代表性部位的彩色照片。

9.4　岩土试样的采取

9.4.1　土试样质量应根据试验目的按表9.4.1分为四个等级。

表9.4.1　土试样质量等级

级别	扰动程度	试验内容
Ⅰ	不扰动	土类定名、含水量、密度、强度试验、固结试验
Ⅱ	轻微扰动	土类定名、含水量、密度
Ⅲ	显著扰动	土类定名、含水量
Ⅳ	完全扰动	土类定名

注：1　不扰动是指原位应力状态虽已改变，但土的结构、密度和含水量变化很小，能满足室内试验各项要求；

2　除地基基础设计等级为甲级的工程外，在工程技术要求允许的情况下可用Ⅱ级土试样进行强度和固结试验，

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但宜先对土试样受扰动程度作抽样鉴定，判定用于试验的适宜性，并结合地区经验使用试验成果。

9.4.2 试样采取的工具和方法可按表 9.4.2 选择。

表 9.4.2 不同等级土试样的取样工具和方法

土试样质量等级	取样工具和方法		适用土类											
			粘性土					粉土	砂土				碎砂、碎石土、软岩
			流塑	软塑	可塑	硬塑	坚硬		粉砂	细砂	中砂	粗砂	
Ⅰ	薄壁取土器	固定活塞	++	++	+	—	—	+	+	—	—	—	—
		水压固定活塞	++	++	+	—	—	+	+	—	—	—	—
		自由活塞	—	+	++	—	—	+	+	—	—	—	—
		敞口	+	—	+	—	—	+	+	—	—	—	—
	回转取土器	单动三重管	—	+	++	++	+	++	++	++	—	—	—
		双动三重管	—	+	—	+	++	—	—	—	++	++	+
	探井(槽)中刻取块状土样		++	++	++	++	++	++	++	++	++	++	++
Ⅱ	薄壁取土器	水压固定活塞	++	++	+	—	—	+	+	—	—	—	—
		自由活塞	+	++	++	—	—	+	+	—	—	—	—
		敞口	++	++	++	—	—	+	+	—	—	—	—
	回转取土器	单动三重管	—	+	++	++	+	++	++	++	—	—	—
		双动三重管	—	—	—	+	++	—	—	—	++	++	++
	厚壁敞口取土器		+	++	++	++	++	+	+	+	+	+	—
Ⅲ	厚壁敞口取土器		++	++	++	++	++	++	++	++	++	+	—
	标准贯入器		++	++	++	++	++	++	++	++	++	++	—
	螺纹钻头		++	++	++	++	++	+	—	—	—	—	—
	岩芯钻头		++	++	++	++	++	++	+	+	+	+	+
Ⅳ	标准贯入器		++	++	++	++	++	++	++	++	++	++	—
	螺纹钻头		++	++	++	++	++	+	—	—	—	—	—
	岩芯钻头		++	++	++	++	++	++	++	++	++	++	++

注：1 ++：适用；+：部分适用；—：不适用；

2 采取砂土试样应有防止试样失落的补充措施；

3 有经验时，可用束节式取土器代替薄壁取土器。

9.4.3 取土器的技术规格应按本规范附录 F 执行。

9.4.4 在钻孔中采取Ⅰ、Ⅱ级砂样时，可采用原状取砂器，并按相应的现行标准执行。

9.4.5 在钻孔中采取Ⅰ、Ⅱ级土试样时，应满足下列要求：

1 在软土、砂土中宜采用泥浆护壁；如使用套管，应保持管内水位等于或稍高于地下水位，取样位置应低于套管底三倍孔径的距离；

2 采用冲洗、冲击、振动等方式钻进时，应在预计取样位置 1m 以上改用回转钻进；

3 下放取土器前应仔细清孔，清除扰动土，孔底残留浮土厚度不应大于取土器废

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土段长度(活塞取土器除外)；

4　采取土试样宜用快速静力连续压入法；

5　具体操作方法应按现行标准《原状土取样技术标准》(JGJ 89)执行。

9.4.6　Ⅰ、Ⅱ、Ⅲ级土试样应妥善密封，防止湿度变化，严防曝晒或冰冻。在运输中应避免振动，保存时间不宜超过三周。对易于振动液化和水分离析的土试样宜就近进行试验。

9.4.7　岩石试样可利用钻探岩芯制作或在探井、探槽、竖井和平洞中刻取。采取的毛样尺寸应满足试块加工的要求。在特殊情况下，试样形状、尺寸和方向由岩体力学试验设计确定。

9.5　地球物理勘探

9.5.1　岩土工程勘察中可在下列方面采用地球物理勘探：

1　作为钻探的先行手段，了解隐蔽的地质界线、界面或异常点；

2　在钻孔之间增加地球物理勘探点，为钻探成果的内插、外推提供依据；

3　作为原位测试手段，测定岩土体的波速、动弹性模量、动剪切模量、卓越周期、电阻率、放射性辐射参数、土对金属的腐蚀性等。

9.5.2　应用地球物理勘探方法时，应具备下列条件：

1　被探测对象与周围介质之间有明显的物理性质差异；

2　被探测对象具有一定的埋藏深度和规模，且地球物理异常有足够的强度；

3　能抑制干扰，区分有用信号和干扰信号；

4　在有代表性地段进行方法的有效性试验。

9.5.3　地球物理勘探，应根据探测对象的埋深、规模及其与周围介质的物性差异，选择有效的方法。

9.5.4　地球物理勘探成果判释时，应考虑其多解性，区分有用信息与干扰信号。需要时应采用多种方法探测，进行综合判释，并应有已知物探参数或一定数量的钻孔验证。

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10 原位测试

10.1 一般规定

10.1.1 原位测试方法应根据岩土条件、设计对参数的要求、地区经验和测试方法的适用性等因素选用。

10.1.2 根据原位测试成果，利用地区性经验估算岩土工程特性参数和对岩土工程问题做出评价时，应与室内试验和工程反算参数作对比，检验其可靠性。

10.1.3 原位测试的仪器设备应定期检验和标定。

10.1.4 分析原位测试成果资料时，应注意仪器设备、试验条件、试验方法等对试验的影响，结合地层条件，剔除异常数据。

10.2 载荷试验

10.2.1 载荷试验可用于测定承压板下应力主要影响范围内岩土的承载力和变形模量。浅层平板载荷试验适用于浅层地基土；深层平板载荷试验适用于深层地基土和大直径桩的桩端土；螺旋板载荷试验适用于深层地基土或地下水位以下的地基土。深层平板载荷试验的试验深度不应小于5m。

10.2.2 载荷试验应布置在有代表性的地点，每个场地不宜少于3个，当场地内岩土体不均时，应适当增加。浅层平板载荷试验应布置在基础底面标高处。

10.2.3 载荷试验的技术要求应符合下列规定：

1 浅层平板载荷试验的试坑宽度或直径不应小于承压板宽度或直径的三倍；深层平板载荷试验的试井直径应等于承压板直径；当试井直径大于承压板直径时，紧靠承压板周围土的高度不应小于承压板直径；

2 试坑或试井底的岩土应避免扰动，保持其原状结构和天然湿度，并在承压板下铺设不超过20mm的砂垫层找平，尽快安装试验设备；螺旋板头入土时，应按每转一圈下入一个螺距进行操作，减少对土的扰动；

3 载荷试验宜采用圆形刚性承压板，根据土的软硬或岩体裂隙密度选用合适的尺寸；土的浅层平板载荷试验承压板面积不应小于0.25m^2，对软土和粒径较大的填土不应小于0.5m^2；土的深层平板载荷试验承压板面积宜选用0.5m^2；岩石载荷试验承压板的面积不宜小于0.07m^2；

4 载荷试验加荷方式应采用分级维持荷载沉降相对稳定法(常规慢速法)；有地区经验时，可采用分级加荷沉降非稳定法(快速法)或等沉降速率法；加荷等级宜取10～12级，并不应少于8级，荷载量测精度不应低于最大荷载的±1%；

5 承压板的沉降可采用百分表或电测位移计量测，其精度不应低于±0.01mm；

6 对慢速法，当试验对象为土体时，每级荷载施加后，间隔5 min、5 min、10 min、

10min、15 min、15min 测读一次沉降，以后间隔 30 min 测读一次沉降，当连读两小时每小时沉降量小于等于 0.1mm 时，可认为沉降已达相对稳定标准，施加下一级荷载；当试验对象是岩体时，间隔 1 min、2 min、2 min、5min 测读一次沉降，以后每隔 10min 测读一次，当连续三次读数差小于等于 0.01mm 时，可认为沉降已达相对稳定标准，施加下一级荷载；

7 当出现下列情况之一时，可终止试验：

1）承压板周边的土出现明显侧向挤出，周边岩土出现明显隆起或径向裂缝持续发展；

2）本级荷载的沉降量大于前级荷载沉降量的 5 倍，荷载与沉降曲线出现明显陡降；

3）在某级荷载下 24 小时沉降速率不能达到相对稳定标准；

4）总沉降量与承压板直径（或宽度）之比超过 0.06。

10.2.4 根据载荷试验成果分析要求，应绘制荷载（p）与沉降（s）曲线，必要时绘制各级荷载下沉降（s）与时间（t）或时间对数（lg$t$）曲线。

应根据 Ps 曲线拐点，必要时结合 s-lg$t$ 曲线特征，确定比例界限压力和极限压力。当 p-s 呈缓变曲线时，可取对应于某一相对沉降值（即 s/d，d 为承压板直径）的压力评定地基土承载力。

