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JTG D40-2011

Specifications for Design of Highway Cement Concrete Pavement

公路水泥混凝土路面设计规范

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Public Notice of the Ministry of Transport of the People's Republic of China

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Public Notice of Announcing Specifications for Design of Highway Cement Concrete Pavement

Specifications for Design of Highway Cement Concrete Pavement (JTG D40 -2011) is hereby announced which will come into force from December 1, 2011, and the original *Specifications for Design of Highway Cement Concrete Pavement* (JTG D40 -2002) will be repealed simultaneously. The administration authority and interpretation authority of the Specification belong to Ministry of Transport, and the daily interpretation and administration work is borne by the chief editorial unit CCCC Highway Consultants Co., Ltd.

The units concerned should pay more attention to summer up the experience, and the problems and amendments founded should write letters to inform the CCCC Highway Consultants Co., Ltd. (Address: Room **305**, Block **A**, Desheng International Center, No.85, Deshengmen Exterior Street, Beijing, Post Code: **100088**) for research and use in the revision.

Hereby make an announcement.

Ministry of Transport of the People's Republic of China

September 19, 2011

Subject Term: Road Pavement Design Specification Public notice

General Office of the Ministry of Transport

Printed and issued on September 20, 2011

Foreword

Specifications for Design of Highway Cement Concrete Pavement (JTG D40-2002) (hereinafter referred to as the original specification) has played an important role in guiding our national design of highway cement concrete pavement of our country and guaranteeing pavement quality since it is published and implemented. With the development of China's highway construction, the highway engineering technicians have accumulated rich experience in the construction of cement concrete pavement, and have gotten many research results. What's more, cement concrete pavement technological level has been greatly improved, and technical indicators in the original specification have not meet needs. According to the requirement of the *Notice on Issuing 2007 Highway Engineering Revision Project Plan of the Ministry of Transport* (formerly Ministry of Communication) (JGLF [2007] No. 378), the CCCC Highway Consultants CO., Ltd. will act as the chief editorial unit to be responsible for the revision of the original specification.

During revision process, the preparation group conducts a more comprehensive technical research on the national highway cement concrete pavements that have been finished and are being constructed, refers to domestic scientific research results and technical information for nearly past decade home and broad, fully absorbs the construction experience of the cement concrete pavement, and extensively seeks for opinions from the relevant units and experts in this industry.

The Specification after revision is divided into 8 chapters and 5 appendices, mainly including the structure combination design of cement concrete pavement, the thickness design, the joint design, the reinforcement design of the concrete surface, the material composition design and the overlay structure design, etc.. This revision mainly increases checking standard for the concrete slab fracture limit and fatigue crack design standards for the lean concrete and RCC grassroots; increase level of heavy traffic loads in consideration of the special vehicles and special road structure design; improves joint design and caulking material model selection, perfects the two design index formulas for the crack spacing and crack width of the continuous reinforcement; increase the amount of concrete slab flat and joint load transfer rating criteria; and improves the material design parameter experience reference values.

If the organizations and individuals concerned have found problems in using this Specification, please write letters to inform the Highway Planning and Design Institute Limited (Address: Room

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1 General

1.0.1 This specification has been established to adapt the requirements of traffic development and highway construction, improve design quality and technical level of cement concrete pavement, and guarantee the safety, reliability, economics and rationality of project.

1.0.2 This specification is suitable for cement concrete pavement design of new-building and rebuilding highway.

1.0.3 Cement concrete pavement design scheme shall, base on the highway function and level, and combined with the local climate, hydrology, geology, materials, construction and maintenance conditions, engineering practice, environmental protection, etc., be determined through comprehensive analysis.

1.0.4 The cement concrete pavement design shall include designs of structural combination, structural layer thickness, material composition, joint structure, reinforcement configuration and others.

1.0.5 Cement concrete pavement structure shall according the stated safety level and target reliability requirements, withstand the expected traffic loads function in the design reference period, adapt to its natural environment, and meet the scheduled operational performance requirements.

1.0.6 The cement concrete pavement design besides complying with the requirements of this specification; it also should be consistent with the requirements of the national existing related standards.

2.1.11 Reliability index

A quantitative index for the measurement of pavement structural reliability. The reliability index required of the designed structures is called the objective reliability index.

2.1.12 Reliability coefficient

Single comprehensive coefficient adopted in limit state design expression to guarantee designed structure possessing regulated reliability.

2.2 Symbols

2.2.1 Symbols of action and action effects

N —The number of the role of axle load;

P —Axle load;

σ —Stress;

ε —Strain;

w —Deflection.

2.2.2 Symbols of design parameters and calculation coefficients

C —Coefficient of temperature strain

C_v —Coefficient of variation

γ_r —Reliability coefficient;

ρ —Reinforcement ratio;

t —Time;

T —Temperature.

2.2.3 Geometric parameter

A —Area;

b —Width;

d —Diameter;

h —The thickness of structural layer;

l —Length;

L —Distance.

2.2.4 Material performance

D —Bending stiffness

E —Elastic modulus;

f —Intensity;

r —Relative stiffness radius;

α —Coefficient of liner expansion;

ν —Poisson's ratio.

reliability, variation level and variation coefficient;

f_t —The standard value of flexural-tensile strength of cement concrete(MPa) should comply to Table 3.0.8

3.0.5 The lean concrete or roller compacted concrete base layer shall take the traffic load not inducing fatigue crack within the design reference period as the design standard. Its limit state design expression can use formula (3.0.5).

$$\gamma_s \sigma_{bpr} \leq f_{br} \quad (3.0.5)$$

Where: σ_{bpr} —The calculation method of vehicle load fatigue stress generated within the basic layer (MPa), see Appendix B;

f_{br} —Flexural strength standard value of base material (MPa).

