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Technical code for appraisal and reinforcement of building slope

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Foreword

As per the requirements of Construction Standard [2009] No. 88 issued by the Ministry of Housing and Urban-Rural Development - *Notice on Printing and Distributing the "Formulation and Amendment Plan for National Standards on Engineering Construction in 2009"*, the code compilation team hereby compiled this Code through extensive investigation and research, with practical experience summarized in earnest, by reference to relevant national and international standards, and on the basis of extensive solicitation.

The technical contents of this Code mainly consist of general provisions, terms and symbols, basic requirements, geological investigation of slope strengthening engineering, appraisal of slope engineering, slope strengthening engineering calculation, slope engineering strengthening method, slope strengthening engineering, monitoring of slope engineering, construction and quality acceptance of slope strengthening engineering.

The provision(s) of this Code printed in bold type is (are) mandatory one(s) and must be enforced strictly.

The Ministry of Housing and Urban-Rural Development is responsible for the administration of this Code and the interpretation of mandatory provisions. The Chongqing First Construction Group Co., Ltd is responsible for the interpretation of specific technical contents.

Any opinions or advice in the process of execution, can be posted or passed on to the Chongqing First Construction Group Co., Ltd at 1# Office Building, Guangsha Community, Tanzikou, Jiulongpo District, Chongqing, Zip Code: 400053.

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Chongqing First Construction Group Co., Ltd

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Participating development organizations of this Code:

China Building Technique Group Co., Ltd

Chongqing Construction Science Research Institute

Central Research Institute of Building and Construction Co., Ltd

Sichuan Institute of Building Research

Table of Contents

2 Terms and symbols

2.1 Terms

2.1.1 Building slope

Artificial slopes formed on or near the construction sites or due to excavation or filling of building engineering and municipal engineering; natural slopes that affect the safety or stability of buildings, hereinafter referred to as slope in this Code.

2.1.2 Existing building slope engineering

The whole or part of the completed building slope engineering.

2.1.3 Appraisal of existing building slope engineering

A series of activities such as surveying, inspection, analysis-checking, assessment, etc. carried out for the safety, normal usability of existing building slope engineering.

2.1.4 Strengthening of existing building slope engineering

The measures such as strengthening, local replacement, etc. for the existing building slope engineering and its related parts, taken to meet the safety, suitability and durability specified in current national standards.

2.1.5 Geological investigation of slope strengthening engineering

Geotechnical investigation activities for existing building slope engineering, carried out prior to slope appraisal and strengthening.

2.1.6 Design working life for strengthening of existing building slope engineering

The period where under normal conditions, the existing building slope engineering, or retaining structure, members may be used in accordance with their intended purpose after strengthening, with no need to be re-inspected or re-appraised.

2.1.7 Target working life

Expected years of use of the existing building slope engineering.

2.1.8 Inspection

Checking, surveying, testing and verification activities for the assessment of construction quality or performance.

2.1.9 Appraisal unit

Sections that may be appraised independently, divided in accordance with different retaining structure systems, structural features, structural layouts, slope heights and action sizes of the building slope engineering being appraised. Each section refers to an appraisal unit.

2.1.10 Sub-system

Basic appraisal unit in the appraisal unit, subdivided in accordance with different composing forms of the retaining structure.

2.1.11 Member

Basic stress unit that can be further subdivided in the retaining structure.

2.1.12 Anchor

A member that transmits tension to a stable rock-soil layer. In the event that steel stranded wires or high-strength steel tendons are used as the rod material, it may also be called anchorage. Unless otherwise specified in this Code, anchor shall be the collective name of anchor and pre-stressed anchorage.

2.1.13 Cut unloading at top of slope

A strengthening method that fulfills the predetermined function of the strengthened existing building slope engineering through the decrease in slope thrust by removing the rock-soil mass in the thrust zone of the building slope.

2.1.14 Back loading at toe of slope

A strengthening method that fulfills the predetermined function of the strengthened existing building slope engineering through back loading at toe of slope of the existing building slope engineering.

2.1.15 Slide-resistant pile method

A strengthening method that fulfills the predetermined function of the strengthened existing building slope engineering by setting slide-resistant piles.

2.1.16 Structure member strengthening with R.C

x_{gi} - x-coordinate of the point of vertical additional load per unit width of the i^{th} calculation slice;

x_{ni}, y_{ni} - x-coordinate and y-coordinate of the midpoint on the slip surface of the i^{th} calculation slice;

y_{qi} - y-coordinate of the point of horizontal load per unit width of the i^{th} calculation slice;

x_{ri}, y_{ri} - x-coordinate and y-coordinate of the effective resistance point of the i^{th} calculation slice;

a, a_i - Inclination for the effective resistance per unit width of the landslide mass and the i^{th} calculation slice;

θ, θ_i - Inclination of the slip surface and the i^{th} calculation slice.

2.2.4 Calculated coefficients

F_s, F_t - Anti-sliding, anti-overturning stability safety coefficients of the slope;

F_{st} - Overall stability safety coefficient;

i - Calculation slice number, numbered from the latter ones;

n - Number of slices;

x'_i - Relative horizontal distance FROM the vertical interface between the i^{th} calculation slice and the $(i + 1)^{th}$ calculation slice TO the front of the slip surface, is the ratio OF the horizontal distance to the front of the slip surface TO the horizontal distance between the front and back of the slip surface;

γ_0 - Importance coefficient of the retaining structure;

ζ_L - Resistance coefficient of exertion of new retaining structure or member;

ψ_i - Transfer coefficient of the residual downslide thrust of the i^{th} calculation slice to the $(i + 1)^{th}$ calculation slice.