10.2.5 土的变形模量应根据 p-s 曲线的初始直线段，可按均质各向同性半无限弹性介质的弹性理论计算。

浅层平板载荷试验的变形模量 E_0（MPa），可按下式计算：

$$E_0 = I_0(1-\mu^2)\frac{pd}{s} \tag{10.2.5-1}$$

深层平板载荷试验和螺旋板载荷试验的变形模量 E_0（MPa），可按下式计算：

$$E_0 = \omega\frac{pd}{s} \tag{10.2.5-2}$$

式中 I_0——刚性承压板的形状系数，圆形承压板取 0.785；方 形承压板取 0.886；

μ——土的泊松比（碎石土取 0.27，砂土取 0.30，粉土 取 0.35，粉质粘土取 0.38，粘土取 0.42）；

d——承压板直径或边长（m）；

p——p-s 曲线线性段的压力（kPa）；

s——与 p 对应的沉降（mm）；

ω——与试验深度和土类有关的系数，可按表 10.2.5 选用。

10.2.6 基准基床系数 K_v 可根据承压板边长为 30cm 的平板载荷试验，按下式计算：

$$K_v = \frac{p}{s} \tag{10.2.6}$$

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表 10.2.5　深层载荷试验计算系数 ω

土类 / d/z	碎石土	砂土	粉土	粉质粘土	粘土
0.30	0.477	0.489	0.491	0.515	0.524
0.25	0.469	0.480	0.482	0.506	0.514
0.20	0.460	0.471	0.474	0.497	0.505
0.15	0.444	0.454	0.457	0.479	0.487
0.10	0.435	0.446	0.448	0.470	0.478
0.05	0.427	0.437	0.439	0.461	0.468
0.01	0.418	0.429	0.431	0.452	0.459

注：d/z 为承压板直径和承压板底面深度之比。

10.3　静力触探试验

10.3.1　静力触探试验适用于软土、一般粘性土、粉土、砂土和含少量碎石的土。静力触探可根据工程需要采用单桥探头、双桥探头或带孔隙水压力量测的单、双桥探头，可测定比贯入阻力（p_s）、锥尖阻力（q_c）、侧壁摩阻力（f_s）和贯入时的孔隙水压力（u）。

10.3.2　静力触探试验的技术要求应符合下列规定：

1　探头圆锥锥底截面积应采用 10cm² 或 15cm²，单桥探头侧壁高度应分别采用 57mm 或 70mm，双桥探头侧壁面积应采用 150～300cm²，锥尖锥角应为 60°；

2　探头应匀速垂直压入土中，贯入速率为 1.2m/min；

3　探头测力传感器应连同仪器、电缆进行定期标定，室内探头标定测力传感器的非线性误差、重复性误差、滞后误差、温度漂移、归零误差均应小于 1%FS，现场试验归零误差应小于 3%，绝缘电阻不小于 500MΩ；

4　深度记录的误差不应大于触探深度的±1%；

5　当贯入深度超过 30m，或穿过厚层软土后再贯入硬土层时，应采取措施防止孔斜或断杆，也可配置测斜探头，量测触探孔的偏斜角，校正土层界线的深度；

6　孔压探头在贯入前，应在室内保证探头应变腔为已排除气泡的液体所饱和，并在现场采取措施保持探头的饱和状态，直至探头进入地下水位以下的土层为止；在孔压静探试验过程中不得上提探头；

7　当在预定深度进行孔压消散试验时，应量测停止贯入后不同时间的孔压值，其计时间隔由密而疏合理控制；试验过程不得松动探杆。

10.3.3　静力触探试验成果分析应包括下列内容：

1　绘制各种贯入曲线：单桥和双桥探头应绘制 p_s-z 曲线、q_c-z 曲线、f_s-z 曲线、R_f-z 曲线；孔压探头尚应绘制 u_i-z 曲线、q_t-z 曲线、f_t-z 曲线、B_q-z 曲线和孔压消散曲线：u_t-lg$t$ 曲线；

其中　R_f——摩阻比；

u_i——孔压探头贯入土中量测的孔隙水压力（即初始孔压）；

q_t——真锥头阻力（经孔压修正）；

f_s——真侧壁摩阻力(经孔压修正)；

B_q——静探孔压系数，$B_q=\dfrac{u_i-u_0}{q_t-\sigma_{v0}}$；

u_0——试验深度处静水压力(kPa)；

σ_{v0}——试验深度处总上覆压力(kPa)；

u_t——孔压消散过程时刻 t 的孔隙水压力。

2 根据贯入曲线的线型特征，结合相邻钻孔资料和地区经验，划分土层和判定土类；计算各土层静力触探有关试验数据的平均值，或对数据进行统计分析，提供静力触探数据的空间变化规律。

10.3.4 根据静力触探资料，利用地区经验，可进行力学分层，估算土的塑性状态或密实度、强度、压缩性、地基承载力、单桩承载力、沉桩阻力，进行液化判别等。根据孔压消散曲线可估算土的固结系数和渗透系数。

10.4 圆锥动力触探试验

10.4.1 圆锥动力触探试验的类型可分为轻型、重型和超重型三种，其规格和适用土类应符合表 10.4.1 的规定。

表 10.4.1 圆锥动力触探类型

类型		轻型	重型	超重型
落锤	锤的质量(kg)	10	63.5	120
	落距(cm)	50	76	100
探头	直径(mm)	40	74	74
	锥角(°)	60	60	60
探杆直径(mm)		25	42	50～60
指标(mm)		贯入 30cm 的读数 N_{10}	贯入 10cm 的读数 $N_{63.5}$	贯入 10cm 的读数 N_{120}
主要适用岩土		浅部的填土、砂土、粉土、粘性土	砂土、中密以下的碎石土、极软岩	密实和很密的碎石土、软岩、极软岩

10.4.2 圆锥动力触探试验技术要求应符合下列规定：

1 采用自动落锤装置；

2 触探杆最大偏斜度不应超过 2%，锤击贯入应连续进行；同时防止锤击偏心、探杆倾斜和侧向晃动，保持探杆垂直度；锤击速率每分钟宜为 15～30 击；

3 每贯入 1m，宜将探杆转动一圈半；当贯入深度超过 10m，每贯入 20cm 宜转动探杆一次；

4 对轻型动力触探，当 $N_{10}>100$ 或贯入 15cm 锤击数超过 50 时，可停止试验；对重型动力触探，当连续三次 $N_{63.5}>50$ 时，可停止试验或改用超重型动力触探。

10.4.3 圆锥动力触探试验成果分析应包括下列内容：

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1　单孔连续圆锥动力触探试验应绘制锤击数与贯入深度关系曲线；

2　计算单孔分层贯入指标平均值时，应剔除临界深度以内的数值、超前和滞后影响范围内的异常值；

3　根据各孔分层的贯入指标平均值，用厚度加权平均法计算场地分层贯入指标平均值和变异系数。

10.4.4　根据圆锥动力触探试验指标和地区经验，可进行力学分层，评定土的均匀性和物理性质（状态、密实度）、土的强度、变形参数、地基承载力、单桩承载力，查明土洞、滑动面、软硬土层界面，检测地基处理效果等。应用试验成果时是否修正或如何修正，应根据建立统计关系时的具体情况确定。

10.5　标准贯入试验

10.5.1　标准贯入试验适用于砂土、粉土和一般粘性土。

10.5.2　标准贯入试验的设备应符合表 10.5.2 的规定。

表 10.5.2　标准贯入试验设备规格

落　锤		锤的质量（kg）	63.5
		落距（cm）	76
贯入器	对开管	长度（mm）	＞500
		外径（mm）	51
		内径（mm）	35
	管　靴	长度（mm）	50～76
		刃口角度（°）	18～20
		刃口单刃厚度（mm）	1.6
钻　杆		直　　径（mm）	42
		相对弯曲	＜1/1000

10.5.3　标准贯入试验的技术要求应符合下列规定：

1　标准贯入试验孔采用回转钻进，并保持孔内水位略高于地下水位。当孔壁不稳定时，可用泥浆护壁，钻至试验标高以下 15cm 处，清除孔底残土后再进行试验；

2　采用自动脱钩的自由落锤法进行锤击，并减小导向杆与锤间的摩阻力，避免锤击时的偏心和侧向晃动，保持贯入器、探杆、导向杆联接后的垂直度，锤击速率应小于 30 击/min；

3　贯入器打入土中 15cm 后，开始记录每打入 10cm 的锤击数，累计打入 30cm 的锤击数为标准贯入试验锤击数 N。当锤击数已达 50 击，而贯入深度未达 30cm 时，可记录 50 击的实际贯入深度，按下式换算成相当于 30cm 的标准贯入试验锤击数 N。并终止试验。

$$N=30\times\frac{50}{\Delta S} \tag{10.5.3}$$

式中　ΔS——50 击时的贯入度(cm)。

10.5.4　标准贯入试验成果 N 可直接标在工程地质剖面图上，也可绘制单孔标准贯入

击数 N 与深度关系曲线或直方图。统计分层标贯击数平均值时，应剔除异常值。

10.5.5 标准贯入试验锤击数 N 值，可对砂土、粉土、粘性土的物理状态，土的强度、变形参数、地基承载力、单桩承载力，砂土和粉土的液化，成桩的可能性等做出评价。应用 N 值时是否修正和如何修正，应根据建立统计关系时的具体情况确定。

10.6 十字板剪切试验

10.6.1 十字板剪切试验可用于测定饱和软粘性土（$\varphi \approx 0$）的不排水抗剪强度和灵敏度。

10.6.2 十字板剪切试验点的布置，对均质土竖向间距可为 1m，对非均质或夹薄层粉细砂的软粘性土，宜先作静力触探，结合土层变化，选择软粘土进行试验。

10.6.3 十字板剪切试验的主要技术要求应符合下列规定：

1 十字板板头形状宜为矩形，径高比 1：2，板厚宜为 2～3mm；

2 十字板头插入钻孔底的深度不应小于钻孔或套管直径的 3～5 倍；

3 十字板插入至试验深度后，至少应静止 2～3min，方可开始试验；

4 扭转剪切速率宜采用（1°～2°）/10s，并应在测得峰值强度后继续测记 1min；

5 在峰值强度或稳定值测试完后，顺扭转方向连续转动 6 圈后，测定重塑土的不排水抗剪强度；

6 对开口钢环十字板剪切仪，应修正轴杆与土间的摩阻力的影响。

10.6.4 十字板剪切试验成果分析应包括下列内容：

1 计算各试验点土的不排水抗剪峰值强度、残余强度、重塑土强度和灵敏度；

2 绘制单孔十字板剪切试验土的不排水抗剪峰值强度、残余强度、重塑土强度和灵敏度随深度的变化曲线，需要时绘制抗剪强度与扭转角度的关系曲线；

3 根据土层条件和地区经验，对实测的十字板不排水抗剪强度进行修正。

10.6.5 十字板剪切试验成果可按地区经验，确定地基承载力、单桩承载力，计算边坡稳定，判定软粘性土的固结历史。

10.7 旁压试验

10.7.1 旁压试验适用于粘性土、粉土、砂土、碎石土、残积土、极软岩和软岩等。

10.7.2 旁压试验应在有代表性的位置和深度进行，旁压器的量测腔应在同一土层内。试验点的垂直间距应根据地层条件和工程要求确定，但不宜小于 1m，试验孔与已有钻孔的水平距离不宜小于 1m。

