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Code for Seismic Design of Railway Engineering

铁路工程抗震设计规范

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1 General Provisions

1.0.1 This code is formulated with a view to implementing "Law of the People's Republic of China on Protecting Against and Mitigating Earthquake Disasters", unifying seismic design standard of railway engineering, and meeting the performance requirements for seismic fortification of railway engineering.

1.0.2 This code is applicable to seismic design of route, subgrade, bridge, tunnel, etc. works of Grade I and II railway engineering of rapid transit railway, passenger dedicated line (including intercity railway) and newly-built and renovated standard gauge mixed passenger and freight railway in the region with a fortification intensity of Intensity 6, Intensity 7, Intensity 8 or Intensity 9.

For the engineering with fortification intensity larger than Intensity 9 or with special seismic requirements and new type structure, the seismic design shall be specialized.

1.0.3 Seismic fortification intensity shall be adopted according to the basic seismic intensity specified in Appendix D of the national standard "Seismic Ground Motion Parameter Zonation Map of China" GB 18306-2001.

1.0.4 Under general situation, seismic design may comply with ground motion parameters specified in the national standard "Seismic Ground Motion Parameter Zonation Map of China" GB 18306-2001.

For the region subjected to special earthquake research, the seismic design may be carried out according to approved seismic fortification intensity or design parameters of ground motion.

For specially important railway engineering, the site position shall be subjected to seismic safety evaluation.

1.0.5 Seismic design shall be carried out for railway engineering according to low-level earthquake, design earthquake and high-level earthquake.

1.0.6 Concrete structures, with durability requirements, of route, subgrade, bridge and tunnel of rapid transit railway, passenger dedicated line (including intercity railway) and newly-built and renovated standard gauge mixed passenger and freight railway engineering in seismic region shall not only comply with this code, but also meet the relevant requirements of "Temporary Regulation for Durability Design of Railway Concrete Structures" Tie Jian She [2005] No. 157.

1.0.7 Seismic design of railway engineering shall not only comply with this code, but also those in the current relevant ones of the nation.

2 Terms and Symbols

2.1 Terms

2.1.1 Seismic design

Engineering design for defending seismic hazard, including seismic checking and seismic measures.

2.1.2 Seismic fortification intensity

Seismic intensity which is approved according to the authority specified by the nation as the criterion of seismic fortification of one region.

2.1.3 Seismic peak ground acceleration

Horizontal acceleration corresponding to maximum value of seismic acceleration response spectrum.

2.1.4 Low-level earthquake

Ground motion that the earthquake recurrence interval is 50 years.

2.1.5 Design earthquake

Ground motion that the earthquake recurrence interval is 475 years.

2.1.6 High-level earthquake

Ground motion that the earthquake recurrence interval is 2475 years.

2.1.7 Characteristic period of the seismic response spectrum

A period of the points when seismic acceleration response spectrum starts to drop.

2.1.8 Isolation technology

Adopt special components to change structure vibration characteristic and energy consumption mechanism at some position of engineering structure so as to reduce seismic force generated by the structure during earthquake.

2.1.9 Ductility design

Utilize nonlinear deformation capacity of engineering structure to consume seismic energy and conduct structure seismic design.

2.1.10 Seismic fortification measures

Seismic design content except seismic action calculation and resistance calculation, including seismic structural measures.

2.1.11 Site

Location of the engineering, with similar response spectrum characteristic.

2.2 Symbols

2.2.1 Ground motion parameters

T_g——Characteristic period of the seismic response spectrum;

A_g——Seismic peak ground acceleration;

α——Basic acceleration of horizontal earthquake.

2.2.2 Action and action effect

M_0——Pier foundation top section moment;

M_{mnx}——Maximum bending moment of linear response of pier under high-level earthquake;

F_{iwE}——Horizontal earthquake hydrodynamic force in unit pier height acted on i point of pier in water;

V_0——Pier foundation top section shear force;

R_0——Counter stress of bridge bearing.

2.2.3 Calculation coefficient

η——Correction coefficient of horizontal seismic action;

η_i——Amplification coefficient of horizontal seismic action along height;

K_c——Safety coefficient of stability against sliding;

K_0——Safety coefficient of stability against overturning;

β——Dynamic coefficient (amplification coefficient of acceleration response spectrum);

f——Coefficient of sliding friction;

ψ——Correction coefficient of allowable bearing pressure of foundation soil;

ψ_1——Reduction coefficient of mechanical index of liquefied soil.