2.2.5 Appraisal

A_s, B_s, C_s - Normal usability grade of the sub-systems;

A_{ss}, B_{ss}, C_{ss} - Normal usability grade of the appraisal units;

A_{su}, B_{su}, C_{su}, D_{su} - Safety grade of the appraisal units;

A_u, B_u, C_u, D_u - Safety grade of the sub-systems;

2 When the bonded rebars and carbon fiber sheets are used in the retaining structures for strengthening, the design working life shall be considered as 30 years. If the retaining structures are considered to function properly after re-appraisal upon the expiration, the working life may still continue to be extended.

3.3.5 For the retaining structures or members using the bonding method or mixed with polymer for strengthening, the working status thereof shall be checked on a regular basis. The checking time shall be determined by the design organization. However, the first check shall not exceed 10 years.

3.3.6 The design of the strengthening scheme for slope engineering shall meet the following requirements:

1 The appraisal report, investigation report, strengthening purpose, reliability and expected effects of the strengthening design, difficulty and conditions of construction, impact on neighboring buildings and environment, construction period, cost and other factors of the slope engineering shall be taken into consideration during the slope strengthening design. MAKE a comprehensive technical and economic analysis to determine a reasonable strengthening design scheme.
2 According to the appraisal report, the design of strengthening scheme shall consider the reasonable use of the effective resistance of the original retaining structures.
3 The scope of slope strengthening shall be determined according to the appraisal results and design analysis. It shall be able to strengthen the whole, sections, retaining structures or members, cut-off and draining system of the slope engineering. However, consideration shall be given to the integrity of the slope engineering and the interaction between the strengthened part and the adjacent buildings.
4 The slope strengthening engineering shall consider its technical-economic effect, to avoid unnecessary removal or replacement. The slope engineering with poor repair-suitability shall not be strengthened.
5 The design of slope strengthening engineering shall take into account the landscape and environmental requirements to beautify the environment and protect the ecology.

3.3.7 The slope engineering where large deformation or collapse might occur during the strengthening construction shall be stipulated in the design document. IMPLEMENT temporary pre-strengthening and TAKE other effective and safe measures before implementing permanent strengthening measures.

3.3.8 The design and construction of the following existing building slope engineering strengthening shall be specially demonstrated:

4 Geological investigation of slope strengthening engineering

4.1 General requirements

4.1.1 Before strengthening, the existing building slope engineering shall be conducted with geological investigation of slope strengthening engineering.

4.1.2 The geological investigation of existing slope strengthening engineering shall be carried out on the basis of full utilization of the geological investigation data of existing building slope engineering, along with necessary verification of existing data.

4.1.3 During the geological investigation of existing slope strengthening engineering, the work shall be carried out according to the characteristics and failure conditions of the slope, appraisal requirements and strengthening modes of the slope engineering.

4.1.4 The existing slope strengthening engineering may be directly conducted with detailed stages of investigation.

4.1.5 The geological investigation report of the slope strengthening engineering shall include the following contents:

1 DETERMINE the types and possible failure modes of slope, on the basis of ascertaining the causes of deformation, cracking and failure of slope engineering as well as the engineering geological and hydrogeological conditions;
2 PROVIDE the geotechnical parameters needed for slope stability and deformation checking as well as slope engineering appraisal and strengthening design;
3 EVALUATE the stability of slope, drawing the conclusion of stability;
4 PUT forward the suggestions for strengthening measures and monitoring schemes of the slope engineering.

4.2 Geological investigation of slope

4.2.1 Before geological investigation of slope strengthening engineering, the following information shall be obtained:

1 meteorological and hydrological data, especially the data of rainfall and rainstorm intensity;
2 existing geotechnical investigation data of the site;

assessment according to the rock-soil type and possible failure modes of the slope as well as the characteristics and functions of the retaining structures.

4.3.2 The stability assessment of the slope strengthening engineering includes the qualitative assessment and quantitative assessment. The qualitative assessment shall be carried out first, followed by the quantitative assessment. The stability assessment of the slope strengthening engineering shall meet the relevant requirements of current national standard GB 50330 *Technical code for building slope engineering*.

4.3.3 When the original retaining structure plays a favorable role in slope stability, the stability checking of slope engineering shall take its effective resistance into consideration. The effective resistance of the original retaining structure shall be determined based on the failure modes, deformation and failure condition of the slope engineering as well as the regional engineering experience.

4.3.4 The slope stability in the presence of the effective resistance of the original retaining structure shall be calculated according to the method provided in Annex A of this Code. The stability checking of other cases shall meet the relevant requirements of current national standards GB 50021 *Code for investigation of geotechnical engineering* and GB 50330 *Technical code for building slope engineering*.

4.3.5 When the slip surface is arc-shaped and fold-line, the cut-off points of the calculation slice shall be divided in the position with significant changes in inclination angle of slip surface, at the intersection of slip surface and water line, in the position with changes in strength index of slip surface, in the position with significant changes in inclination angle of groundwater level, in the position with significant changes in topographic slope angle, at the intersection of form line and river (reservoir) water line, in the position with significant changes in ground load, etc. The number of calculation slices shall meet the requirements of calculation accuracy.