3.0.6 When conduct the structural analysis with fatigue crack design according to the fatigue fracture standard, take a pair of double-wheel loading (100kN for each axial) as the design axle load, for the cement concrete pavement with extremely heavy traffic loads, the axle load of the special heavy vehicle accounting for a major share in trucks is appropriate choice as the design axle load. The number of role of all levels of axial load N_i can be converted into the role number of the design axle load N_s according to equation (3.0.6).

$$N_s = \sum_{i=1}^n N_i \left(\frac{P_i}{P_s} \right)^{16} \quad (3.0.6)$$

Where: P_i — i -th class axle load (kN), coupling should be counted separately as per axle load;

P_s —Design axle load (kN);

n —Axial load level digits of variety of shaft type;

N_i —The role number of i -th class axle load;

N_s —The role number of design axle load.

3.0.7 The effect numbers of cumulative axle loading borne by the cement concrete pavement design lane in the design reference period shall be investigated and analyzed according to the Appendix A, i.e. effect numbers of cumulative axle loading borne at the design lane critical load are fifth class. See Table 3.0.7 for the grading scope.

4 Structural composite design

4.1 General provisions

4.1.1 We shall select and compose the corresponding cement concrete pavement structure according to highway level, traffic load, subgrade condition, local temperature and humidity condition as well as operational performance requirements.

4.1.2 The pavement structural combination design shall make the mechanical properties and composition material properties of various structural layers meet corresponding functional requirements.

4.1.3 Shall take full account of interaction, interlayer bonding condition and requirement of all adjacent structural layers, as well as coordination and balance of structural combination.

4.1.4 Should take full account of the infiltration and erosion effect of surface water. Measures of sealing and drainage are used to reduce surface water infiltration and prevent the stagnation of infiltration of water in the pavement structure. The base should use the material with strong anti-erosion ability.

4.2 Subgrade

4.2.1 Subgrade shall be stable, dense and homogenous, which shall be able to provide even support for pavement structure.

4.2.2 The comprehensive resilience modulus on the top surface of the road bed shall be not less than 40MPa for the light traffic load class, not lower than 60MPa for the moderate or heavy traffic load class, and not lower than 80MPa for especially heavy or extremely heavy traffic load class.

4.2.3 Subgrade filler shall meet the following requirements:

1 High liquid limit clay and fine-grained soil containing organic substances shall be not used as roadbed filler of express highway and first class highway, or upper roadbed filler of second-class highway and other highways.

2 High liquid limit silt and low liquid limit clay with plasticity index higher than 16 or expansion ratio higher than 3% shall not be applied for upper roadbed filler of express highway

and first class highway.

3 When the abovementioned soil must be adopted as the filler due to constraints, the binders of cement, fly-ash or lime shall be adulterated to improve the situation.

4.2.4 When the roadbed top surface comprehensive resilience modulus does not meet the requirement of Article 4.2.2, the coarse-grained soil or low dosage of inorganic binder stabilized soil shall be selected as roadbed or upper roadbed filler. When the subgrade working area underside approaches or is lower than the underground water level, we can take measures of changing fillers, setting drainage sewer and others.

4.2.5 For the moderately moistening, moistening and excessive moistening roadbeds in seasonally- frozen areas, when frost line depth reach to the easily frost heaving layer of the roadbed, the easily frost heaving layer shall be provided with cushion or be replaced with the not-easily frost heaving soil within the range of frost lined depth.

4.2.6 Underground drainage measures should be taken for the poor soil cuttings with poor hydrogeological conditions.

4.2.7 After reinforcing and treating weak and soft foundations below embankment, the settlement after construction shall meet the provisions of *Highway Subgrade Design Regulations* (JTG D30), and the aggregate layer shall be paved on top of roadbed.

4.2.8 When cutting or filling the junction section or the combination section of new and old subgrade, the technical measures to prevent the differential settlement should be taken

4.2.9 Leveling layer should be laid on the rocky excavation or the top of the rock fill road bed. The leveling layer can adopt gravels, low dosage of stable cement aggregates and other materials, and its thickness can be determined according to the leveling degree of roadbed top surface, but the minimum thickness shall not be less than 100mm.

4.3 Bed layer

4.3.1 In case of the following conditions, under layer should be set under the base or subbase:

1 When the pavement structure thickness is smaller than the minimum anti-freezing depth (Table 3.0.9) in seasonal frozen area, the anti-freezing bedding shall be set to make the pavement structure thickness meet the requirements.

subbase layer may not be set. When the stable inorganic binder materials are adopted for base layer and the upper roadbed is composed of fine-grained soil, the subbase layer of granular material shall be set below base layer.

4.4.4 When the stable inorganic binder materials are adopted for base layer, the granular materials with the particle size of less than 0.075mm and content of less than 7% shall be selected for subbase layer.

4.4.5 Lean concrete or roller compacted concrete base should be laid with the asphalt concrete sandwich, and the layer thickness should not less than 40mm. The seal coat shall be set on the inorganic binder stabilized crushed stone base layer, which can adopt single-layer asphalt surface treatment or suitable coating materials. When using a single layer of asphalt surface to treatment, the thickness of the layer should not less than 6mm.

4.4.6 In high-rainfall areas, the expressway and first class highway whose roadbed consists of fine-grained soil with low permeability or the secondary road that bears the extremely heavy or extra heavy traffic load shall be provided with the drainage base that consists of ATPB (asphalt-treated permeable base) and cement-stabilized gravel base. The waterproof subbase layer composed of the close-graded aggregates or cement stabilized crushed stone shall be set below the drainage base layer. The top surface of the subbase should be laid with asphalt type of seal coat or waterproof geotextile.

4.4.7 The suitable compaction depth of various structural layers of base layer and subbase layer shall be determined according to the maximum nominal particle size and compaction effect requirements of the selected aggregates. The layered laying and compaction shall be conducted when the design layer thickness of base layer or subbase layer exceeds the suitable compaction depth range of corresponding materials.

4.4.8 The calculation thickness of lean concrete or roller compacted concrete base layer shall meet the requirement of Formula (3.0.5). The base design thickness should round up to an integer from 10mm according to the calculated thickness.