10.7.3 旁压试验的技术要求应符合下列规定：

1 预钻式旁压试验应保证成孔质量，钻孔直径与旁压器直径应良好配合，防止孔壁坍塌；自钻式旁压试验的自钻钻头、钻头转速、钻进速率、刃口距离、泥浆压力和流量等应符合有关规定；

2 加荷等级可采用预期临塑压力的 1/5～1/7，初始阶段加荷等级可取小值，必要时，可作卸荷再加荷试验，测定再加荷旁压模量；

3 每级压力应维持 1min 或 2min 后再施加下一级压力，维持 1min 时，加荷后 15s、

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30s、60s 测读变形量，维持 2min 时，加荷后 15s、30s、60s、120s 测读变形量；

4 当量测腔的扩张体积相当于量测腔的固有体积时，或压力达到仪器的容许最大压力时，应终止试验。

10.7.4 旁压试验成果分析应包括下列内容：

1 对各级压力和相应的扩张体积(或换算为半径增量)分别进行约束力和体积的修正后，绘制压力与体积曲线，需要时可作蠕变曲线；

2 根据压力与体积曲线，结合蠕变曲线确定初始压力、临塑压力和极限压力；

3 根据压力与体积曲线的直线段斜率，按下式计算旁压模量：

$$E_m = 2(1+\mu)\left(V_c + \frac{V_0+V_f}{2}\right)\frac{\Delta p}{\Delta V} \tag{10.7.4}$$

式中 E_m——旁压模量(kPa)；

μ——泊松比，按式 10.2.5 取值；

V_c——旁压器量测腔初始固有体积(cm^3)；

V_0——与初始压力 p_0 对应的体积(cm^3)；

V_f——与临塑压力 p_f 对应的体积(cm^3)；

$\Delta p/\Delta V$——旁压曲线直线段的斜率(kPa/cm^3)。

10.7.5 根据初始压力、临塑压力、极限压力和旁压模量，结合地区经验可评定地基承载力和变形参数。根据自钻式旁压试验的旁压曲线，还可测求土的原位水平应力、静止侧压力系数、不排水抗剪强度等。

10.8 扁铲侧胀试验

10.8.1 扁铲侧胀试验适用于软土、一般粘性土、粉土、黄土和松散～中密的砂土。

10.8.2 扁铲侧胀试验技术要求应符合下列规定：

1 扁铲侧胀试验探头长 230～240mm、宽 94～96mm、厚 14～16mm；探头前缘刃角 12°～16°，探头侧面钢膜片的直径 60mm；

2 每孔试验前后均应进行探头率定，取试验前后的平均值为修正值；膜片的合格标准为：

率定时膨胀至 0.05mm 的气压实测值 $\Delta A = 5 \sim 25kPa$；

率定时膨胀至 1.10mm 的气压实测值 $\Delta B = 10 \sim 110kPa$；

3 试验时，应以静力匀速将探头贯入土中，贯入速率宜为 2cm/s；试验点间距可取 20～50cm；

4 探头达到预定深度后，应匀速加压和减压测定膜片膨胀至 0.05mm、1.10mm 和回到 0.05mm 的压力 A、B、C 值；

5 扁铲侧胀消散试验，应在需测试的深度进行，测读时间间隔可取 1min、2min、4min、8min、15min、30min、90min，以后每 90min 测读一次，直至消散结束。

10.8.3 扁铲侧胀试验成果分析应包括下列内容：

1 对试验的实测数据进行膜片刚度修正：

$$p_0 = 1.05(A - z_m + \Delta A) - 0.05(B - z_m - \Delta B) \quad (10.8.3\text{-}1)$$

$$p_1 = B - z_m - \Delta B \quad (10.8.3\text{-}2)$$

$$p_2 = C - z_m + \Delta A \quad (10.8.3\text{-}3)$$

式中 p_0——膜片向土中膨胀之前的接触压力(kPa)；

p_1——膜片膨胀至 1.10mm 时的压力(kPa)；

p_2——膜片回到 0.05mm 时的终止压力(kPa)；

z_m——调零前的压力表初读数(kPa)。

2 根据 p_0、p_1 和 p_2 计算下列指标：

$$E_D = 34.7(p_1 - p_0) \quad (10.8.3\text{-}4)$$

$$K_D = (p_0 - u_0)/\sigma_{vo} \quad (10.8.3\text{-}5)$$

$$I_D = (p_1 - p_0)/(p_0 - u_0) \quad (10.8.3\text{-}6)$$

$$U_D = (p_2 - u_0)/(p_0 - u_0) \quad (10.8.3\text{-}7)$$

式中 E_D——侧胀模量(kPa)；

K_D——侧胀水平应力指数；

I_D——侧胀土性指数；

U_D——侧胀孔压指数；

u_0——试验深度处的静水压力(kPa)；

σ_{vo}——试验深度处土的有效上覆压力(kPa)。

3 绘制 E_D、I_D、K_D 和 U_D 与深度的关系曲线。

10.8.4 根据扁铲侧胀试验指标和地区经验，可判别土类，确定粘性土的状态、静止侧压力系数、水平基床系数等。

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10.9 现场直接剪切试验

10.9.1 现场直剪试验可用于岩土体本身、岩土体沿软弱结构面和岩体与其他材料接触面的剪切试验，可分为岩土体试体在法向应力作用下沿剪切面剪切破坏的抗剪断试验，岩土体剪断后沿剪切面继续剪切的抗剪试验(摩擦试验)，法向应力为零时岩体剪切的抗切试验。

10.9.2 现场直剪试验可在试洞、试坑、探槽或大口径钻孔内进行。当剪切面水平或近于水平时，可采用平推法或斜推法；当剪切面较陡时，可采用楔形体法。

同一组试验体的岩性应基本相同，受力状态应与岩土体在工程中的实际受力状态相近。

10.9.3 现场直剪试验每组岩体不宜少于 5 个。剪切面积不得小于 $0.25m^2$。试体最小边长不宜小于、50cm，高度不宜小于最小边长的 0.5 倍。试体之间的距离应大于最小边长的 1.5 倍。

每组土体试验不宜少于 3 个。剪切面积不宜小于 $0.3m^2$，高度不宜小于 20cm 或为最大粒径的 4～8 倍，剪切面开缝应为最小粒径的 1/3～1/4。

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10.9.4 现场直剪试验的技术要求应符合下列规定：

1 开挖试坑时应避免对试体的扰动和含水量的显著变化；在地下水位以下试验时，应避免水压力和渗流对试验的影响；

2 施加的法向荷载、剪切荷载应位于剪切面、剪切缝的中心；或使法向荷载与剪切荷载的合力通过剪切面的中心，并保持法向荷载不变；

3 最大法向荷载应大于设计荷载，并按等量分级；荷载精度应为试验最大荷载的±2%；

4 每一试体的法向荷载可分4～5级施加；当法向变形达到相对稳定时，即可施加剪切荷载；

5 每级剪切荷载按预估最大荷载的8%～10%分级等量施加，或按法向荷载的5%～10%分级等量施加；岩体按每5～10min，土体按每30s施加一级剪切荷载；

6 当剪切变形急剧增长或剪切变形达到试体尺寸的1/10时，可终止试验；

7 根据剪切位移大于10mm时的试验成果确定残余抗剪强度，需要时可沿剪切面继续进行摩擦试验。

10.9.5 现场直剪试验成果分析应包括下列内容：

1 绘制剪切应力与剪切位移曲线、剪应力与垂直位移曲线，确定比例强度、屈服强度、峰值强度、剪胀点和剪胀强度；

2 绘制法向应力与比例强度、屈服强度、峰值强度、残余强度的曲线，确定相应的强度参数。

10.10 波速测试

10.10.1 波速测试适用于测定各类岩土体的压缩波、剪切波或瑞利波的波速，可根据任务要求，采用单孔法、跨孔法或面波法。

10.10.2 单孔法波速测试的技术要求应符合下列规定：

1 测试孔应垂直；

2 将三分量检波器固定在孔内预定深度处，并紧贴孔壁；

3 可采用地面激振或孔内激振；

4 应结合土层布置测点，测点的垂直间距宜取1～3m。层位变化处加密，并宜自下而上逐点测试。

10.10.3 跨孔法波速测试的技术要求应符合下列规定：

1 振源孔和测试孔，应布置在一条直线上；

2 测试孔的孔距在土层中宜取2～5m，在岩层中宜取8～15m，测点垂直间距宜取1～2m；近地表测点宜布置在0.4倍孔距的深度处，震源和检波器应置于同一地层的相同标高处；