4.3.6 For the slope engineering with multiple slip surfaces, the stability of various possible slip surfaces shall be checked and analyzed, respectively. TAKE the minimum stability coefficient as the stability coefficient of slope engineering. For the slope engineering with multi-level slip surfaces, the stability of all levels of slip surfaces shall be checked and analyzed, respectively.

4.3.7 The anti-sliding stability of slope shall be divided into stable, basically stable, less stable and unstable, which may be determined according to the anti-sliding stability coefficient of slope in Table 4.3.7.

5.2.3 The appraisal schemes shall be developed according to the characteristics of the appraisal objects, initial investigation results, purposes, scope, contents and requirements of appraisal. The appraisal schemes should include the following contents:

1 engineering overview, mainly including the types, total height of slope and surroundings of slope engineering, slope design, construction and supervision organizations, time of construction, etc.;
2 purposes, scope, contents and requirements of appraisal;
3 appraisal basis, mainly including the standards and relevant technical information used as the basis of inspection and appraisal, etc.;
4 inspection items, selected inspection methods, and number of sampling inspections;
5 inspection and appraisal personnel, and equipment condition;
6 appraisal schedule;
7 required cooperation;
8 safety measures during inspection;
9 environmental protection measures during inspection.

5.2.4 Detailed investigation and inspection should select the following work contents according to the actual needs:

1 STUDY relevant documentation in detail. When the slope engineering investigation data is incomplete or other engineering geological problems are discovered during inspection, it shall be implemented according to the requirements of Chapter 4 in this Code.
2 INVESTIGATE and VERIFY the working conditions. INVESTIGATE the construction and use history such as design, construction, use, maintenance, strengthening, etc. Meanwhile, INVESTIGATE the permanent load, variable load, accidental loading and indirect action. When the environmental effect has a great influence on slope safety, the environmental effect shall be investigated.
3 Inspection analysis of material properties. Design values may be used when there is a description in the drawings and no suspicion of changes in material properties. When no drawing is available or there are problems, field sampling inspection or in-situ testing shall be carried out in accordance with the current national standards for inspection techniques.
4 Check and sampling inspection of the retaining structures and members. Field sampling review may be carried out when drawings are available. When no drawing is available or the drawings are incomplete, important and representative retaining structures and members shall be conducted with field sampling inspection, through the field investigation and analysis of the retaining structures, in accordance

of slope engineering. The investigation may be carried out according to the items listed in Table 5.3.4.

Table 5.3.4 -- Investigation items for the service environments of slope engineering

Environmental conditions	Investigation items
Meteorological condition	Rainfall season, rainfall, snowfall, frost period, freeze-thaw cycles, soil frozen depth, etc.
Geological condition	Terrain, landform, engineering geology, surrounding buildings, etc.
Working environment of slope engineering	Erosive gases, liquids, solids, etc.

5.3.5 The environment classification and action grade of slope engineering may be determined according to the relevant requirements of current national standard GB 50144 *Standard for appraisal of reliability of industrial buildings and structures*. In the case of chemical corrosive environment, it may be determined according to the relevant requirements of current national standards GB 50046 *Code for anticorrosion design of industrial constructions* and GB 50021 *Code for investigation of geotechnical engineering*.

5.3.6 The investigation and inspection for the deformation and cracking of slope engineering and its surroundings shall meet the following requirements:

1 The investigation scope covers the landslip zone of slope engineering and the ground, buildings, pipelines to be protected, etc. in its impact area;
2 Marks and records shall be made for the positions where deformation or cracks have occurred;
3 Corresponding instruments and equipment shall be used for inspecting the deformation and tilt of the buildings;
4 Corresponding instruments and equipment shall be used for inspecting or observing the depth, width and propagation direction of the cracks on the ground or structures, and for monitoring or determining its variation trend.

5.3.7 The in-situ inspection of slope engineering shall meet the following requirements:

1 The inspection sampling principle and sample size shall meet the requirements of current national standard GB/T 50344 *Technical standard for inspection of building structure*. The sample size of the retaining structure members may be in accordance with the

2) When conditions permit, INSPECT the construction quality of the anchor rods.
3) After taking effective safety measures or pre-strengthening measures, TAKE 5% of the total number of anchors for pull-out test of anchors to check their pull-out bearing capacity. Each type of anchor shall not be less than 3 in number.

5.5.5 The durability of anchors shall be evaluated by analogy according to the anchor construction time, material selection, anti-corrosion measures, environmental category and action grade as well as the local engineering experience. The pits may be locally excavated to inspect the corrosion of the anchors, if necessary. The endurance life shall be evaluated according to the current national standard.

5.5.6 The endurance life of concrete members may be evaluated according to the current national standard GB 50144 *Standard for appraisal of reliability of industrial buildings and structures*.

5.5.7 The endurance life of the masonry materials for the gravity retaining walls may be evaluated according to the current national standard GB/T 2542 *Test methods for wall bricks*.

5.5.8 The slope engineering, constructed by using the slope ratio method, shall be divided into several appraisal units according to the geological characteristics, height and serviced life of slope engineering, so as to investigate the degree of weathering of exposed rock-soil mass as well as the cracks and damage degree of local mass materials in each appraisal unit. The endurance life of slope engineering shall be determined according to its overall or partial sliding possibility, the severity of the consequences and local engineering experience.