2.2.4 Geometric parameters

d_w——Buried depth of underground water;

d_s——Depth of standard penetration or cone penetration test point;

d_u——Thickness of non-liquefied soil layer covered on liquefied soil layer;

h——Depth of foundation placed on ground or below general scour line;

h_w——Height from normal water level at pier to foundation top;

ρ——Core radius of foundation bottom in calculation direction;

I_0——Inertia moment of transformed section.

2.2.5 Material indexes

C_0——Vertical foundation coefficient corresponding to foundation soil at base;

E——Elasticity modulus of materials;

m——Proportionality coefficient of soil foundation coefficient;

I_p——Plasticity index of cohesive soil;

γ——Gravity density of materials;

V_{se}——Equivalent shear wave velocity of soil layer;

φ——Internal friction angle of soil;

φ0——Integrated internal friction angle of soil;

δ——Friction angle between retaining wall back or abutment back and fill.

2.2.6 Others

N——Measured standard penetration blow count;

N_{cr}——Critical liquefaction standard penetration blow count;

P_c——Weight percentage of sticky particle;

F_i——Anti-liquefaction index of liquefied soil;

T——Natural vibration period of structure;

m_b——Calculation mass of pier top;

m_d——Calculation mass of beam at pier top;

g——Gravity acceleration.

3 Basic Requirements of Seismic Design

3.0.1A The railway engineering shall be divided into Category A, B, C and D seismic protection according to railway classification, the importance of the engineering in the road network and the difficulty degree of repair (emergency repair). The classification of all kinds of railway engineering shall meet the requirements of Table 3.0.1A.

Table 3.0.1 A Classification for Seismic Protection Category of Railway Engineering

4.0.5 Where the liquefied soil strata are included in the subgrade, its dynamics index may be reduced in accordance with Appendix C of this code. The correction coefficient of allowable bearing capacity of soil strata below liquefied soil strata shall meet the requirements of Article 4.0.4 of this code. The allowable bearing capacity of soil strata above the liquefied soil strata shall not be corrected.

5 Route

5.0.1 The lines shall be selected at the section where the engineering geologic condition is good and the topography is open and flat or the slopes are very easy and avoided the area where the fault fracture zone moves recently, the subgrade of sandy soil, silty soil and soft soil are easy to be liquefacient and the slope wash deposit is loose and thicker and the serious debris-flow develops and such districts unfavorable to the seismic protection as unsteady cliff and couloir, serious hillside deformation and underground cavity easy to be collapsed.

5.0.2 The lines shall keep clear of the main motional fault zone in the seismic region with Intensity 8 and 9 seismic fortification intensity; if it is difficult to be avoided, get through it in a narrower place; the influence of the seismic secondary disaster shall be considered comprehensively during selection of the lines.

5.0.3 Where the lines get through the soft areas like liquefiable soil and soft soil etc., they should be selected at the place where the ground surface has thicker non-liquefied soil strata or duricrust strata, setting with low embankment.

5.0.4 Deep and long cutting shall not be made in the lines with soft soil nature or broken rock strata and the unfavorable geologic structure.

5.0.5 The lines shall keep clear of unsteady cliff area or get it through the tunnel if it is difficult to be avoided.

5.0.6 If the tunnel is built close to the mountains, it shall be moved inward; the tunnel mouth shall not be set at the area with adverse geologic condition and easy to generate such seismic hazard as collapse, landslide, scattering. The high-intensity seismic region should not be set up with the short tunnel group close to the mountains.

5.0.7 The bridge shall be selected at the districts with good subgrade and stable river bank. If the liquefiable soil strata and soft foundation are difficult to be avoided, the bridge center line should be orthogonal to the river. The bridge height shall be controlled at the high-intense seismic region which is passed with a simple structure form.

5.0.8 The track of the high-intense seismic region should adopt ballast track; if not, a construction of ballastless tracks shall be selected easy to be cured and maintained.

6 Subgrade

6.1 Checking of Seismic Strength and Stability

6.1.1 Checking scope of seismic strength and seismic stability of subgrade engineering shall meet the following requirements:

$$K_0 = \frac{\sum M_y}{\sum M_0} \tag{6.1.7-2}$$

Where,

$\sum M_y$——the total moment of stabilizing force system for toe of wall (kN·m);

$\sum M_0$——the total moment of overturning force systems for toe of wall (kN·m).

5 Safety coefficient K_c of stability against sliding of retaining wall along foundation bottom shall not be less than 1.1 and the safety coefficient K_0 of stability against overturning shall not be less than 1.3.

6.1.8 The horizontal seismic force of gliding mass in the engineering influenced by the landslide shall be calculated in accordance with Article 6.1.3 of this code and the safety coefficient of the residual gliding force of the sliding block shall be determined according to the development of the landslide, soil and rock mechanics index, influence degree of the earthquake, classification of rail and the importance of the engineering and taken 1.05~1.20 generally.