4.4.9 The calculation thickness of open-graded asphalt stabilized crushed stone or cement stabilized crushed stone drainage base shall meet the need of design permeating amount of

removing surface water. Drainage base design thickness should plus 20mm after rounded up to an integer from 10mm according to the calculated thickness.

4.4.10 When hardened verge using the concrete pavement, the base structure and thickness should be in line with the traffic lane. The base layer shall be 300mm (for construction with small machines and tools) or 650mm (for construction with sliding mode paver) wider than concrete surface layer in each side.

4.4.11 Roller compacted concrete base should set seams corresponding to the concrete pavement. The traverse contraction joint corresponding to surface layer shall be set when the flexural-tensile strength of lean concrete base layer is larger than 1.5MPa; the longitudinal contraction joint shall be set when the paving width at a time is larger than 7.5m.

4.5 Surface layer

4.5.1 Cement concrete surface layer shall be of enough strength and durability, skid resistant, wear resistant and flattening.

4.5.2 Plain concrete with joint shall be adopted for surface layer; reinforcing concrete surface with dowel bar shall be adopted when plane dimensions of surface sheet is large or the shape of sheet is irregular, or subsidence, or underground establishment is lain under pavement structure, or the subgrade is high-filled base, soft-soil foundation or cut-cover junctions, where uneven subsidence is likely to appear. The continuous reinforced concrete, roller compacted concrete, steel fiber concrete and other surface layer types can be selected according to suitable conditions.

4.5.3 The thickness calculation of the joint plain cement concrete, reinforced concrete, RCC and continuously reinforced concrete pavement can be determined based on traffic load rating, road grade, and variation level through formula (3.0.4-1) and the formula (3.0.4-2). We shall round up the design thickness of various concrete surface layers to an integer by 10mm on the basis of calculation thickness plus 6mm wearing layer.

4.5.4 The steel fiber volume fraction of steel fiber concrete shall be 0.6%-1.0%, and its surface layer shall be 0.75-0.65 times of ordinary concrete surface layer in thickness, which is determined by adulterate steel fiber amount. In case of extra heavy or heavy traffic load, the

4.6.2 Traffic lane concrete pavement should be 0.6m wider than the outside lane edge line.

4.6.3 As for the express highway, first class highway and those bearing extremely heavy, extra heavy and heavy traffic load, the road shoulder pavement shall be the same as the carriageway pavement in the combined and composed structural layer materials. As for other classes of highways, the road shoulder pavement base layer and subbase layer shall be the same as the carriageway pavement structure in material type and thickness.

4.6.4 The cement concrete or asphalt materials shall be selected for the road shoulder surface layer. When selecting asphalt material for the road shoulder surface, the highway with medium traffic load or above level shall adopt hot mix asphalt; the low-grade highway and the highway with light traffic can adopt asphalt surface for the treatment. When the aggregate material is used for the road shoulder base layer, the content of fine materials (less than 0.075mm) shall not exceed 6%.

4.6.5 The road shoulder concrete surface layer and carriageway surface layer shall be linked with tension rod, and the traverse contraction joint of the two shall be connected. In case the continuous reinforced concrete is used for carriageway surface layer, the traverse contraction joint space of the road shoulder concrete surface layer shall be 4.5m.

4.7 Surface drainage

4.7.1 The cross slope of carriageway pavement shall be 1%-2%, and that of road shoulder surface shall be 2%-3%.

4.7.2 Longitudinal collecting ditch and collector drain with holes shall be set in the outside of drainage base or bed layer when drainage base or bed is set in driveway surface structure, meanwhile, traverse drainage pipe shall be set in each 50—100m.

4.7.3 For the catch pit of drainage base longitudinal edge can be set in the inner edge of the shoulder when asphalt surface layer is adopted for shoulder, or set under the shoulder or external edge of the shoulder when cement concrete pavement is adopted for shoulder. The longitudinal edges collecting gutter of the drainage under layer should be located on the road bed edges.

4.7.4 Hole diameter of collector drain with holes is generally adopted 100-150mm. The width

5 Joint design

5.1 General provisions

5.1.1 The plane layout of the joint plain cement concrete, reinforced concrete, RCC and steel fiber concrete pavement shall adopt the rectangular blocks, and its longitudinal and transverse joints shall be perpendicularly intersected; the transverse joints on both sides of the longitudinal joints shall not be mutually staggered.

5.1.2 The spacing of the longitudinal seams (i.e. plate width) should be selected in the range of 3.0 - 4.5m.

5.1.3 The spacing of the lateral seams (i.e., plate length) should be selected according to the pavement type and thickness:

- 1 The reinforced concrete surface layer shall be 4-6m long, the length-width ratio of surface layer plate shall not exceed 1.35, and the area of plane shall not be larger than 25m².
- 2 Roller compacted concrete or steel fiber concrete pavement should be 6 - 10m.
- 3 The reinforced concrete surface layer shall be 6-15m long, the length-width ratio of surface layer plate shall not exceed 2.5, and the area of plane shall not be larger than 45m².

5.2 Longitudinal joint

5.2.1 The laying of longitudinal joint shall be determined depending upon the total width of pavement, width of carriageway and hard shoulder and paving width of construction:

- 1 Longitudinal construction joint shall be set when one-off paving width is lower than pavement width. Flat joint with sawing groove filled in joint filler in upside shall be adopted for longitudinal construction joint, the depth and width of which is 30-40mm and 3-8mm, respectively. Its structure is shown in Figure 5.2.1 a).
- 2 Longitudinal contraction joint shall be set when one-off paving width is higher than 4.5m. Pull rod dummy joint form shall be set for longitudinal contraction joint, with sawing rabbet depth higher than that of construction joint. Rabbet depth shall be 1/3 and 2/5 of board thickness for grain base and semirigid base, respectively. Its structure is shown in Figure 5.2.1. b).
- 3 When the one-off paving width of the roller compacted concrete pavement is greater than

concrete pavement should be determined by the following requirements:

- 1 The average width of the crack gap in the buried depth of the longitudinal reinforcement should be no more than 0.5mm.
- 2 The average spacing of the transverse cracks should no more than 1.8m.
- 3 The tensile stress born by the reinforcement should not exceed its yield strength.
- 4 The longitudinal reinforcement ratio that meets the above requirement shall be 0.6% to 0.7% for the moderate traffic load rating, 0.7% to 0.8% for the heavy traffic load rating, and 0.9% to 1.0% for the extra heavy traffic load rating. The ratio of reinforcement of the pavement in frozen regions should by 0.1% higher than the general regions. See the calculation method of the required ratio of reinforcement in Appendix D.
- 5 When the continuous reinforced concrete is used for the lower layer combined surface layer, its longitudinal reinforcement ratio can be reduced by 0.1%.