3 当测试深度大于15m时，应进行激振孔和测试孔倾斜度和倾斜方位的量测，测点间距宜取1m。

10.10.4 面波法波速测试可采用瞬态法或稳态法，宜采用低频检波器，道间距可根据场

地条件通过试验确定。

10.10.5 波速测试成果分析应包括下列内容：

1 在波形记录上识别压缩波和剪切波的初至时间；

2 计算由振源到达测点的距离；

3 根据波的传播时间和距离确定波速；

4 计算岩土小应变的动弹性模量、动剪切模量和动泊松比。

10.11 岩体原位应力测试

10.11.1 岩体应力测试适用于无水、完整或较完整的岩体。可采用孔壁应变法、孔径变形法和孔底应变法测求岩体空间应力和平面应力。

10.11.2 测试岩体原始应力时，测点深度应超过应力扰动影响区；在地下洞室中进行测试时，测点深度应超过洞室直径的二倍。

10.11.3 岩体应力测试技术要求应符合下列规定：

1 在测点测段内，岩性应均一完整；

2 测试孔的孔壁、孔底应光滑、平整、干燥；

3 稳定标准为连续三次读数(每隔 10min 读一次)之差不超过 5$\mu\varepsilon$；

4 同一钻孔内的测试读数不应少于三次。

10.11.4 岩芯应力解除后的围压试验应在 24 小时内进行；压力宜分 5～10 级，最大压力应大于预估岩体最大主应力。

10.11.5 测试成果整理应符合下列要求：

1 根据测试成果计算岩体平面应力和空间应力，计算方法应符合现行国家标准《工程岩体试验方法标准》(GB/T 50266)的规定；

2 根据岩芯解除应变值和解除深度，绘制解除过程曲线；

3 根据围压试验资料，绘制压力与应变关系曲线，计算岩石弹性常数。

10.12 激振法测试

10.12.1 激振法测试可用于测定天然地基和人工地基的动力特性，为动力机器基础设计提供地基刚度、阻尼比和参振质量。

10.12.2 激振法测试应采用强迫振动方法，有条件时宜同时采用强迫振动和自由振动两种测试方法。

10.12.3 进行激振法测试时，应搜集机器性能、基础形式、基底标高、地基土性质和均匀性、地下构筑物和干扰振源等资料。

10.12.4 激振法测试的技术要求应符合下列规定：

1 机械式激振设备的最低工作频率宜为 3～5Hz，最高工作频率宜大于 60Hz；电磁激振设备的扰力不宜小于 600N；

2 块体基础的尺寸宜采用 2.0m×1.5m×1.0m。在同一地层条件下，宜采用两个块体基础进行对比试验，基底面积一致，高度分别为 1.0m 和 1.5m；桩基测试应采用两

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根桩，桩间距取设计间距；桩台边缘至桩轴的距离可取桩间距的1/2，桩台的长宽比应为2∶1，高度不宜小于1.6m；当进行不同桩数的对比试验时，应增加桩数和相应桩台面积；测试基础的混凝土强度等级不宜低于C15；

3 测试基础应置于拟建基础附近和性质类似的土层上。其底面标高应与拟建基础底面标高一致；

4 应分别进行明置和埋置两种情况的测试，埋置基础的回填土应分层夯实；

5 仪器设备的精度，安装、测试方法和要求等，应符合现行国家标准《地基动力特性测试规范》(GB/T 50269)的规定。

10.12.5 激振法测试成果分析应包括下列内容：

1 强迫振动测试应绘制下列幅频响应曲线：

1）竖向振动为竖向振幅随频率变化的幅频响应曲线(A_z-f曲线)；

2）水平回转耦合振动为水平振幅随频率变化的幅频响应曲线($A_{x\varphi}$-f曲线)和竖向振幅随频率变化的幅频响应曲线($A_{z\varphi}$-f曲线)；

3）扭转振动为扭转扰力矩作用下的水平振幅随频率变化的幅频响应曲线($A_{x\varphi}$-f曲线)；

2 自由振动测试应绘制下列波形图：

1）竖向自由振动波形图；

2）水平回转耦合振动波形图；

3 根据强迫振动测试的幅频响应曲线和自由振动测试的波形图，按现行国家标准《地基动力特性测试规范》(GB/T 50269)计算地基刚度系数、阻尼比和参振质量。

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11 室内试验

11.1 一般规定

11.1.1 岩土性质的室内试验项目和试验方法应符合本章的规定，其具体操作和试验仪器应符合现行国家标准《土工试验方法标准》(GB/T 50123)和国家标准《工程岩体试验方法标准》(GB/T 50266)的规定。岩土工程评价时所选用的参数值，宜与相应的原位测试成果或原型观测反分析成果比较，经修正后确定。

11.1.2 试验项目和试验方法，应根据工程要求和岩土性质的特点确定。当需要时应考虑岩土的原位应力场和应力历史，工程活动引起的新应力场和新边界条件，使试验条件尽可能接近实际；并应注意岩土的非均质性、非等向性和不连续性以及由此产生的岩土体与岩土试样在工程性状上的差别。

11.1.3 对特种试验项目，应制定专门的试验方案。

11.1.4 制备试样前，应对岩土的重要性状做肉眼鉴定和简要描述。

11.2 土的物理性质试验

11.2.1 各类工程均应测定下列土的分类指标和物理性质指标：

砂土：颗粒级配、比重、天然含水量、天然密度、最大和最小密度。

粉土：颗粒级配、液限、塑限、比重、天然含水量、天然密度和有机质含量。

粘性土：液限、塑限、比重、天然含水量、天然密度和有机质含量。

注：1 对砂土，如无法取得Ⅰ级、Ⅱ级、Ⅲ级土试样时，可只进行颗粒级配试验；

2 目测鉴定不含有机质时，可不进行有机质含量试验。

11.2.2 测定液限时，应根据分类评价要求，选用现行国家标准《土工试验方法标准》(GB/T 50123)规定的方法，并应在试验报告上注明。有经验的地区，比重可根据经验确定。

11.2.3 当需进行渗流分析，基坑降水设计等要求提供土的透水性参数时，可进行渗透试验。常水头试验适用于砂土和碎石土；变水头试验适用于粉土和粘性土；透水性很低的软土可通过固结试验测定固结系数、体积压缩系数，计算渗透系数。土的渗透系数取值应与野外抽水试验或注水试验的成果比较后确定。

11.2.4 当需对土方回填或填筑工程进行质量控制时，应进行击实试验，测定土的干密度与含水量关系，确定最大干密度和最优含水量。

11.3 土的压缩一固结试验

11.3.1 当采用压缩模量进行沉降计算时，固结试验最大压力应大于土的有效自重压力与附加压力之和，试验成果可用 e-p 曲线整理，压缩系数和压缩模量的计算应取自土的有效自重压力至土的有效自重压力与附加压力之和的压力段。当考虑基坑开挖卸荷和

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再加荷影响时，应进行回弹试验，其压力的施加应模拟实际的加、卸荷状态。

11.3.2 当考虑土的应力历史进行沉降计算时，试验成果应按 e-lg$p$ 曲线整理，确定先期固结压力并计算压缩指数和回弹指数。施加的最大压力应满足绘制完整的 e-lg$p$ 曲线。为计算回弹指数，应在估计的先期固结压力之后，进行一次卸荷回弹，再继续加荷，直至完成预定的最后一级压力。

11.3.3 当需进行沉降历时关系分析时，应选取部分土试样在土的有效自重压力与附加压力之和的压力下，作详细的固结历时记录，并计算固结系数。

11.3.4 对厚层高压缩性软土上的工程，任务需要时应取一定数量的土试样测定次固结系数，用以计算次固结沉降及其历时关系。

11.3.5 当需进行土的应力应变关系分析，为非线性弹性、弹塑性模型提供参数时，可进行三轴压缩试验，并宜符合下列要求：

1 采用三个或三个以上不同的固定围压，分别使试样固结，然后逐级增加轴压，直至破坏；每个围压的试验宜进行一至三次回弹，并将试验结果整理成相应于各固定围压的轴向应力与轴向应变关系曲线；

2 进行围压与轴压相等的等压固结试验，逐级加荷，取得围压与体积应变关系曲线。

11.4 土的抗剪强度试验

11.4.1 三轴剪切试验的试验方法应按下列条件确定：

1 对饱和粘性土，当加荷速率较快时宜采用不固结不排水（UU）试验；饱和软土应对试样在有效自重压力下预固结后再进行试验；

2 对经预压处理的地基、排水条件好的地基、加荷速率不高的工程或加荷速率较快但土的超固结程度较高的工程，以及需验算水位迅速下降时的土坡稳定性时，可采用固结不排水（CU）试验；当需提供有效应力抗剪强度指标时，应采用固结不排水测孔隙水压力（$\overline{C}\,\overline{U}$）试验。

11.4.2 直接剪切试验的试验方法，应根据荷载类型、加荷速率和地基土的排水条件确定。对内摩擦角 $\varphi \approx 0$ 的软粘土，可用Ⅰ级土试样进行无侧限抗压强度试验。

11.4.3 测定滑坡带等已经存在剪切破裂面的抗剪强度时，应进行残余强度试验。在确定计算参数时，宜与现场观测反分析的成果比较后确定。

11.4.4 当岩土工程评价有专门要求时，可进行 K_0 固结不排水试验、K_0 固结不排水测孔隙水压力试验，特定应力比固结不排水试验，平面应变压缩试验和平面应变拉伸试验等。

11.5 土的动力性质试验

11.5.1 当工程设计要求测定土的动力性质时，可采用动三轴试验、动单剪试验或共振柱试验。在选择试验方法和仪器时，应注意其动应变的适用范围。

11.5.2 动三轴和动单剪试验可用于测定土的下列动力性质：

1 动弹性模量、动阻尼比及其与动应变的关系；

2 既定循环周数下的动应力与动应变关系；

3 饱和土的液化剪应力与动应力循环周数关系。

11.5.3 共振柱试验可用于测定小动应变时的动弹性模量和动阻尼比。

11.6 岩石试验

11.6.1 岩石的成分和物理性质试验可根据工程需要选定下列项目：

1 岩矿鉴定；

2 颗粒密度和块体密度试验；

3 吸水率和饱和吸水率试验；

4 耐崩解性试验；

5 膨胀试验；

6 冻融试验。

11.6.2 单轴抗压强度试验应分别测定干燥和饱和状态下的强度，并提供极限抗压强度和软化系数。岩石的弹性模量和泊松比，可根据单轴压缩变形试验测定。对各向异性明显的岩石应分别测定平行和垂直层理面的强度。

11.6.3 岩石三轴压缩试验宜根据其应力状态选用四种围压，并提供不同围压下的主应力差与轴向应变关系、抗剪强度包络线和强度参数 c、φ 值。

11.6.4 岩石直接剪切试验可测定岩石以及节理面、滑动面、断层面或岩层层面等不连续面上的抗剪强度，并提供 c、φ 值和各法向应力下的剪应力与位移曲线。

11.6.5 岩石抗拉强度试验可在试件直径方向上，施加一对线性荷载，使试件沿直径方向破坏，间接测定岩石的抗拉强度。

11.6.6 当间接确定岩石的强度和模量时，可进行点荷载试验和声波速度测试。

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12 水和土腐蚀性的评价

12.1 取样和测试

12.1.1 当有足够经验或充分资料，认定工程场地及其附近的土或水（地下水或地表水）对建筑材料不具腐蚀性时，可不取样进行腐蚀性评价。否则，应取水试样或土试样进行试验，并按本章评定其对建筑材料的腐蚀性。