5.6 Sub-system appraisal

5.6.1 The safety appraisal of retaining structure subgrade and foundation shall meet the requirements of Annex B in this Code.

5.6.2 The safety appraisal of the retaining structures shall be performed according to the integrity, bearing capacity and deformation of the retaining structures. The appraisal shall meet the following requirements:

1 The integrity appraisal of the retaining structures shall meet the requirements of Table 5.6.2-1;

6 Slope strengthening engineering calculation

6.1 General requirements

6.1.1 The calculation of existing slope strengthening engineering shall meet the relevant requirements of current national standard GB 50330 *Technical code for building slope engineering*, among which the calculation of concrete member strengthening design shall meet the relevant requirements of current national standard GB 50367 *Code for design of strengthening concrete structure*, and the calculation of masonry member strengthening design shall meet the relevant requirements of current national standard GB 50702 *Code for design of strengthening masonry structures*.

6.1.2 Not only the requirements of this Code, but also the ones of relevant current national standards shall be complied with during the calculation for the strengthening design of the slope engineering in seismic areas, water-related slope engineering and slope engineering under dynamic load.

6.1.3 The geometric dimensions of the original retaining structure and members shall be determined according to the appraisal results.

6.1.4 The strength standard values of the original retaining structure and member materials shall be taken according to the following requirements;

1 When the in-situ inspection data is in line with the original design value, the original design standard value may be used;

2 When the in-situ inspection data is different from the original design value, the standard value estimated from the inspection results shall be used. The estimation method of standard value shall meet the requirements of relevant current national standards.

6.2 Calculation principle

6.2.1 The calculation of slope strengthening engineering shall meet the following requirements:

1 During strengthening by cut unloading at top of slope, back loading at toe of slope, and structure member strengthening with R.C, the geotechnical pressure shall be calculated based on the geotechnical parameters provided in the geological investigation data of slope strengthening engineering, according to the relevant requirements of current national standard GB 50330 *Technical code for building slope engineering*;

R_0 - Effective resistance of original retaining structure or member, determined according to Article 6.2.3 and Article 6.2.4 of this Code;

K - Safety coefficient, determined based on different calculation modes of different types of retaining structure and according to the relevant requirements of current national standard GB 50330 *Technical code for building slope engineering*;

S - External action on the retaining structure or member, determined based on the failure mode of slope engineering and according to the relevant requirements of current national standard GB 50330 *Technical code for building slope engineering*.

6.2.3 During strengthening design of slope engineering, the effective resistance of original retaining structure or member may be calculated based on the geometric dimensions and material properties of original retaining structure member and according to the relevant requirements of current national standards GB 50330 *Technical code for building slope engineering* and GB 50010 *Code for design of concrete structures*. The geometric dimensions and material properties of original retaining structure member should be determined according to the following requirements:

1 For the members with an appraisal grade of Grade a_u, the geometric dimensions and material properties may be taken according to the original design documents;
2 For the members with the appraisal grade of Grade b_u, Grade c_u and Grade d_u, the geometric dimensions and material properties shall be taken according to the appraisal results.

6.2.4 During strengthening design of slope engineering, the effective resistance of original retaining structure or member shall not be taken into consideration in the following cases:

1 in the case that the foundation of the retaining structure is located above the potential slip surface, and the overall slope engineering is unstable;
2 in the case that the anchorage section of the anchor is located in the unstable formation;
3 the resistance of the retaining structure or member that is difficult to recover effectively after strengthening, except for the gravity of the structure itself;
4 the resistance when the retaining structure or member has been identified to be failed through the appraisal results, except for the gravity of the structure itself and the members meeting the safety requirements of the structure.

7 Slope engineering strengthening method

7.1 General requirements

7.1.1 The strengthening methods of existing building slope engineering may be divided into cut unloading at top of slope, back loading at toe of slope, anchoring method, slide-resistant pile method, structure member strengthening with R.C, grouting method, cut-off and draining method, etc. Other locally mature, reliable and effective strengthening methods may also be available.

7.1.2 The strengthening methods in this Chapter shall also meet the following requirements:

1 When the original retaining structure and member have local damage, the damaged retaining structure and member shall be strengthened according to the relevant current national standards;
2 According to the situation of slope engineering, necessary measures such as drainage, seepage control and vegetation greening shall be taken;
3 In the case that deformation of slope engineering causes building deformation or cracking at top of slope, the buildings at top of slope shall be monitored and strengthened.

7.1.3 The design and construction requirements of all kinds of strengthening methods in this Chapter shall meet not only the requirements of this Chapter, but also those of current national standard GB 50330 *Technical code for building slope engineering*.

7.2 Cut unloading at top of slope

7.2.1 The cut unloading at top of slope is mainly used for the strengthening when the overall stability of the slope and the stability of the retaining structures do not meet the requirements.

7.2.2 The cut unloading at top of slope should not be used in the following cases:

1 After cutting, it may jeopardize the safety and normal use of neighboring buildings and pipelines;
2 In non-slide-resistant section, the slope engineering cannot be stabilized by cut unloading at top of slope;
3 For the slope engineering of traction slope or expansive soil.

7.2.3 The cut unloading at top of slope shall meet the following requirements:

1 Prestressed anchors shall use the anchorage system that is easy to adjust the prestress value, such as finish-rolled threaded reinforcing bars, un-bonded steel strands, etc.
2 The locked prestress value of new anchor should be the design value of anchor tension. When the displacement control value of the retaining structure by anchoring is low, the locked prestress value of prestressed anchor may be 75% to 90% of the design value of anchor tension.
3 Corrosion prevention of anchors and others shall meet the relevant requirements of current national standard GB 50330 *Technical code for building slope engineering*.