6.3.2 The dosage of traverse reinforcement shall be calculated and determined according to Article 6.2.1, and shall meet the requirement of fixing and keeping longitudinal reinforcement position during construction.

6.3.3 The longitudinal and traverse reinforcements of continuous reinforced concrete surface layer shall be the screw-thread reinforcements, and the diameter shall be 12-20mm. The corrosion prevention materials such as epoxy resin shall be coated outside of reinforcement when it may be subject to severe corrosion.

6.3.4 The reinforcement layout shall comply with the following requirements:

- 1 The distance between longitudinal reinforcement and surface layer top surface shall not be less than 90mm, and the maximum depth shall not be larger than 1/2 of surface layer thickness and shall be nearly 90mm in the condition of not influencing construction.
- 2 The space of longitudinal reinforcement shall be no more than 250mm and no less than 2.5 times of the maximum aggregate particle size.
- 3 The length of the longitudinal reinforcement to be welded should be greater than 10 times (one side welding) of the reinforcement diameter and be staggered. The included angle formed by

should be 4%-6%, while medium and light it should be 4%.

7.3.3 The claimed maximum granule diameter of the lime powder aggregate should be 26.5mm. The fine granule less than 0.075mm should contain no more than 7%. The granule less than 4.75mm should contain no more than 50%. The proportioning of lime and coal powder lime should be 1:2-1:4 and the proportioning of between granule and the lime as well as coal powder lime should be 85:15-80:20.

7.3.4 Asphalt concrete base shall adopt the mixture with the aggregate nominal maximum particle size of 19.0mm or 26.5mm, asphalt treated base shall use mixture with the aggregate nominal maximum particle size of 26.5mm or 31.5mm, and asphalt concrete interlayer shall adopt mixture with the aggregate nominal maximum particle size of 9.5mm or 13.2mm. The asphalt dosage in various asphalt mixture should be increased appropriately.

7.3.5 The nominal maximum particle size of the open gradation asphalt stabilized crushed stone aggregate is appropriate as 26.5mm or 31.5mm. The fine particle content with the particle size less than 0.075mm shall not be larger than 2%; the content of particle size less than 2.36mm shall be no more than 5%; the content of particle size less than 4.75mm shall be no more than 10%; The cement dosage should be 9.5%-11%.

7.3.6 The nominal maximum particle size of the open gradation asphalt stabilized crushed stone aggregate is appropriate as 19.0mm or 26.5mm. The fine particle content with the particle size less than 0.075mm shall be no more than 2%; the content of particle size less than 0.6mm shall be no more than 5%; the content of particle size less than 2.36mm shall be no more than 15%; the content of particle size less than 4.75mm shall be no more than 20%. Asphalt label should be used 50A or 70A, the amount of asphalt is desirable to 2.5% to 3.5%.

7.4 Surface material

7.4.1 The nominal maximum particle size of roller compacted concrete aggregate should not be greater than 26.5mm. The sand fineness modulus shall not be less than 2.5; the siliceous sand or quartz sand content in the sand adopted in express highway surface layer shall not be lower than 25%. The cement dosage shall not be less than 300kg /m³ (not cold area) or 320kg /m³ (cold area). The concrete in frozen regions must be mixed with air-entraining agent.

7.4.2 The ordinary concrete surface layer with width of more than 300mm can be paved continuously as upper and lower layer. The upper layer thickness shall not be less than 1/3 of total thickness, the high-strength wear-resistant concrete materials shall be adopted, and the maximum nominal particle size of aggregates shall not be larger than 19mm.

7.4.3 The maximum nominal particle size of steel fiber concrete aggregates shall be 1/2-2/3 of steel fiber length and shall not be larger than 16mm. The standard value of flexural-tensile strength of steel fiber shall not be less than Level 600 (600 -1,000MPa). The cement dosage shall not be less than 360kg /m³ (not cold area) or 380kg /m³ (cold area).

7.4.4 The claimed maximum granule diameter of the roller concrete aggregate in the roller concrete surfacing should be no more than 19.0mm. The cement dosage should be no less than 280kg/m³ (not cold area) or 310kg/m³ (cold area).

7.4.5 The compressive strength of the concrete block should be no less than 50MPa (not cold area) or 60MPa (cold area). The natural sand with the fineness modulus of 2.3-3.0 shall be selected as the sand mat, the accumulative screen residue of 4.75mm mesh shall not be larger than 5%, and the silt content shall not be larger than 5%.

7.5 Material design parameters

7.5.1 The rebound modulus of soil and aggregate shall be determined by repeated load triaxial compression test. The dimensions of the soil specimen should be of 100mm in diameter and 200mm in height (the maximum particle size of no more than 19mm), the dimensions of aggregate specimen should be of 150mm in diameter and 300mm in height.

7.5.2 The elasticity modulus of inorganic binder stabilized material should be determined by uniaxial compression test. The dimensions of specimen size should be of 100mm in diameter and 200mm in height or 150mm in diameter and 300mm in height. 90d shall be adopted as the test piece age of stable cement material, and 180d for that of stable fly-ash material. The test piece shall be soaked in water for 1d before determination.

7.5.3 The dynamic Modulus of asphalt mixture should be determined by periodically loaded uniaxial compression test. The dimensions of the specimen should be of 100mm in diameter and 150mm in height.