土对钢结构腐蚀性的评价可根据任务要求进行。

12.1.2 采取水试样和土试样应符合下列规定：

1 混凝土结构处于地下水位以上时，应取土试样作土的腐蚀性测试；

2 混凝土结构处于地下水或地表水中时，应取水试样作水的腐蚀性测试；

3 混凝土结构部分处于地下水位以上、部分处于地下水位以下时，应分别取土试样和水试样作腐蚀性测试；

4 水试样和土试样应在混凝土结构所在的深度采取，每个场地不应少于2件。当土中盐类成分和含量分布不均匀时，应分区、分层取样，每区、每层不应少于2件。

12.1.3 水和土腐蚀性的测试项目和试验方法应符合下列规定：

1 水对混凝土结构腐蚀性的测试项目包括：pH值、Ca^{2+}、Mg^{2+}、Cl^-、SO_4^{2-}、HCO_3^-、CO_3^{2-}、侵蚀性CO_2、游离CO_2、NH_4^+、OH^-、总矿化度；

2 土对混凝土结构腐蚀性的测试项目包括：pH值、Ca^{2+}、Mg^{2+}、Cl^-、SO_4^{2-}、HCO_3^-、CO_3^{2-}的易溶盐（土水比1:5）分析；

3 土对钢结构的腐蚀性的测试项目包括：pH值、氧化还原电位、极化电流密度、电阻率、质量损失；

4 腐蚀性测试项目的试验方法应符合表12.1.3的规定。

表12.1.3 腐蚀性试验方法

序号	试验项目	试验方法
1	pH值	电位法或锥形玻璃电极法
2	Ca^{2+}	EDTA容量法
3	Mg^{2+}	EDTA容量法
4	Cl^-	摩尔法
5	SO_4^{2-}	EDTA容量法或质量法
6	HCO_3^-	酸滴定法
7	CO_3^{2-}	酸滴定法
8	侵蚀性CO_2	盖耶尔法
9	游离CO_2	碱滴定法
10	NH_4^+	钠氏试剂比色法

续表 12.1.3

序号	试验项目	试验方法
11	OH^-	酸滴定法
12	总矿化度	计算法
13	氧化还原电位	铂电极法
14	极化电流密度	原位极化法
15	电阻率	四极法
16	质量损失	管罐法

12.1.4 水和土对建筑材料的腐蚀性，可分为微、弱、中、强四个等级，并可按本规范第 12.2 节进行评价。

12.2 腐蚀性评价

12.2.1 受环境类型影响，水和土对混凝土结构的腐蚀性，应符合表 12.2.1 的规定；环境类型的划分按本规范附录 G 执行。

表 12.2.1 按环境类型水和土对混凝土结构的腐蚀性评价

腐蚀等级	腐蚀介质	环境类型		
		Ⅰ	Ⅱ	Ⅲ
微	硫酸盐含量 SO_4^{2-} (mg/L)	≤200	≤300	≤500
弱		200～500	300～1500	500～3000
中		500～1500	1500～3000	3000～6000
强		>1500	>3000	>6000
微	镁盐含量 Mg^{2+} (mg/L)	≤1000	≤2000	≤3000
弱		1000～2000	2000～3000	3000～4000
中		2000～3000	3000～4000	4000～5000
强		>3000	>4000	>5000
微	铵盐含量 NH_4^+ (mg/L)	≤100	≤500	≤800
弱		100～500	500～800	800～1000
中		500～800	800～1000	1000～1500
强		>800	>1000	>1500
微	苛性碱含量 OH^- (mg/L)	≤35000	≤43000	≤57000
弱		35000～43000	43000～57000	57000～70000
中		43000～57000	57000～70000	70000～100000
强		>57000	>70000	>100000
微	总矿化度 (mg/L)	≤10000	≤20000	≤50000
弱		10000～20000	20000～50000	50000～60000
中		20000～50000	50000～60000	60000～70000
强		>50000	>60000	>70000

注：1 表中的数值适用于有干湿交替作用的情况，Ⅰ、Ⅱ类腐蚀环境无干湿交替作用时，表中硫酸盐含量数值应乘以 1.3 的系数；

2 （此注取消）；

3 表中数值适用于水的腐蚀性评价，对土的腐蚀性评价，应乘以 1.5 的系数；单位以 mg/kg 表示；

4 表中苛性碱（OH^-）含量（mg/L）应为 NaOH 和 KOH 中的 OH^- 含量（mg/L）。

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12.2.2 受地层渗透性影响，水和土对混凝土结构的腐蚀性评价，应符合表 12.2.2 的规定。

表 12.2.2 按地层渗透性水和土对混凝土结构的腐蚀性评价

腐蚀等级	pH 值		侵蚀性 CO_2（mg/L）		HCO_3^-（mmol/L）
	A	B	A	B	A
微	≥6.5	≥5.0	≤15	≤30	≥1.0
弱	6.5～5.0	5.0～4.0	15～30	30～60	1.0～0.5
中	5.0～4.0	4.0～3.5	30～60	60～100	＜0.5
强	＜4.0	＜3.5	＞60	—	—

注：1 表中 A 是指直接临水或强透水层中的地下水；B 是指弱透水层中的地下水；强透水层是指碎石土和砂土；弱透水层是指粉土和粘性土；

2 HCO_3^- 含量是指水的矿化度低于 0.1g/L 的软水时，该类水质 HCO_3^- 的腐蚀性；

3 土的腐蚀性评价只考虑 pH 值指标；评价其腐蚀性时，A 是指强透水土层；B 是指弱透水土层。

12.2.3 当按表 12.2.1 和 12.2.2 评价的腐蚀等级不同时，应按下列规定综合评定：

1 腐蚀等级中，只出现弱腐蚀，无中等腐蚀或强腐蚀时；

2 腐蚀等级中，无强腐蚀；最高为中等腐蚀时，应综全评价为中等腐蚀；

3 腐蚀等级中，有一个或一个以上为强腐蚀，应综合评价为强腐蚀。

12.2.4 水和土对钢筋混凝土结构中钢筋的腐蚀性评价，应符合表 12.2.4 的规定。

表 12.2.4 对钢筋混凝土结构中钢筋的腐蚀性评价

腐蚀等级	水中的 Cl^- 含量（mg/L）		土中的 Cl^- 含量（mg/kg）	
	长期浸水	干湿交替	A	B
微	≤10000	≤100	≤400	≤250
弱	10000～20000	100～500	400～750	250～500
中	—	500～5000	750～7500	500～5000
强	—	＞5000	＞7500	＞5000

注：A 是指地下水位以上的碎石土、砂土，坚硬、硬塑的粘性土；B 是湿、很湿的粉土，可塑、软塑、流塑的粘性土。

12.2.5 土对钢结构的腐蚀性评价，应符合表 12.2.5 的规定。

表 12.2.5 土对钢结构腐蚀性评价

腐蚀等级	pH	氧化还原电位（mV）	视电阻率（Ω·m）	极化电流密度（mA/cm^2）	质量损失（g）
微	≥5.5	≥400	≥100	≤0.02	≤1
弱	5.5～4.5	400～200	100～50	0.02～0.05	1～2
中	4.5～3.5	200～100	50～20	0.05～0.20	2～3
强	＜3.5	＜100	≤20	＞0.20	≥3

注：土对钢结构的腐蚀性评价，取各指标中腐蚀等级最高者。

12.2.6 水、土对建筑材料腐蚀的防护，应符合现行国家标准《工业建筑防腐蚀设计规范》(GB 50046)的规定。

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13 现场检验和监测

13.1 一般规定

13.1.1 现场检验和监测应在工程施工期间进行。对有特殊要求的工程，应根据工程特点，确定必要的项目，在使用期内继续进行。

13.1.2 现场检验和监测的记录、数据和图件，应保持完整。并应按工程要求整理分析。

13.1.3 现场检验和监测资料，应及时向有关方面报送。当监测数据接近危及工程的临界值时，必须加密监测，并及时报告。

13.1.4 现场检验和监测完成后，应提交成果报告。报告中应附有相关曲线和图纸，并进行分析评价，提出建议。

13.2 地基基础的检验和监测

13.2.1 天然地基的基坑(基槽)开挖后，应检验开挖揭露的地基条件是否与勘察报告一致。如有异常情况，应提出处理措施或修改设计的建议。当与勘察报告出入较大时，应建议进行施工勘察。检验应包括下列内容：

1 岩土分布及其性质；

2 地下水情况；

3 对土质地基，可采用轻型圆锥动力触探或其他机具进行检验。

13.2.2 桩基工程应通过试钻或试打，检验岩土条件是否与勘察报告一致。如遇异常情况，应提出处理措施。当与勘察报告差异较大时，应建议进行施工勘察。单桩承载力的检验，应采用载荷试验与动测相结合的方法。对大直径挖孔桩，应逐桩检验孔底尺寸和岩土情况。

13.2.3 地基处理效果的检验，除载荷试验外，尚可采用静力触探、圆锥动力触探、标准贯入试验、旁压试验、波速测试等方法，并应按本规范第 10 章的规定执行。

13.2.4 基坑工程监测方案，应根据场地条件和开挖支护的施工设计确定，并应包括下列内容：

1 支护结构的变形；

2 基坑周边的地面变形；

3 邻近工程和地下设施的变形；

4 地下水位；

5 渗漏、冒水、冲刷、管涌等情况。

13.2.5 下列工程应进行沉降观测：

1 地基基础设计等级为甲级的建筑物；

2 不均匀地基或软弱地基上的乙级建筑物；

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3　加层、接建，邻近开挖、堆载等，使地基应力发生显著变化的工程；