7.4.6 When corrosion or protective layer cracking is seen on the out-laid anchor head of the original anchor, repair shall be made according to the relevant requirements of current national standards.

7.4.7 Construction by the anchoring method shall meet the following requirements:

1 When the construction by wet drilling may lead to increase in slope deformation and decrease in stability, the construction shall be carried out by dry drilling;
2 During anchor construction, do not cause damage to the original retaining structure, members and adjacent building foundation;
3 The tensioning sequence of prestressed anchor shall avoid mutual effect of similar anchors; the construction shall be carried out by hierarchical tensioning in place;
4 In the process of prestressed tensioning, enhance the deformation monitoring or the original retaining structure and members to prevent prestressed tensioning from causing damage to it.

7.5 Slide-resistant pile method

7.5.1 The slide-resistant pile method is applicable to the strengthening of slope engineering and retaining structures such as pile retaining wall, gravity retaining wall, etc.

7.5.2 The slide-resistant pile may be used in conjunction with the prestressed anchor, and may be combined with the original retaining structure, thus forming a slide-resistant retaining system.

7.5.3 The slide-resistant pile method shall meet the following requirements:

1 The slide-resistant pile settings shall be determined according to the stability checking analysis of slope engineering.

7.6.2 When the structure member strengthening with R.C is applied to the retaining structures and members, the resistance calculation of the strengthened retaining structures and members shall meet the relevant requirements of current national standards GB 50367 *Code for design of strengthening concrete structure* and GB 50702 *Code for design of strengthening masonry structures*.

7.6.3 When the structure member strengthening with R.C is applied to the retaining structure foundation, it shall also meet the relevant requirements of current industry standard JGJ 123 *Technical code for improvement of soil and foundation of existing buildings*.

7.7 Grouting method

7.7.1 The grouting method is applicable to the strengthening of soil subgrade such as sand, silt, clay, artificial fill, etc., geotechnical slope, and soil in front of the slide-resistant piles as well as the improvement of shear parameter value of soil.

7.7.2 The grouting method shall meet the following requirements:

1 Grouting quality index and grouting range shall be determined according to the characteristics and strengthening purposes of slope engineering, combined with geological conditions and construction conditions.

2 Consideration shall be given to the adverse effects of the grouting process on the slope engineering.

3 The grouting materials and methods shall be selected according to the requirements of slope strengthening. When focusing on increasing the shear parameter of rock-soil mass, the cement-based grout may be used. When focusing on seepage prevention and leaking stoppage, clay-cement grout and clay-water glass grout may be used. The penetration grouting method may be used in the sand-gravel layer and fractured-rock layer with larger porosity. The split grouting method may be used in the clay layer.

4 Before grouting design, it is advisable to carry out the laboratory test of grout mix ratio and the in-situ grouting test, so as to determine the grout diffusion radius, spacing and layout of grouting holes, and other design parameters as well as the methods and equipment of inspection and construction. The design parameters may also be determined according to the experience in local similar engineering.

5 Equidistant and quincuncial layout may be applied to grouting holes. The spacing of grouting holes may be taken as 1.0m to 2.0m for sand layer with good permeability, 0.8m to 1.5m for clay layer.

1 REDUCE the grouting pressure, while increasing the grout concentration; MIX with sand or water glass, if necessary;
2 Limited grouting, intermittent grouting;
3 Padding is treated by back loading on the ground.

7.7.5 During grouting, in the case of excess grout loss to non-grouting range, the following measures may be taken:

1 low-pressure or gravity grouting;
2 SWITCH to thicker grout;
3 ADD coarse aggregate;
4 ADD quick-setting agent;
5 intermittent grouting;
6 ADJUST the grouting construction sequence. PERFORM surrounding closed-hole grouting first.

7.7.6 Standard penetration test, light dynamic penetration test, static cone penetration test, resistivity method, acoustic method or core drilling pulling-out method is optional for the grouting quality inspection. Load test can be applied to important engineering for inspection.

7.7.7 The design, construction and quality inspection of the grouting method shall meet the relevant requirements of current industry standard JGJ 123 *Technical code for improvement of soil and foundation of existing buildings*.

7.8 Cut-off and draining method

7.8.1 When deformation and instability of slope engineering are directly related to slope ponding, the cut-off and draining method should be used for strengthening of slope engineering.

7.8.2 When applying the cut-off and draining method to slope strengthening engineering, the following methods shall be adopted according to the permeability of the slope, water source, amount of seepage and environmental conditions:

1 When the original surface cut-off and draining system and underground draining system fail, they shall be dredged and repaired.
2 When the drainage hole fails, it shall be dredged or a new one shall be provided.
3 When the original cut-off and draining system does not meet the requirements, a new cut-off and draining system shall be provided. The horizontal distance from the new cut-off and draining system to the top of slope shall not be less than 5m.

8.2.3 The use of slide-resistant pile method shall meet the following requirements:

1 The slide-resistant piles should be installed between the ribs, and equipped with a reliable force transferring member. Or PERFORM in-situ casting of the slide-resistant pile close to the retaining plate.