7.5.4 We can refer to Appendix E for the value when determining various design parameters

8 The design of the additional layer structure

8.1 General provisions

8.1.1 The following should be investigated before laying the additional layer on the old concrete surfacing.

1 The material of road construction and maintenance: the road structure, material makeup, joint structure and maintenance history.

2 The damage condition of the road: damage type, damage extent and scope as well as the repair measures.

3 The structure strength of the road: crook and sink of the road, load transfer ability of joint, the hollow condition of the board, thickness of the surfacing and the concrete strength and so on.

4 The endured traffic load and the expected traffic need: traffic capacity, load makeup and the growth rate and so on.

5 Environment conditions: the climate condition along the road, the water table and the drainage of the road bedding and surfacing and so on.

6 Bridge and tunnel clearance: The requirements of along flyover and tunnel clearance.

8.1.2 As for the highway with bad surface- and sub-drainage, we shall take measures to improve it or increase surface- and sub-drainage facilities; as for the highway of old concrete pavement structure with bad drainage, we shall increase drainage system on pavement edges.

8.1.3 The additional paving layer design shall include the design scheme of traffic maintenance and traffic safety organization and administration, etc. during construction.

8.1.4 The waste pavement materials should be fully utilized to reduce the adverse impact on the environment.

8.2 Road damage condition assessment through investigation.

8.2.1 The damage condition could be accessed through two indexes: the board cracking rate and average wrong flat. The investigation and calculation of the board cracking rate could be carried out in accordance to *Maintenance Technical Regulations of Cement Concrete Road Surface* (JTJ 073.1). The stagger instrument shall be used to measure elevation of plate edges at both sides of the joint, and the measured point is at 300mm of the right edge of the serious staggering lane, so as to investigate that average of elevation difference of each joint represents

8.4 The structure coefficient investigation of the old concrete road

8.4.1 The standard value of old concrete surface course thickness can be calculated and determined according to the measured height of drilling core and Formula (8.4.1).

$$h_e = \bar{h}_e - 1.04s_h \quad (8.4.1)$$

Where: h_e —The standard values of the old concrete surface layer measured thickness (mm);

$\bar{h}_e$ —The average values of the old concrete surface layer measured thickness (mm);

s_h —The standard deviation of the Old concrete surface layer measured thickness (mm).

8.4.2 Calculate and determine the standard value of flexural-tensile strength of old concrete pavement according to Formula (8.4.2-1) and Formula (8.4.2-2) by adopting the splitting test determination result of drilling core.

$$f_r = 1.87f_{sp}^{0.87} \quad (8.4.2-1)$$

$$f_{sp} = \bar{f}_{sp} - 1.04s_{sp} \quad (8.4.2-2)$$

Where: f_r —The flexural-tensile strength standard value of the old concrete surface layer (MPa);

f_{sp} —The splitting strength standard value of the old concrete surface layer (MPa);

$\bar{f}_{sp}$ —The average value of the splitting strength measured values of the old concrete surface layer(MPa);

s_{sp} —The standard deviations of the splitting strength measured values of the old concrete surface layer (MPa).

8.4.3 The flexural-tensile elasticity modulus standard value of the old concrete surface layer can be determined according to formula (8.4.3).

$$E_c = \frac{10^4}{0.09 + \frac{0.96}{f_r}} \quad (8.4.3)$$

Where: E_c —The flexural-tensile strength standard value of the old concrete surface layer (MPa)

f_r —The standard value of bending elasticity modulus of the old concrete surface layer (MPa).

8.4.4 The standard value of equivalent modulus of resilience of basal topping of old concrete pavement was measured according to Formula (8.4.4-1) and Formula (8.4.4-2) by using the falling weight deflectometer (design load 100kN,radius of bearing plate:150mm) to measure the deflection curve with load effect on the side plate.

$$E_t = 100e^{3.60 + 24.03\omega_0^{0.007} - 15.635\omega_0^{0.002}} \quad (8.4.4-1)$$

$$SI = \frac{w_0 + w_{300} + w_{600} + w_{900}}{w_0} \quad (8.4.4-2)$$

Where: E_t —The standard value of equivalent modulus of resilience of basal top surface (MPa);

SI —The load diffusion coefficient of pavement structure;

ω_0 —The deflection value at the center of the load (μm);

ω_{300} , ω_{600} , ω_{900} —These are the deflections values at the location with the distance of 300mm, 600mm and 900mm from the load center respectively (μm).

When conditions are limited for using the falling weight deflectometer, beam deflection measure can also be conducted on the base top after clearing the broken concrete slab, and then conduct the back calculation according to the Appendix B (Formula B.2.5), or it can be determined according to the material composition of the base drilled core and property condition.

8.5 Selection of overlay scheme

8.5.1 According to the operating requirement and comprehensive assessment result of old concrete pavement, the addition scheme of separated or combined cement concrete and asphalt concrete can be selected, which can be determined after technological and economical comparison.

8.5.2 When the damaged conditions and joint load transfer of the old concrete pavement are rated as excellent, plane size of the surface plate and joint arrangement are reasonable, and road hump cross slope meets the requirements, combined concrete overlay scheme, separating concrete overlay scheme or asphalt concrete overlay scheme can be selected.

8.5.3 When the damaged conditions and joint load transfer of the old concrete pavement are rated as moderate or more, or the old and new concrete slabs are different in plan sizes, joint form or position does not correspond, or the road hump cross slopes are inconsistent, separating concrete overlay scheme or asphalt concrete overlay scheme can be selected.

8.5.4 The rating of old concrete pavement damage condition and joint load transfer ability is above inferiority, the additional paving scheme of asphalt concrete can be adopted.

8.5.5 During overlaying, old cement concrete pavement must be treated, it is necessary to replace broken plates, repair and fill in cracks, mud-jack and pack slab hollow, polish staggering, remove the loose debris, oil stains or tire scratches on the old concrete surface layer, remove the

invalid fillers and debris in joints, and re-seal the joints.

8.5.6 During overlaying, for the road section with significant slab hollow in inspection, it shall use pressed materials to fill in the slab hollow. The slurry material shall have good fluidity, high early strength, no segregation, no bleeding, no shrinkage, etc.