4　因抽水等原因，地下水位发生急剧变化的工程；

5　其他有关规范规定需要做沉降观测的工程。

13.2.6　沉降观测应按现行标准《建筑物变形测量规范》(JGJ 8)的规定执行。

13.2.7　工程需要时可进行岩土体的下列监测：

1　洞室或岩石边坡的收敛量测；

2　深基坑开挖的回弹量测；

3　土压力或岩体应力量测。

13.3　不良地质作用和地质灾害的监测

13.3.1　下列情况应进行不良地质作用和地质灾害的监测：

1　场地及其附近有不良地质作用或地质灾害，并可能危及工程的安全或正常使用时；

2　工程建设和运行，可能加速不良地质作用的发展或引发地质灾害时；

3　工程建设和运行，对附近环境可能产生显著不良影响时。

13.3.2　不良地质作用和地质灾害的监测，应根据场地及其附近的地质条件和工程实际需要编制监测纲要，按纲要进行。纲要内容包括：监测目的和要求、监测项目、测点布置、观测时间间隔和期限、观测仪器、方法和精度、应提交的数据、图件等，并及时提出灾害预报和采取措施的建议。

13.3.3　岩溶土洞发育区应着重监测下列内容：

1　地面变形；

2　地下水位的动态变化；

3　场区及其附近的抽水情况；

4　地下水位变化对土洞发育和塌陷发生的影响。

13.3.4　滑坡监测应包括下列内容：

1　滑坡体的位移；

2　滑面位置及错动；

3　滑坡裂缝的发生和发展；

4　滑坡体内外地下水位、流向、泉水流量和滑带孔隙水压力；

5　支挡结构及其他工程设施的位移、变形、裂缝的发生和发展。

13.3.5　当需判定崩塌剥离体或危岩的稳定性时，应对张裂缝进行监测。对可能造成较大危害的崩塌，应进行系统监测，并根据监测结果，对可能发生崩塌的时间、规模、塌落方向和途径、影响范围等做出预报。

13.3.6　对现采空区，应进行地表移动和建筑物变形的观测，并应符合下列规定：

1　观测线宜平行和垂直矿层走向布置，其长度应超过移动盆地的范围；

2　观测点的间距可根据开采深度确定，并大致相等；

3　观测周期应根据地表变形速度和开采深度确定。

13.3.7　因城市或工业区抽水而引起区域性地面沉降，应进行区域性的地面沉降监测，监测要求和方法应按有关标准进行。

13.4　地下水的监测

13.4.1　下列情况应进行地下水监测：

1　地下水位升降影响岩土稳定时；

2　地下水位上升产生浮托力对地下室或地下构筑物的防潮、防水或稳定性产生较大影响时；

3　施工降水对拟建工程或相邻工程有较大影响时；

4　施工或环境条件改变，造成的孔隙水压力、地下水压力变化，对工程设计或施工有较大影响时；

5　地下水位的下降造成区域性地面沉降时；

6　地下水位升降可能使岩土产生软化、湿陷、胀缩时；

7　需要进行污染物运移对环境影响的评价时。

13.4.2　监测工作的布置，应根据监测目的、场地条件、工程要求和水文地质条件确定。

13.4.3　地下水监测方法应符合下列规定：

1　地下水位的监测，可设置专门的地下水位观测孔，或利用水井、地下水天然露头进行；

2　孔隙水压力、地下水压力的监测，可采用孔隙水压力计、测压计进行；

3　用化学分析法监测水质时，采样次数每年不应少于4次，进行相关项目的分析。

13.4.4　监测时间应满足下列要求：

1　动态监测时间不应少于一个水文年；

2　当孔隙水压力变化可能影响工程安全时，应在孔隙水压力降至安全值后方可停止监测；

3　对受地下水浮托力的工程，地下水压力监测应进行至工程荷载大于浮托力后方可停止监测。

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14 岩土工程分析评价和成果报告

14.1 一般规定

14.1.1 岩土工程分析评价应在工程地质测绘、勘探、测试和搜集已有资料的基础上，结合工程特点和要求进行。各类工程、不良地质作用和地质灾害以及各种特殊性岩土的分析评价，应分别符合本规范第4章、第5章和第6章的规定。

14.1.2 岩土工程分析评价应符合下列要求：

1 充分了解工程结构的类型、特点、荷载情况和变形控制要求；

2 掌握场地的地质背景，考虑岩土材料的非均质性、各向异性和随时间的变化，评估岩土参数的不确定性，确定其最佳估值；

3 充分考虑当地经验和类似工程的经验；

4 对于理论依据不足、实践经验不多的岩土工程问题，可通过现场模型试验或足尺试验取得实测数据进行分析评价；

5 必要时可建议通过施工监测，调整设计和施工方案。

14.1.3 岩土工程分析评价应在定性分析的基础上进行定量分析。岩土体的变形、强度和稳定应定量分析；场地的适宜性、场地地质条件的稳定性，可仅作定性分析。

14.1.4 岩土工程计算应符合下列要求：

1 按承载能力极限状态计算，可用于评价岩土地基承载力和边坡、挡墙、地基稳定性等问题，可根据有关设计规范规定，用分项系数或总安全系数方法计算，有经验时也可用隐含安全系数的抗力容许值进行计算；

2 按正常使用极限状态要求进行验算控制，可用于评价岩土体的变形、动力反应、透水性和涌水量等。

14.1.5 岩土工程的分析评价，应根据岩土工程勘察等级区别进行。对丙级岩土工程勘察，可根据邻近工程经验，结合触探和钻探取样试验资料进行；对乙级岩土工程勘察，应在详细勘探、测试的基础上，结合邻近工程经验进行，并提供岩土的强度和变形指标；对甲级岩土工程勘察，除按乙级要求进行外，尚宜提供载荷试验资料，必要时应对其中的复杂问题进行专门研究，并结合监测对评价结论进行检验。

14.1.6 任务需要时，可根据工程原型或足尺试验岩土体性状的量测结果，用反分析的方法反求岩土参数，验证设计计算，查验工程效果或事故原因。

14.2 岩土参数的分析和选定

14.2.1 岩土参数应根据工程特点和地质条件选用，并按下列内容评价其可靠性和适用性。

1 取样方法和其他因素对试验结果的影响；

2 采用的试验方法和取值标准；

3 不同测试方法所得结果的分析比较；

4 测试结果的离散程度；

5 测试方法与计算模型的配套性。

14.2.2 岩土参数统计应符合下列要求：

1 岩土的物理力学指标，应按场地的工程地质单元和层位分别统计；

2 应按下列公式计算平均值、标准差和变异系数：

$$\phi_m=\frac{\sum_{i=1}^{n}\phi_i}{n} \tag{14.2.2-1}$$

$$\sigma_f=\sqrt{\frac{1}{n-1}\left[\sum_{i=1}^{n}\phi_i^2-\frac{\left(\sum_{i=1}^{n}\phi_i\right)^2}{n}\right]} \tag{14.2.2-2}$$

$$\delta=\frac{\sigma_f}{\phi_m} \tag{14.2.2-3}$$

式中 ϕ_m——岩土参数的平均值；

σ_f——岩土参数的标准差；

δ——岩土参数的变异系数。

3 分析数据的分布情况并说明数据的取舍标准。

14.2.3 主要参数宜绘制沿深度变化的图件，并按变化特点划分为相关型和非相关型。需要时应分析参数在水平方向上的变异规律。

相关型参数宜结合岩土参数与深度的经验关系，按下式确定剩余标准差，并用剩余标准差计算变异系数。

$$\sigma_r=\sigma_f\sqrt{1-r^2} \tag{14.2.3-1}$$

$$\delta=\frac{\sigma_r}{\phi_m} \tag{14.2.3-2}$$

式中 σ_r——剩余标准差；

r——相关系数；对非相关型，$r=0$。

14.2.4 岩土参数的标准值 ϕ_k 可按下列方法确定：

$$\phi_k=\gamma_s\phi_m \tag{14.2.4-1}$$

$$\gamma_s=1\pm\left\{\frac{1.704}{\sqrt{n}}+\frac{4.678}{n^2}\right\}\delta \tag{14.2.4-2}$$

式中 γ_s——统计修正系数。

注：式中正负号按不利组合考虑，如抗剪强度指标的修正系数应取负值。

统计修正系数 γ_s 也可按岩土工程的类型和重要性、参数的变异性和统计数据的个数，根据经验选用。

14.2.5 在岩土工程勘察报告中，应按下列不同情况提供岩土参数值：

1 一般情况下，应提供岩土参数的平均值、标准差、变异系数、数据分布范围和数据

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的数量；

2　承载能力极限状态计算所需要的岩土参数标准值，应按式(14.2.4-1)计算；当设计规范另有专门规定的标准值取值方法时，可按有关规范执行。

14.3　成果报告的基本要求

14.3.1　岩土工程勘察报告所依据的原始资料，应进行整理、检查、分析，确认无误后方可使用。

14.3.2　岩土工程勘察报告应资料完整、真实准确、数据无误、图表清晰、结论有据、建议合理、便于使用和适宜长期保存，并应因地制宜，重点突出，有明确的工程针对性。

14.3.3　岩土工程勘察报告应根据任务要求、勘察阶段、工程特点和地质条件等具体情况编写，并应包括下列内容：

1　勘察目的、任务要求和依据的技术标准；

2　拟建工程概况；

3　勘察方法和勘察工作布置；

4　场地地形、地貌、地层、地质构造、岩土性质及其均匀性；

5　各项岩土性质指标，岩土的强度参数、变形参数、地基承载力的建议值；

6　地下水埋藏情况、类型、水位及其变化；

7　土和水对建筑材料的腐蚀性；

8　可能影响工程稳定的不良地质作用的描述和对工程危害程度的评价；

9　场地稳定性和适宜性的评价。

14.3.4　岩土工程勘察报告应对岩土利用、整治和改造的方案进行分析论证，提出建议；对工程施工和使用期间可能发生的岩土工程问题进行预测，提出监控和预防措施的建议。

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14.3.5　成果报告应附下列图件：

1　勘探点平面布置图；

2　工程地质柱状图；

3　工程地质剖面图；

4　原位测试成果图表；

5　室内试验成果图表。

注：当需要时，尚可附综合工程地质图、综合地质柱状图、地下水等 水位线图、素描、照片、综合分析图表以及岩土利用、整治和改 造方案的有关图表、岩土工程计算简图及计算成果图表等。