6.1.9 Retaining structures for the railway shall consider the influence of horizontal seismic action and check the seismic strength and stability. The light ones shall cover the checking of the external stability and internal stability which includes horizontal seismic force generated by mound gravity between non-anchorage zone and potential failure surface and wall surface. The horizontal seismic force generated by load combination, active soil pressure of earthquake and structure gravity shall meet the requirements of the current professional standard "Design Code for Retaining Structures of Railroad Foundation" TB 10025

6.2 Seismic Measures

6.2.1 Selection of road embankment filling shall meet the following requirements:

1 Road embankment filling shall meet the relevant requirements of current railroad design codes and shall select filling better in seismic stability. Category C engineering shall not adopt silty sand, fine sand as filling and Category D engineering should not adopt the silty sand and fine sand as filling; if they must be used under the limited conditions, the measures like soil improvement or reinforcement measures shall be taken

2 The filling for the road embankment in water shall adopt permeable soil. Category C engineering shall not adopt silty sand, fine sand and medium sand as filling and Category D engineering should not adopt silty sand, fine sand and medium sand as filling; if they must be used under limited conditions, such measures to prevent the liquefaction shall be taken.

6.2.2 Where the side slope height of road embankment on rock and non-liquefied soil and non-soft foundation is larger than those specified in Table 6.2.2, its slope ratio shall be lowered by one grade in accordance with the current professional standard "Design Code for Railway Foundation" TB 10001 or such measures shall be taken as to adopt geosynthetics reinforcement etc. to reinforce side slope

Table 6.2.2 Height Limit of Side Slope of Road Embankment (m)

Seismic fortification type / A_g / Filling	Category C engineering				Category D engineering		
	0.1g, 0.15g	0.2g	0.3g	0.4g	0.2g	0.3g	0.4g

protection and reinforcement measures as removing, anchorage, supporting and protection etc. and the reinforcement measures shall be taken, or the open cut tunnel shall be set. The slope protection should adopt anchor bolt (cable) frame beam and the surface and shallow treatment measure should not be taken as mixture by hanging wire netting with Zn, grouting slab-stone slope protection.

6.2.12 The rock cutting may adopt controlled blasting technology like smooth blasting and presplitting blasting etc. according to rock mass structure, rock character, structural plane occurrence by combination of the safety requirements of existing building in the scope influenced by the construction and the major blasting shall not be adopted.

6.2.13A Where the fortification intensity is Intensity 8 and Intensity 9, the retaining structures of the railway should adopt such light flexible structures as pile siding wall or piled anchor structures, reinforced soil retaining wall, soil nail wall ,anchor bolt and prestressed tendon etc.

6.2.14 Gravity retaining wall shall adopt integral pouring of slab-stone concrete or concrete and its intensity category shall not be less than C25. The retaining wall height shall meet the following requirements:

1 For the height of shoulder, road embankment and retaining wall for soil cutting, Category C engineering should not be larger than 6m and Category D engineering should not be larger than 8m.

2 For the height of retaining wall for stone cutting, Category C engineering should not be larger than 8m and Category D engineering should not be larger than 10m.

6.2.15 Rabbet setting or short steel bars reinforcement must be taken at the construction joint of concrete retaining wall or variable cross section of balance weight retaining wall and the area of rabbets shall not be less than 20% of section area.

6.2.16 Where the fortification intensity is Intensity 8 and Intensity 9, and the total height of the railway revetment wall is larger than 10m, the integral concrete pouring should be adopted and the intensity category shall not be less than C25.

6.2.17 The retaining wall shall be constructed by segments and length per segment should not be larger than 15m; the settlement joint shall be set at the segment joints and the area where the foundation soil strata and the variation in wall height is relatively large.

6.2.18 The retaining wall at the liquefiable soil strata and on soft foundation should take such foundation reinforcement measures as to composite the foundation and the pile foundation and the pile tip shall be stretched into the stable soil strata.

7 Bridge

7.1 General Requirements

7.1.1 This chapter is applicable to seismic design of beam bridge whose steel beam has span of less than 150m and railway reinforced concrete and prestressed concrete have span of less than 120m. Each railway culvert located in the seismic region may be free from seismic design.

7.1.2 Bridge whose fortification intensity is Intensity 7, 8 and 9 and Category B bridge

of high-level earthquake should adopt nonlinear time history response analysis method; the ductility checking shall meet the requirements of the following formula:

$$\mu_u = \frac{\Delta_{\max}}{\Delta_y} \pi [\mu_u] \tag{7.3.3}$$

Where,

μ_u——the ductility ratio of nonlinear displacement;

$[\mu_u]$——the permitted displacement ductility ratio, taking 4.8;

Δ_{max}——the maximum displacement of nonlinear response of pier;

Δ_y——the yielding displacement of pier.