8.5.7 When the old cement concrete pavement is damaged seriously, crack and seat scheme or rubblization scheme can be used to treat old concrete pavement. According to road grade and traffic conditions, the treated old pavement is used for the base or subbase of the rebuilt pavement.

8.5.8 For the crack and seat scheme, after cracking, more than 75% old concrete slab shall be used to produce irregular cracking, and block area formed between adjacent cracks is 0.4 - 0.6m²; for the rubblization reconstruction scheme, after cracking, 75% old concrete slab shall be crushed into particles with maximum size less than 400mm.

8.6 The design of the pitch additional layer structure

8.6.1 For the asphalt overlay, single-layer or double-layer asphalt pavement can be set, and at least one layer uses dense graded asphalt mixture; the leveling layer can be set up as required; at the edge of the pavement, internal drainage system shall be arranged.

8.6.2 We shall spread modified asphalt between the additional asphalt paving layer and original cement concrete panel, strengthen combination among layers, and avoid slippage among layers.

8.6.3 We shall reasonably select the following measures of slowing down reflection crack according to temperature, load, bearing capacity of old concrete pavement, joint load transfer ability, etc.:

- 1 Increase the thickness of asphalt overlay.
- 2 Mix fibers, rubber and other modifiers in the overlay asphalt mixture.
- 3 Set up stress absorbing layer, polyester fiberglass cloth or geotextile interlayer on the top face of the old concrete slab or overlay.
- 4 Use large particle size asphalt macadam in the sublayer of asphalt overlay.

8.6.4 Asphalt overlay thickness should be determined by considering the matching of the nominal maximum particle size and the requirements of mitigation reflection crack. The minimum

thickness of expressway and the first class highway is desirable for 100mm, and that of the other grade highway is desirable for 80mm.

8.6.5 The stress analysis of the old concrete slab under the asphalt overlay should be conducted according to Appendix C. The thickness of the old concrete, bend and pull of the concrete, standard elasticity modulus, and equivalent weight standard elasticity modulus should adopt the tested results, prescribed in 8.4. The old concrete slab stress should meet the requirements of formula (3.0.4).

8.6.6 The composition design of asphalt mixture shall be conducted according to the current *Highway Asphalt Pavement Construction Technology Regulations* (JTGF40).

8.7 Additional layer structure design of the separated concrete

8.7.1 The isolation layer should be set up between the old concrete surface layer and the overlay. The isolation layer material should be selected asphalt concrete with the thickness of not less than 40mm.

8.7.2 The joint form and location of separated concrete overlay should be arranged according to the requirements of the newly built concrete surface layer.

8.7.3 The additional layer could adopt plain concrete, steel fiber reinforced concrete, joined reinforced concrete and continuous reinforced concrete. The thickness of the additional layer of plain concrete, joined reinforced concrete and continuous reinforced concrete should be no less than 180mm. While the steel fiber reinforced concrete, should be no less than 140mm.

8.7.4 The stress analysis of the additional layer and old concrete layer could be carried out in a way the separated double-layer does. Please refer to Appendix B.4 and B.5. Thickness of the old concrete, bend and pull strength, elasticity modulus and equivalent weight elasticity modulus of the root course surface should be decided in a way prescribed in 8.4. The standard bend and pull value should apply to the Table 3.0.8. The thickness of the additional layer should meet the requirement of the formula (3.0.4) according to the stress of the additional layer and the old concrete board.

8.8 Additional layer structure design of the combined concrete

8.8.1 Milling, or high-pressure water jetting, acid etching and other methods shall be adopted to trim and clean old concrete pavement surface and apply adhesive on the surface after cleaning, so that the overlay and the old concrete pavement can be combined into a whole.

8.8.2 The thickness of combined type overlay should not be less than 80mm. The form and position of additional paving layer shall completely correspond to and align with the joint of old concrete surface course, and the tension rod or dowel bar may not be set in the additional paving layer.

8.8.3 The stress analysis of the added layer and old concrete, should be done in a combined double-layer way. Refer to the Appendix B.6 for a calculation method. The thickness of the old concrete, bend and pull of the concrete, standard elasticity modulus, and equivalent weight standard elasticity modulus should adopt the tested results, prescribed in 8.4. The designed thickness of the added layer should meet the requirement of the formula (3.0.4) according to the stress of the additional layer and the old concrete board.

8.9 The structural design of the old asphalt pavement overlayed by cement concrete pavement

8.9.1 Old asphalt concrete can use cement concrete overlay. The severe track and upheaval shall be milled and planed before construction of additional paving layer, and the structural reinforcement shall be conducted for the highway with severe potholes and net-shaped cracking.

8.9.2 Leveling layer should be paved between the old asphalt surface and the cement concrete overlay. Leveling layer materials can use asphalt concrete and other materials.

8.9.3 The additional layer could adopt plain concrete, steel fiber reinforced concrete, joined reinforced concrete and continuous reinforced concrete. The thickness of the additional layer of plain concrete, joined reinforced concrete and continuous reinforced concrete should be no less than 180mm. While the steel fiber reinforced concrete, should be no less than 140mm.

8.9.4 We can calculate and determine the equivalent resilience modulus of old asphalt pavement surface course according to Formula (B.2.5) in Appendix B, and design the additional layer according to the newly built cement concrete pavement.

8.9.5 Ultra-thin cement concrete overlay thickness is preferably 80 - 130mm, panel plane size

local economic and transportation development.

A.2 Axial loading investigation and analysis

A.2.1 We can conduct the axle type investigation of various vehicles and axle weight measurement by setting stations on the spot, or utilize the area or according to vehicle types, shaft types and axle load measurement statistics of the similar road types in the existing weighing station, obtain vehicle type, axle shaft type and axle load data of the designed highway, as well as the heaviest axle loads and axle load of the heavy vehicles that account for a major part.