14.3.6　对岩土的利用、整治和改造的建议，宜进行不同方案的技术经济论证，并提出对设计、施工和现场监测要求的建议。

14.3.7　任务需要时，可提交下列专题报告：

1　岩土工程测试报告；

2　岩土工程检验或监测报告；

3　岩土工程事故调查与分析报告；

4　岩土利用、整治或改造方案报告；

5　专门岩土工程问题的技术咨询报告。

14.3.8　勘察报告的文字、术语、代号、符号、数字、计量单位、标点，均应符合国家有关标准的规定。

14.3.9　对丙级岩土工程勘察的成果报告内容可适当简化，采用以图表为主，辅以必要的文字说明；对甲级岩土工程勘察的成果报告除应符合本节规定外，尚可对专门性的岩土工程问题提交专门的试验报告、研究报告或监测报告。

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附录 A　岩土分类和鉴定

A.0.1　岩石坚硬程度等级可按表 A.0.1 定性划分。

表 A.0.1　岩石坚硬程度等级的定性分类

坚硬程度等级		定性鉴定	代表性岩石
硬质岩	坚硬岩	锤击声清脆，有回弹，震手，难击碎，基本无吸水反应	未风化～微风化的花岗岩、闪长岩、辉绿岩、玄武岩、安山岩、片麻岩、石英岩、石英砂岩、硅质砾岩、硅质石灰岩等
	较硬岩	锤击声较清脆，有轻微回弹，稍震手，较难击碎，有轻微吸水反应	1 微风化的坚硬岩； 2 未风化～微风化的大理岩、板岩、石灰岩、白云岩、钙质砂岩等
软质岩	较软岩	锤击声不清脆，无回弹，较易击碎，浸水后指甲可刻出印痕	1 中等风化～强风化的坚硬岩或较硬岩； 2 未风化～微风化的凝灰岩、千枚岩、泥灰岩、砂质泥岩等
	软岩	锤击声哑，无回弹，有凹痕，易击碎，浸水后手可掰开	1 强风化的坚硬岩或较硬岩； 2 中等风化～强风化的较软岩； 3 未风化～微风化的页岩、泥岩、泥质砂岩等
极软岩		锤击声哑，无回弹，有较深凹痕，手可捏碎，浸水后可捏成团	1 全风化的各种岩石； 2 各种半成岩

A.0.2　岩体完整程度等级可按表 A.0.2 定性划分。

表 A.0.2　岩体完整程度的定性分类

完整程度	结构面发育程度		主要结构面的结合程度	主要结构面类型	相应结构类型
	组数	平均间距（m）			
完整	1～2	>0.1	结合好或结合一般	裂隙、层面	整体状或巨厚层状结构

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续表 A.0.2

完整程度	结构面发育程度		主要结构面的结合程度	主要结构面类型	相应结构类型
	组数	平均间距（m）			
较完整	1～2	>1.0	结合差	裂隙、层面	块状或厚层状结构
	2～3	1.0～0.4	结合好或结合一般		块状结构
较破碎	2～3	1.0～0.4	结合差	裂隙、层面、小断层	裂隙块状或中厚层状结构
	≥3	0.4～0.2	结合好		镶嵌碎裂结构
			结合一般		中、薄层状结构
破碎	≥3	0.4～0.2	结合差	各种类型结构面	裂隙块状结构
		≤0.2	结合一般或结合差		碎裂状结构
极破碎	无序		结合很差		散体状结构

注：平均间距指主要结构面（1～2组）间距的平均值。

A.0.3 岩石风化程度可按表A.0.3划分。

表 A.0.3 岩石按风化程度分类

风化程度	野外特征	风化程度参数指标	
		波速比（K_v）	风化系数 K_f
未风化	岩质新鲜，偶见风化痕迹	0.9～1.0	0.9～1.0
微风化	结构基本未变，仅节理面有渲染或略有变色，有少量风化裂隙	0.8～0.9	0.8～0.9
中等风化	结构部分破坏，沿节理面有次生矿物，风化裂隙发育，岩体被切割成岩块。用镐难挖，岩芯钻方可钻进	0.6～0.8	0.4～0.8
强风化	结构大部分破坏，矿物成分显著变化，风化裂隙很发育，岩体破碎，用镐可挖，干钻不易钻进	0.4～0.6	<0.4
全风化	结构基本破坏，但尚可辨认，有残余结构强度，可用镐挖，干钻可钻进	0.2～0.4	—
残积土	组织结构全部破坏，已风化成土状，锹镐易挖掘，干钻易钻进，具可塑性	<0.2	—

注：1 波速比 K_v 为风化岩石与新鲜岩石压缩波速度之比；

2 风化系数 K_f 为风化岩石与新鲜岩石饱和单轴抗压强度之比；

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3 岩石风化程度，除按表列野外特征和定量指标划分外，也可根据当地经验划分；

4 花岗岩类岩石，可采用标准贯入试验划分，$N \geqslant 50$ 为强风化；$50 > N \geqslant 30$ 为全风化；$N < 30$ 为残积土；

5 泥岩和半成岩，可不进行风化程度划分。

A.0.4 岩体根据结构类型可按表 A.0.4 划分：

表 A.0.4 岩体按结构类型划分

岩体结构类型	岩体地质类型	结构体形状	结构面发育情况	岩土工程特征	可能发生的岩土工程问题
整体状结构	巨块状岩浆岩和变质岩，巨厚层沉积岩	巨块状	以层面和原生、构造节理为主，多呈闭合型，间距大于 1.5m，一般为 1～2 组，无危险结构	岩体稳定，可视为均质弹性各向同性体	局部滑动或坍塌，深埋洞室的岩爆
块状结构	厚层状沉积岩，块状岩浆岩和变质岩	块状 柱状	有少量贯穿性节理裂隙，结构面间距 0.7～1.5m。一般为 2～3 组，有少量分离体	结构面互相牵制，岩体基本稳定，接近弹性各向同性体	
层状结构	多韵律薄层、中厚层状沉积岩，副变质岩	层状 板状	有层理、片理、节理，常有层间错动	变形和强度受层面控制，可视为各向异性弹塑性体，稳定性较差	可沿结构面滑塌，软岩可产生塑性变形
碎裂状结构	构造影响严重的破碎岩层	碎块状	断层、节理、片理、层理发育，结构面间距 0.25～0.50m，一般 3 组以上，有许多分离体	整体强度很低，并受软弱结构面控制，呈弹塑性体，稳定性很差	易发生规模较大的岩体失稳，地下水加剧失稳
散体状结构	断层破碎带，强风化及全风化带	碎屑状	构造和风化裂隙密集，结构面错综复杂，多充填粘性土，形成无序小块和碎屑	完整性遭极大破坏，稳定性极差，接近松散体介质	易发生规模较大的岩体失稳，地下水加剧失稳

A.0.5 土根据有机质含量可按表 A.0.5 分类。

表 A.0.5　土按有机质含量分类

分类名称	有机质含量 W_u(%)	现场鉴别特征	说　明
无机土	$W_u<5\%$		
有机质土	$5\%\leqslant W_u\leqslant 10\%$	深灰色，有光泽，味臭，除腐殖质外尚含少量未完全分解的动植物体，浸水后水面出现气泡，干燥后体积收缩	1 如现场能鉴别或有地区经验时，可不做有机质含量测定； 2 当 $w>w_L$，$1.0\leqslant e<1.5$ 时称淤泥质土； 3 当 $w>w_L$，$e\geqslant 1.5$ 时称淤泥
泥炭质土	$10\%\leqslant W_u\leqslant 60\%$	深灰或黑色，有腥臭味，能看到未完全分解的植物结构，浸水体胀，易崩解，有植物残渣浮于水中，干缩现象明显	可根据地区特点和需要按 W_u 细分为： 弱泥炭质土($10\%\leqslant W_u\leqslant 25\%$)； 中泥炭质土 ($25\%\leqslant W_u\leqslant 40\%$)； 强泥炭质土 ($40\%\leqslant W_u\leqslant 60\%$)
泥炭	$W_u>60\%$	除有泥炭质土特征外，结构松散，土质很轻，暗无光泽，干缩现象极为明显	

注：有机质含量 W_u 按灼失量试验确定。

A.0.6　碎石土密实度野外鉴别可按表 A.0.6 执行。

表 A.0.6　碎石土密实度野外鉴别

密实度	骨架颗粒含量和排列	可挖性	可钻性
松散	骨架颗粒质量小于总质量的60%。排列混乱，大部分不接触	锹可以挖掘，井壁易坍塌，从井壁取出大颗粒后，立即塌落	钻进较易，钻杆稍有跳动，孔壁易坍塌
中密	骨架颗粒质量等于总质量的60%～70%，呈交错排列。大部分接触	锹镐可挖掘，井壁有掉块现象，从井壁取出大颗粒处，能保持凹面形状	钻进较困难，钻杆、吊锤跳动不剧烈，孔壁有坍塌现象
密实	骨架颗粒质量大于总质量的70%，呈交错排列，连续接触	镐镐挖掘困难，用撬棍方能松动，井壁较稳定	钻进困难，钻杆、吊锤跳动剧烈，孔壁较稳定

注：密实度应按表列各项特征综合确定。

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附录 B　圆锥动力触探锤击数修正

B.0.1　当采用重型圆锥动力触探确定碎石土密实度时，锤击数 $N_{63.5}$ 应按下式修正：

$$N_{63.5}=\alpha_1 \cdot N'_{63.5} \tag{B.0.1}$$

式中　$N_{63.5}$——修正后的重型圆锥动力触探锤击数；

α_1——修正系数，按表 B.0.1 取值；

$N'_{63.5}$——实测重型圆锥动力触探锤击数。

表 B.0.1　重型圆锥动力触探锤击数修正系数

L（m） \ $N'_{63.5}$	5	10	15	20	25	30	35	40	≥50
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
4	0.96	0.95	0.93	0.92	0.90	0.89	0.87	0.86	0.84
6	0.93	0.90	0.88	0.85	0.83	0.81	0.79	0.78	0.75
8	0.90	0.86	0.83	0.80	0.77	0.75	0.73	0.71	0.67
10	0.88	0.83	0.79	0.75	0.72	0.69	0.67	0.64	0.61
12	0.85	0.79	0.75	0.70	0.67	0.64	0.61	0.59	0.55
14	0.82	0.76	0.71	0.66	0.62	0.58	0.56	0.53	0.50
16	0.79	0.73	0.67	0.62	0.57	0.54	0.51	0.48	0.45
18	0.77	0.70	0.63	0.57	0.53	0.49	0.46	0.43	0.40
20	0.75	0.67	0.59	0.53	0.48	0.44	0.41	0.39	0.36