The ductility design of simply-supported beam bridge pier may be calculated according to the simplified method in Appendix F of this Code.

7.4 Support and Abutment

7.4.1A The seismic region shall adopt support of which the structure is simple and easy to replace; the seismic capacity of main body of support shall be larger than its connected components; the connection of support and beam shall be stronger than the connection of support and bridge abutment; and vulnerable positions of support should adopt removable members.

Where conditions in seismic region with strong intensity permit, design of seismic reduction and isolation may be adopted; bridges which adopt seismic reduction and isolation design shall meet the requirements of normal use.

7.4.1 For the checking of support components, connection between beam and support, abutment anchor bolt and rubber support retaining facilities, the horizontal seismic force shall be calculated according to the following formula:

1 Horizontal seismic force of along-bridge fixed end:

$$F_{hE}=1.5A_g \cdot m_d - \sum \mu R_a \tag{7.4.1-1}$$

Where,

F_{hE}——the horizontal seismic force of fixed end, (kN);

A_g——the seismic peak ground acceleration value (m/s2);

m_d——the mass of simply-supported beam when it is one hole beam and of bridge floor, (t);

μ——the friction coefficient of movable support; for steel roll axle, rockshaft support and basin rubber support, μ=0.05; for plate type curved support and plate rubber support, μ=0.1~0.2;

R_a——the counterforce of movable support, (kN);

$\sum\mu R_a$——the sum of movable support friction resistance, (kN), and shall meet the relevant requirements: $\sum\mu R_a \leq 0.75A_g \cdot m_d$.

2 The movable support and fixed support bears cross-bridge direction together. Horizontal seismic force at one pier top point:

$$F'_{hE}=1.5A_g \cdot m_b \tag{7.4.1-2}$$

Where,

F'_{hE}——the horizontal seismic force at one pier top point, (kN);

A_g——the seismic peak ground acceleration value (m/s2);

m_b——see Article 7.2.5 of this Code.

7.4.2 The seismic action of abutment is calculated according to design earthquake by adopting static method, and shall meet the following requirements:

1 Horizontal seismic force of earth pillar and cone filling at front edge of foundation shall not be counted in.

2 Seismic active soil pressure acted on abutment shall be calculated according to Article 6.1.5 of this Code. The action point is located at 1/3 point of calculated height above calculated section. Where seismic soil pressure in front of abutment is calculated, corrections shall be carried out according to seism angle and the following formula:

$$\varphi_E=\varphi+\theta \qquad (7.4.2\text{-}1)$$

Where,

φ_E——the internal friction angle of soil after correction (°);

φ——the internal friction angle of soil (°);

θ——the seismic angle, which shall be selected according to those specified in Table 6.1.5.

3 Where soil pressure produced by train live load on failure wedge is calculated, the seism angle shall not be counted in.

4 The horizontal seismic force of abutment body shall be calculated according to the requirements of Article 6.1.6 of this Code; therein H is the height between abutment top surface and foundation top; the enhancement coefficient of foundation level seismic action along abutment height η_i shall take 1.

Where seismic force caused by transverse live load is calculated, the enhancement coefficient η_i value shall be the same as abutment top surface.

5 The horizontal seismic force of beam mass acted on abutment shall be calculated according to the following formula:

$$F_E=\eta\cdot A_g\cdot m_d \qquad (7.4.2\text{-}2)$$

Where,

F_E——the horizontal seismic force of beam acted on abutment, (kN);

η——the correction coefficient of horizontal seismic action; rock foundation shall take 0.20 and non-rock foundation shall take 0.25.

Where the beam is fixed support at abutment end, m_d shall be calculated by one hole beam; where both ends of beam are same support, m_d shall be calculated by half hole beam. m_d in cross-bridge direction shall be calculated by half hole beam.

The horizontal seismic force of beam mass along bridge shall act on the center of support; in cross-bridge direction shall act on 1/2 point of beam depth.

6 Where seismic soil pressure of abutment crossing liquefied soil layer is calculated, the reduction coefficient of internal friction angle shall meet the requirements of Appendix C of this Code. Any soil layer with different dynamics parameters shall be calculated in layers.

7.5 Seismic Measures

7.5.1 The aperture of bridge should be arranged according to equal span; the pier shall avoid bearing inclined direction soil pressure; the abutment should adopt T-shaped or U-shaped

------ The End ------