2 In the case of high cantilever height of the slide-resistant pile or large force of the rock-soil mass, the slide-resistant pile method shall be used in conjunction with the anchoring method for strengthening.

8.3 Gravity retaining wall, cantilever retaining wall and counterfort retaining wall strengthening

8.3.1 When the overall instability, anti-sliding, anti-overturning or wall strength of the gravity retaining wall, cantilever retaining wall and counterfort retaining wall do not meet the design requirements, one or more of the following methods may be used for strengthening:

1 In the case that the slope is in rock-soil layer with good anchorage properties, strengthening should give priority to the anchoring method;

2 In the case of high bearing capacity of the retaining wall subgrade, either slide-resistant pile method or structure member strengthening with R.C may be used;

3 In the case of low bearing capacity of the retaining wall subgrade and large settlement deformation of the foundation, the grouting method may be used;

4 The strengthening methods specified in Item 3, Item 4 and Item 5 of Article 8.2.1 in this Code.

8.3.2 The use of anchoring method shall meet the following requirements:

1 When the gravity retaining wall of rock slope is not obviously deformed, it can be strengthened by non-prestressed anchors; when the gravity retaining wall of soil slope has been greatly deformed or requires strict control of deformation and needs to increase the larger applied resistance, it can be strengthened by prestressed anchors.

2 Gravity retaining wall placed on the rock may be strengthened by vertical prestressed anchors with no horizontal anchoring conditions. Longitudinal cast-in-place reinforced concrete beams shall be added at the anchorage point. Beam cross-section and reinforcement shall meet the requirements for the force transferring, structure and overall stress of the out-laid anchor head.

3 The additional anchors and reinforced concrete lattice beams shall form a combined force system with the original retaining wall.

8.4 Pile retaining wall strengthening

8.4.1 When the overall instability of the pile retaining wall, bearing capacity of the pile and retaining plate members do not meet the design requirements, one or more of the following methods may be used for strengthening:

1 In the case that the properties of rock-soil layer in the anchorage zone are better, the anchoring method may be used;
2 In the case of buried depth in the bedrock surface is shallow, the slide-resistant pile method may be used;
3 In the case of horizontal bearing capacity of the soil mass in front of the pile of the pile retaining wall is insufficient, the grouting method may be used;
4 The strengthening methods specified in Item 3, Item 4 and Item 5 of Article 8.2.1 in this Code.

8.4.2 The use of anchoring method shall meet the following requirements:

1 Prestressed anchors shall be used preferentially for strengthening;
2 Anchors may be located on the piles. When the anchors are located on both sides of the pile, a force transferring member shall be equipped to achieve deformation coordination between new anchors and the pile.
3 When the bearing capacity of concrete retaining plate is insufficient, anchors and a reliable force transferring member shall be equipped on the retaining plate.

8.4.3 When the grouting method is used in the subgrade in front of the pile of the pile retaining wall, the grouting area is the passive earth pressure zone of the pile embedded section.

8.4.4 The use of slide-resistant pile method shall meet the following requirements:

1 The slide-resistant piles should be located in the middle of the piles of the pile retaining wall by equidistant arrangement. The center distance between the new slide-resistant pile and the original pile should not be less than 2 times the larger value of the slide-resistant pile diameter and the original pile diameter.
2 Reliable connection members shall be set up at top of pile of the new slide-resistant pile and the original pile retaining wall, respectively.
3 The cast-in-place slide-resistant piles should be close to the panel, or ADD a reliable force transferring member.

1 When the anchorage conditions permit, the shotcreting lattice anchoring method may be used.
2 In the case of large slope inclination and surface soil slippage, the anchor lattice, masonry slope protection and slope protection greening may be used as the strengthening methods.

8.7 Subgrade and foundation strengthening

8.7.1 When the foundation dimensions of the retaining structure or vertical bearing capacity of subgrade do not meet the design requirements, one or more of the following methods should be used for strengthening:

1 When the foundation section has the conditions for increase, the structure member strengthening with R.C may be used.
2 When there are construction conditions and similar engineering experience, the grouting method may be used.
3 When the subgrade is adversely affected by the seepage of groundwater or surface water, the cut-off and draining method may be used.
4 According to the subgrade soil properties, the roof pile method, high-pressure injection grouting method, deep mixing method may also be used for subgrade strengthening, and shall meet the relevant requirements of current industry standard JGJ 123 *Technical code for improvement of soil and foundation of existing buildings*.

8.7.2 When the horizontal bearing capacity of the rock-soil mass outside the embedded section of the retaining structure foundation does not meet the design requirements, one or more of the following methods should be used for strengthening:

1 When the retaining structures are provided with additional anchorage conditions, anchors can be added on the retaining structure foundation so that the slope thrust can be transmitted to the deep stable stratum. In case of no additional anchorage conditions, the slide-resistant pile method may be used.
2 When the subgrade soil in the passive earth pressure zone in the embedded section of the retaining structure foundation, the grouting method may be used for strengthening.

8.7.3 Other strengthening requirements of the retaining structure subgrade and foundation shall meet the relevant requirements of current industry standard JGJ 123 *Technical code for improvement of soil and foundation of existing buildings*.

9.2.6 The deformation observation of the ground within the landslip area behind the top of slope shall meet the following requirements:

1 SELECT more than 2 typical cracks to observe the variation of their lengths, widths, depths and development directions;
2 SELECT more than 2 measuring lines, with not less than 3 control measuring points, to monitor the ground surface displacement changing pattern.