注：表中 L 为杆长。

B.0.2　当采用超重型圆锥动力触探确定碎石土密实度时，锤击数 N_{120} 应按下式修正：

$$N_{120}=\alpha_2 \cdot N'_{120} \tag{B.0.2}$$

式中　N_{120}——修正后的超重型圆锥动力触探锤击数；

α_2——修正系数，按表 B.0.2 取值；

N'_{120}——实测超重型圆锥动力触探锤击数。

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附录 B.0.2　超重型圆锥动力触探锤击数修正系数

L (m) \ N'_{120}	1	3	5	7	9	10	15	20	25	30	35	40
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	0.96	0.92	0.91	0.90	0.90	0.90	0.90	0.89	0.89	0.88	0.88	0.88
3	0.94	0.88	0.86	0.85	0.84	0.84	0.84	0.83	0.82	0.82	0.81	0.81
5	0.92	0.82	0.79	0.78	0.77	0.77	0.76	0.75	0.74	0.73	0.72	0.72
7	0.90	0.78	0.75	0.74	0.73	0.72	0.71	0.70	0.68	0.68	0.67	0.66
9	0.88	0.75	0.72	0.70	0.69	0.68	0.67	0.66	0.64	0.63	0.62	0.62
11	0.87	0.73	0.69	0.67	0.66	0.66	0.64	0.62	0.61	0.60	0.59	0.58
13	0.86	0.71	0.67	0.65	0.64	0.63	0.61	0.60	0.58	0.57	0.56	0.55
15	0.86	0.69	0.65	0.63	0.62	0.61	0.59	0.58	0.56	0.55	0.54	0.53
17	0.85	0.68	0.63	0.61	0.60	0.60	0.57	0.56	0.54	0.53	0.52	0.50
19	0.84	0.66	0.62	0.60	0.58	0.58	0.56	0.54	0.52	0.51	0.50	0.48

注：表中 L 为杆长。

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附录 C　泥石流的工程分类

C.0.1　泥石流的工程分类应按表 C.0.1 执行：

表 C.0.1　泥石流的工程分类和特征

类别	泥石流特征	流域特征	亚类	严重程度	流域面积（km^2）	固体物质一次冲出量（$\times10^4m^3$）	流量（m^3/s）	堆积区面积（km^2）
Ⅰ高频率泥石流沟谷	基本上每年均有泥石流发生。固体物质主要来源于沟谷的滑坡、崩塌。暴发雨强小于 2～4mm/10min。除岩性因素外，滑坡、崩塌严重的沟谷多发生粘性泥石流，规模大，反之多发生稀性泥石流，规模小	多位于强烈抬升区，岩层破碎，风化强烈，山体稳定性差。泥石流堆积新鲜，无植被或仅有稀疏草丛。粘性泥石流沟中下游沟床坡度大于 4%	$Ⅰ_1$	严重	>5	>5	>100	>1
			$Ⅰ_2$	中等	1～5	1～5	30～100	<1
			$Ⅰ_3$	轻微	<1	<1	<30	—
Ⅱ低频率泥石流沟谷	暴发周期一般在 10 年以上。固体物质主要来源于沟床，泥石流发生时“揭床”现象明显。暴雨时坡面产生的浅层滑坡往往是激发泥石流形成的重要因素。暴发雨强，一般大于 4mm/10min。规模一般较大，性质有粘有稀	山体稳定性相对较好，无大型活动性滑坡、崩塌。沟床和扇形地上巨砾遍布。植被较好，沟床内灌木丛密布，扇形地多已辟为农田。粘性泥石流沟中下游沟床坡度小于 4%	$Ⅱ_1$	严重	>10	>5	>100	>1
			$Ⅱ_2$	中等	1～10	1～5	30～100	<1
			$Ⅱ_3$	轻微	<1	<1	<30	—

注：1　表中流量对高频率泥石流沟指百年一遇流量；对低频率泥石流沟指历史最大流量；

2　泥石流的工程分类宜采用野外特征与定量指标相结合的原则，定量指标满足其中一项即可。

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附录 D　膨胀土初判方法

D.0.1　具有下列特征的土可初判为膨胀土：

1　多分布在二级或二级以上阶地、山前丘陵和盆地边缘；

2　地形平缓，无明显自然陡坎；

3　常见浅层滑坡、地裂，新开挖的路堑、边坡、基槽易发生坍塌；

4　裂缝发育，方向不规则，常有光滑面和擦痕，裂缝中常充填灰白、灰绿色粘土；

5　干时坚硬，遇水软化，自然条件下呈坚硬或硬塑状态；

6　自由膨胀率一般大于 40%；

7　未经处理的建筑物成群破坏，低层较多层严重，刚性结构较柔性结构严重；

8　建筑物开裂多发生在旱季，裂缝宽度随季节变化。

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附录 E　水文地质参数测定方法

E.0.1　水文地质参数可用表 E.0.1 的方法测定。

表 E.0.1　水文地质参数测定方法

参　　数	测定方法
水位	钻孔、探井或测压管观测
渗透系数、导水系数	抽水试验、注水试验、压水试验、室内渗透试验
给水度、释水系数	单孔抽水试验、非稳定流抽水试验、地下水位长期观测、室内试验
越流系数、越流因数	多孔抽水试验(稳定流或非稳定流)
单位吸水率	注水试验、压水试验
毛细水上升高度	试坑观测、室内试验

注：除水位外，当对数据精度要求不高时，可采用经验数值。

E.0.2　孔隙水压力可按表 E.0.2 的方法测定。

表 E.0.2　孔隙水压力测定方法和适用条件

仪器类型		适用条件	测定方法
测压计式	立管式测压计	渗透系数大于 10^{-4} cm/s 的均匀孔隙含水层	将带有过滤器的测压管打入土层，直接在管内量测
	水压式测压计	渗透系数低的土层，量测由潮汐涨落、挖方引起的压力变化	用装在孔壁的小型测压计探头，地下水压力通过塑料管传导至水银压力计测定
	电测式测压计(电阻应变式、钢弦应变式)	各种土层	孔压通过透水石传导至膜片，引起挠度变化，诱发电阻片(或钢弦)变化，用接收仪测定
	气动测压计	各种土层	利用两根排气管使压力为常数，传来的孔压在透水元件中的水压阀产生压差测定
孔压静力触探仪		各种土层	在探头上装有多孔透水过滤器、压力传感器，在贯入过程中测定

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附录 F　取土器技术标准

F.0.1　取土器技术参数应符合表 F.0.1 的规定。

表 F.0.1　取土器技术参数

取土器参数	厚壁取土器	薄壁取土器		
		敞口自由活塞	水压固定活塞	固定活塞
面积比 $\frac{D_w^2-D_e^2}{D_e^2}\times100(\%)$	13～20	≤10	10～13	
内间隙比 $\frac{D_S-D_e}{D_e}\times100(\%)$	0.5～1.5	0	0.5～1.0	
外间隙比 $\frac{D_w-D_t}{D_t}\times100(\%)$	0～2.0	0		
刃口角度 α(°)	＜10	5～10		
长度 L(mm)	400，500	对砂土：(5～10) D_e 对粘性土：(10～15) D_e		
外径 D_t(mm)	75～89，108	75，100		
衬管	整圆或半合管，塑料、酚醛层压纸或镀锌铁皮制成	无衬管，束节式取土器衬管同左		

注：1　取样管及衬管内壁必须光滑圆整；

2　在特殊情况下取土器直径可增大至 150～250mm；

3　表中符号：

D_e——取土器刃口内径；

D_s——取样管内径，加衬管时为衬管内径；

D_t——取样管外径；

D_w——取土器管靴外径，对薄壁管 $D_w=D_t$。

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附录 G　场地环境类型

G.0.1　场地环境类型的分类，应符合表 G.0.1 的规定：

表 G.0.1　环境类型分类

环境类别	场地环境地质条件
Ⅰ	高寒区、干旱区直接临水；高寒区、干旱区强透水层中的地下水
Ⅱ	高寒区、干旱区弱透水层中的地下水；各气候区湿、很湿的弱透水层 湿润区直接临水；湿润区强透水层中的地下水
Ⅲ	各气候区稍湿的弱透水层；各气候区地下水位以上的强透水层

注：1　高寒区是指海拔高度等于或大于 3000m 的地区；干旱区是指海拔高度小于 3000m，干燥度指数 K 值等于或大于 1.5 的地区；湿润区是指干燥度指数 K 值小于 1.5 的地区；

2　强透水层是指碎石土和砂土；弱透水层是指粉土和粘性土；

3　含水量 $w<3\%$ 的土层，可视为干燥土层，不具有腐蚀环境条件；

3A　当混凝土结构一边接触地面水或地下水，一边暴露在大气中，水可以通过渗透或毛细作用在暴露大气中的一边蒸发时，应定为Ⅰ类；

4　当有地区经验时，环境类型可根据地区经验划分；当同一场地出现两种环境类型时，应根据具体情况选定。

G.0.2　（此条取消）

G.0.3　（此条取消）

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附录 H　本规范用词说明

H.0.1　为便于在执行本规范条文时区别对待，对要求严格程度不同的用词说明如下：

1　表示很严格，非这样做不可的用词：

正面词采用“必须”，反面词采用“严禁”。

2　表示严格，在正常情况下均应这样做的用词：

正面词采用“应”，反面词采用“不应”或“不得”。

3　表示允许稍有选择，在条件许可时首先应这样做的用词：

正面词采用“宜”，反面词采用“不宜”；

H.0.2　条文中指定应按其他有关标准、规范执行时，写法为“应符合……的规定。非必须按所指定的标准、规范或其他规定执行时，写法为“可参照……”。

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