A.2.2 When weighing and conducting statistics for various types of vehicles by axle type, we can adopt the axle load equivalent conversion coefficient method based on axle type to calculate and analyze the design axle load action times in early use of the design lane. Conduct random statistics for the occurrence times of single axle in different types of axles (such as single axle, double-axle and tri-axle) in 3,000 vehicles of 2 axles and 6 wheels and of above levels, and respectively weigh the single axles. We can get the axle load spectrum after statistics and sorting-out by single axle weight level, and calculate and determine the design axle load equivalent conversion coefficient of different axle weight levels according to Formula (A.2.2-1).

$$k_{p,i} = \left(\frac{P_i}{P_s} \right)^{16} \quad (\text{A. 2. 2-1})$$

Where: $k_{p,i}$ —The design axle load equivalent conversion factor of different uniaxial axle weight level i -th;

P_i —The axle weight of uniaxial level i -th (kN)

P_s —Design the axle weight of the axle load (kN)

Based on the single axle load spectrum and corresponding design axle load equivalent conversion coefficient, the design axle load action times in early use of the design lane can be calculated according to Formula (A.2.2-2).

$$N_s = \text{ADTT} \frac{n}{3\,000} \sum_i (k_{p,i} \times p_i) \quad (\text{A. 2. 2-2})$$

Where: N_s —The Design-lane design axle load times day role [Axle/ (Driveway • Day)];

ADTT—Design annual average daily truck lane traffic [Vehicle/ (Driveway • Day)];

n —The total number of axes of uniaxial appeared in the randomly surveyed 3,000 vehicles with 2 axes 6 wheels or more;

P_i —The frequency of uniaxial axle weight level i -th (in fraction).

A.2.3 When weighing and conducting statistics for axle loads of various types of axles based on vehicle types, the vehicle equivalent axle load coefficient method can be adopted to calculate and analyze the design axle load action times in early use of the design lane.

Classify the vehicles of 2 axles and 6 wheels and of above levels into 3 major kinds of finished vehicle, semi-trailer and multiple-trailer, subdivide each kind of vehicle by number of axles, and get the single axle load spectrum after respectively weighing them by vehicle type. The design axle load equivalent conversion factor of various types of vehicles can be calculated by formula (A.2.2-1) and formula (A.2.3-1).

$$k_{p,k} = \sum_i k_{p,i} P_i \quad (\text{A.2.3-1})$$

Where: $k_{p,k}$ —The design axle load equivalent conversion factor of k type of vehicles;

P_i —The frequency of uniaxial axle weight level i -th of k type of vehicles (In fraction).

We can determine the design axle load action times of the design lane in early use through calculation by Formula (A.2.3-2) based on the vehicle type composition data obtained in investigation.

$$N_s = \text{ADTT} \times \sum_i (k_{p,i} \times p_k) \quad (\text{A.2.3-2})$$

Where: P_k —The composition ratio of k type of vehicles (In fraction).

A.2.4 The accumulative action times of design axle load borne at the critical load position of design lane of cement concrete pavement in the design reference period shall be calculated and determined according to Formula (A.2.4).

$$N_e = \frac{N_s \times [(1 + g_t)^t - 1]}{g_t} \times \eta \quad (\text{A.2.4})$$

Where: N_e —The cumulative number of the design axles born by the design driveway within the design reference period (Axle/lane);

t —design reference period (a);

g_t —The average annual growth rate of the truck traffic volume within the reference period (In

Appendix B

Stress analysis and thickness calculation of the concrete slab

B.1 Mechanical model

B.1.1 The following mechanical model can be adopted by pavement structural analysis respectively according to different bases, surface types and combinations:

1 Monolayer plate model of elastic foundation—Apply to concrete pavement on granular base and concrete surface overlaid of old asphalt pavement; section under surface plate is treated according to elastic foundation.

2 Doubling plate model of elastic foundation—Suitable for inorganic binder base or asphalt base concrete pavement, old concrete pavement overlaying separate concrete surface; pavement and base or of new or old pavement as double-layer plate, the part under base bottom or old pavement bottom are treated as the elastic foundation.

3 Composite plate model—Apply to topping plate or basal composite plates combined with two layers of different performance materials. Old concrete pavement overlays combined concrete pavement, and the felted pavement composed of two layers of different material properties is taken as the monolayer plate on elastic foundation or upper plate of the doubling plate on elastic foundation; the base consisting of inorganic binder base or asphalt base and inorganic mixture subbase is taken as the bottom plate of the double-layer plate on elastic foundation.

B.1.2 Critical load position of concrete topping plate locates at the central of the longitudinal seam edge. Critical load position of basal plate is same with the same plate.

B.2 Load stress of elastic foundation monolayer plate

B.2.1 Load fatigue stress generated by design axle load at the critical load of topping plate shall be calculated according to formula (B.2.1).

$$\sigma_{pr} = k_1 k_2 k_3 \sigma_p \quad (\text{B.2.1})$$

Where: σ_{pr} —The load fatigue stress (MPa) generated by design axis load at the critical load of topping plate:

B.2.3 Load fatigue stress coefficient k_f within design reference period should be calculated by formula (B.2.3-1).

$$k_f = N_e^{\lambda} \quad (\text{B. 2. 3-1})$$

Where: N_e —Designing number of cumulative effect of axle load within design reference period is calculated by formula (A.2.4) in appendix A.

λ —For the material fatigue index, plain concrete, reinforced concrete, continuously reinforced concrete, $\lambda = 0.057$; for the RCC and lean concrete, $\lambda = 0.065$; for the steel fiber reinforced concrete, calculate according to the formula (B.2.3-2);

$$\lambda = 0.053 - 0.017 \rho_f \frac{l_f}{d_f} \quad (\text{B. 2. 3-2})$$

ρ_f —Volume ratio of steel fiber (%);

l_f —Length of steel fiber (mm);

d_f —Diameter of steel fiber (mm).