9.2.7 The deformation monitoring of the free face of slope engineering and the retaining structures shall meet the following requirements:

1 The total number of monitoring sections should not be less than 3; there shall be at least one monitoring section within the slope length range of 20m;
2 There should not be less than 3 measuring points in each monitoring section;
3 The total number of measuring points of horizontal displacement at top of slope should not be less than 3;
4 There shall be deformation monitoring points on the site with estimated maximum slope deformation.

9.2.8 Anchor stress monitoring shall meet the following requirements:

1 According to the arrangement of slope strengthening construction process, the original anchor that has been subjected to the pull-out test during appraisal and the newly selected representative anchor shall be tested for the variation of anchor stress and prestress, so as to timely reflect the impact of subsequent anchor construction on the variation of existing anchor stress and prestress.
2 The number of non-prestressed anchors for stress monitoring should not be less than 3% of the total number of anchors. The number of prestressed anchors for stress monitoring should not be less than 5% of the total number of anchors, and shall not be less than 3 in number.
3 When the strengthening anchor has an impact on the working condition of the original retaining structure member, it is advisable to monitor the stress variation of the original retaining structure member.

9.2.9 The stress monitoring of the retaining structure members shall meet the following requirements:

1 For the same type of retaining structure members, there shall not be less than 2 stress monitoring points under the same stress state.
2 For the stress monitoring of the retaining structure members, the stress monitoring points shall be arranged at different heights of the slope

10 Construction and quality acceptance of slope strengthening engineering

10.1 General requirements

10.1.1 The construction schemes for existing slope strengthening engineering shall be prepared according to its status quo before strengthening, engineering geology and hydrogeology, strengthening design documents, appraisal results, safety grade, slope environment and other conditions. Appropriate measures shall be taken to ensure construction safety.

10.1.2 For unstable or less unstable slope engineering, effective measures shall be taken to improve the stability of the slope engineering, and to ensure the safety of slope engineering and construction, according to the deformation signs, geological features and possible failure modes of the slope engineering before strengthening. There shall be no disorder large-scale excavation and major blasting operation.

10.1.3 There shall be no excess loading in the potential landslip zone of slope.

10.1.4 During construction of slope strengthening engineering, TAKE organized cut-off and draining measures to meet the drainage requirements of groundwater, rainstorms and construction water. When conditions permit, they should be implemented in combination with the permanent drainage measures for slope engineering.

10.1.5 During construction, the deformation observation points of slope engineering shall be established for self-inspection observation. During construction in rainy season, the frequency of observation shall be appropriately increased.

10.1.6 The construction design of slope strengthening engineering shall be not only reviewed according to the requirements, but also approved by the investigation and design organizations.

10.1.7 The construction method from information shall be applied to Grade I slope strengthening engineering, and shall meet the relevant requirements of the current national standard GB 50330 *Technical code for building slope engineering*.

10.1.8 Acceptance of construction quality of slope strengthening engineering shall meet the requirements of this Code and those of the current national standard GB 50330 *Technical code for building slope engineering*.

anomalies of slope retaining structure and slope environment shall be carried out.

10.3.2 In the case that the deformation of slope engineering is too large, the deformation rate thereof is too fast, and the hazards such as settlement, cracking, etc. appear on the surrounding buildings and ground, the construction shall be suspended. The following emergency measures shall be selected according to the causes of hazards:

1 CUT unloading in the active thrust zone at top of slope to reduce the pressure of rock-soil mass;
2 USE the back loading at toe of slope in the passive zone for temporary emergency treatment;
3 TAKE temporary waterproofing and draining measures for closed slope and slope cracks;
4 PERFORM temporary strengthening on the retaining structures;
5 STRENGTHEN the monitoring of hazardous sections;
6 Immediately FEEDBACK information to the investigation and design organizations. RECHECK the investigation and design data. CHECK the construction conditions according to the current situation. PUT forward reasonable measures for hazard elimination.
7 In the case of endangering the safety of related personnel and causing property damage, the personnel and property within the range affected by the slope strengthening engineering shall be withdrawn.

10.4 Quality acceptance

10.4.1 During the construction quality acceptance of slope strengthening engineering, the following information shall be obtained:

1 design documents of slope strengthening engineering, geological investigation report and appraisal report of slope strengthening engineering;
2 exit-factory certificate of raw materials, re-inspection report or commissioned inspection report of the materials on site;
3 concrete, mortar strength inspection reports;
4 graph of positional relation between the slope strengthening engineering and the surrounding buildings;
5 inspection reports of the retaining structure or member;
6 acceptance records of concealed engineering;
7 monitoring report of the slope strengthening engineering and surrounding buildings;
8 design change notice, major problem handling documents, and technical negotiation records;

Annex B

Safety appraisal of retaining structure subgrade and foundation

B.1 General requirements

B.1.1 The safety appraisal of retaining structure subgrade and foundation includes two items of subgrade and foundation, and three major members of foundation, foundation beam and pile.

B.1.2 The standard value of geotechnical properties and standard value of subgrade bearing capacity for retaining structure subgrade shall be determined according to the investigation data of slope strengthening engineering.

B.1.3 The comprehensive assessment of the safety of retaining structure subgrade and foundation shall be performed according to the deformation observation data of subgrade and foundation, deformation and damage of the upper retaining structure, and experience in local engineering practice, combined with the bearing capacity inspection checking of subgrade and foundation.

B.1.4 During safety appraisal of retaining structure subgrade and foundation, the lower rating of subgrade and foundation is taken as the safety rating of subgrade and foundation.

B.2 Subgrade appraisal

B.2.1 The subgrade inspection of slope engineering shall meet the following requirements:

1 COLLECT the site geotechnical investigation data, design information and drawings of slope foundation and retaining structures, construction records of concealed works, as-built drawings, etc.;

2 For the investigation data of slope strengthening engineering, FOCUS on analyzing the following contents:

1) distribution and homogeneity of subgrade rock-soil layer, soft substratum, special soil, ditches, ponds, fossil river courses, graves, karsts, caves, etc.;

2) physico-mechanical properties of geotechnical foundation;

3) groundwater level, seepage and its corrosiveness;

4) site stability;

5) seismic damage characteristics of subgrade.

50007 *Code for design of building foundation*. Or the retaining structures have serious deformation and cracks, endangering the safety of the retaining structures or members.

B.3 Foundation appraisal

B.3.1 The foundation investigation shall meet the following requirements:

1 COLLECT the design information and as-built drawings of foundation, retaining structures and pipelines, so as to understand the actual load on each part of the foundation of retaining structures.

2 The field investigation shall be carried out. The foundation type, materials, dimensions and embedded depth may be verified by pit excavation to check the extent of foundation cracking, corrosion or damage. DETERMINE the strength grade of foundation materials. For deformed or cracked retaining structures, the tilt, bending and distortion of foundation shall still be ascertained. For pile foundation, the buried depth of rock-soil layer, bearing stratum and pile quality shall be ascertained.

B.3.2 The following inspections of foundation shall be carried out:

1 PERFORM visual inspection of the appearance quality of foundation.

2 USE inspection equipment to identify the foundation quality. USE the non-destructive method or semi-destructive method to inspect the strength of foundation materials.

3 CHECK the diameter, quantity, positions, protective layer thickness and corrosion of rebar.

4 DETERMINE the working status of pile foundation through settlement and lateral displacement observation.

B.3.3 According to the inspection data, calculation analysis results and local experience in engineering, the foundation safety appraisal shall meet the following requirements:

Grade A_u: The foundation strength, stiffness and durability meet the requirements of current national standard. There is no settlement, lateral displacement, cracking and deformation on the foundation of the retaining structures.

Grade B_u: The foundation strength, stiffness and durability basically meets the requirements of current national standard. Uneven settlement, lateral displacement and durability do not exceed the allowable values specified in current national standard. Although the retaining structures have slight cracks and deformation, there is no sign of development.

Annex C

Stability appraisal of appraisal unit

C.0.1 The stability appraisal is divided into stability appraisal of the retaining structures and overall stability appraisal of the appraisal units.

C.0.2 The stability appraisal of the appraisal units shall meet the following requirements:

1 Data investigation shall meet the requirements of Article B.2.1 and Article B.3.1 in this Code;
2 The safety appraisal of the retaining structure members, subgrade foundation and ancillary works has been completed;
3 The stability appraisal shall use the appraisal units or sub-systems as the appraisal objects;
4 The appraisal units with a sign of stability failure or major safety accident shall be directly assessed as Grade D_{su}.

C.0.3 The safety appraisal of the retaining structures according to the anti-sliding stability and anti-overturning stability shall meet the following requirements:

1 The lowest appraisal grade of the anti-sliding stability and anti-overturning stability shall be used as the safety grade of the appraisal units.
2 For the retaining structures with no signs of deformation and overturning, the anti-sliding stability and anti-overturning stability may be directly assessed as Grade A_{su} or Grade B_{su}, combined with the local engineering experience.
3 For the retaining structures with the signs of deformation and overturning, the anti-sliding and anti-overturning stability shall be checked and assessed according to the actual inspection data. The appraisal thereof shall meet the requirements of Table C.0.3-1 and Table C.0.3-2.

Table C.0.3-1 -- Anti-sliding and anti-overturning stability appraisal for the retaining structures of Grade I and Grade II slope engineering

Stability coefficient	≥ 1.00F_s or F_t	≥ 0.95F_s or F_t	≥ 0.90F_s or F_t	< 0.90F_s or F_t
Appraisal	A_{su}	B_{su}	C_{su}	D_{su}

Note: F_s or F_t represents anti-sliding or anti-overturning stability safety coefficient.

List of quoted standards

1 GB 50007 *Code for design of building foundation*

2 GB 50010 *Code for design of concrete structures*

3 GB 50021 *Code for investigation of geotechnical engineering*

4 GB 50026 *Code for engineering surveying*

5 GB 50046 *Code for anticorrosion design of industrial constructions*

6 GB 50144 *Standard for appraisal of reliability of industrial buildings and structures*

7 GB 50300 *Unified standard for constructional quality acceptance of building engineering*

8 GB 50330 *Technical code for building slope engineering*

9 GB/T 50344 *Technical standard for inspection of building structure*

10 GB 50367 *Code for design of strengthening concrete structure*

11 GB 50497 *Technical code for monitoring of building excavation engineering*

12 GB 50702 *Code for design of strengthening masonry structures*

13 GB/T 2542 *Test methods for wall bricks*

14 JGJ 8 *Code for deformation measurement of building and structure*

15 JGJ 123 *Technical code for improvement of soil and foundation of existing buildings*

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