B.2.4 Equivalent rebound modulus of slab bottom of new highway shall be calculated by formula (B.2.4-1).

$$E_t = \left(\frac{E_x}{E_0} \right)^{\alpha} E_0 \quad (\text{B. 2. 4-1})$$

$$\alpha = 0.86 + 0.26 \ln h_x \quad (\text{B. 2. 4-2})$$

$$E_x = \sum_{i=1}^n (h_i^2 E_i) / \sum_{i=1}^n h_i^2 \quad (\text{B. 2. 4-3})$$

$$h_x = \sum_{i=1}^n h_i \quad (\text{B. 2. 4-4})$$

Where: E_0 —Integrated rebound modulus of roadbed top (MPa);

α —The regression coefficients related to the total thickness of aggregate layer h_x is calculated by formula (B.2.4-2);

E_x —Equivalent rebound modulus of aggregate layer (MPa) is calculated by formula (B. 2.4-3);

h_x —The total thickness of aggregate layer (m) is calculated by Formula (B.2.4-4);

n —The number of aggregate layers;

E_i, h_i —Rebound modulus (MPa) of i -th structural layer and thickness (m).

B.2.5 When pave the cement concrete pavement on old asphalt concrete pavement, the foundation comprehensive Equivalent Modulus E_t of top surface of the original asphalt concrete pavement shall be calculated with formula (B.2.5-1) according to measurement results of the center deflection of falling weight deflectometer (load 50kN, bearing plate radius 150mm), or can be calculated with the formula (B.2.5-2) according to Beckman Beam (vehicle with the rear axle load of 100kN) deflection measurement.

$$E_t = 18\,621/w_0 \quad (\text{B. 2. 5-1})$$

$$E_t = 13\,739w_0^{-1.04} \quad (\text{B. 2. 5-2})$$

$$w_0 = \bar{w} + 1.04s_w \quad (\text{B. 2. 5-3})$$

Where: w_0 —Representative deflection value of road segment (0.01mm) is calculated by formula (B.2.5-3);

$\bar{w}$ —Average deflection value of road segment (0.01mm);

s_w —Standard deviation of deflection of road segment (0.01mm).

B.2.6 The maximum load stress generated by heaviest axle load at critical load position of topping plate should be calculated by formula (B.2.6).

$$\sigma_{p, \max} = k_t k_c \sigma_{pm} \quad (\text{B. 2. 6})$$

Where: $\sigma_{p, \max}$ —The maximum load stress generated by heaviest axle load on critical load position of surface slab (MPa);

σ_{pm} —The maximum load stress (MPa) generated by heaviest axle load P_m at critical load position of the plate with four free edges shall be calculated by formula (B.2.2-1), in which, the designed axle load P_s is changed into the heaviest axle load P_m (calculated in single axle, kN).

B.3 Temperature stress of elastic foundation monolayer plate

B.3.1 Temperature fatigue stress generated at critical load position of topping plate shall be calculated by formula (B.3.1).

$$\sigma_{tr} = k_t \sigma_{t, \max} \quad (\text{B.3.1})$$

Where: σ_{tr} —Temperature fatigue stress at critical load position of topping plate (MPa);

$\sigma_{t, \max}$ —The maximum temperature stress generated by topping plate in maximum temperature gradient (MPa) is defined by Article B.3.2;

k_t —Temperature fatigue stress coefficient affected by cumulative fatigue of considering temperature stress is defined by Article B.3.4.

B.3.2 The maximum temperature stress $\sigma_{t, \max}$ of concrete topping plate in maximum temperature gradient shall be calculated by formula (B.3.2).

$$\sigma_{t, \max} = \frac{\alpha_c E_c h_c T_g}{2} B_L \quad (\text{B.3.2})$$

Where: α_c —Linear expansion coefficient of concrete is taken by lithology of coarse aggregate in Table E.0.3-2;

T_g —The fifty years maximum temperature gradient of highway location is taken by Table 3.0.10;

B_L —Temperature stress coefficient of integrated temperature warping stress and internal stress is defined by Article B.3.3.

B.3.3 Temperature stress coefficient of integrated temperature warping stress and internal stress B_L shall be calculated by formula (B.3.3-1).

$$B_L = 1.77e^{-4.48h_c} C_L - 0.131(1 - C_L) \quad (\text{B.3.3-1})$$

$$C_L = 1 - \frac{\sinh t \cosh t + \cosh t \sinh t}{\cosh t \sinh t + \sinh t \cosh t} \quad (\text{B.3.3-2})$$

$$t = \frac{L}{3r} \quad (\text{B.3.3-3})$$

Where: C_L —The warping stress coefficient of concrete topping plate is calculated by formula (B.3.3-2);

L —Cross joint spacing of topping plate, namely plate length (m);

r —Radius of relative stiffness of surface slab (m)

B.4.2 The load fatigue stress of base plate or lower plate of lean concrete or compacted concrete should be calculated formula (B.4.2-1). In which, the method for determining fatigue stress factor k_f and comprehensive coefficient k_c is the same as determination method of the single-layer plate; load stress generated by design axle load P_s at the critical load position of the lower plate shall be calculated by the formula (B.4.2-2).

$$\sigma_{bpr} = k_f k_c \sigma_{bps} \quad (\text{B. 4. 2-1})$$

$$\sigma_{bps} = \frac{1.41 \times 10^{-3}}{1 + D_c/D_b} r_s^{0.68} h_b^{-2} P_s^{0.94} \quad (\text{B. 4. 2-2})$$

Where: σ_{bpr} —Load fatigue stress of the lower plate (MPa);

σ_{bps} —Load stress generated by design axle A at critical load position of lower plate (MPa).

B.4.3 The maximum load stress generated by heaviest axle load at critical load position of upper plate should be calculated by formula (B.2.6). In which, the stress reduction factor k_r and comprehensive coefficient k_c shall be determined according to Article B.2.1; maximum load stress generated at the critical load position by the heaviest axle load on the plate with four free sides shall be calculated by formula (B.4.1-1), where designed axle load P_s is changed into the heaviest axle load P_m (calculated in single axle, kN).

B.5 Temperature stress of elastic foundation doubling plate

B.5.1 The formula for the upper plate temperature fatigue stress σ_w , maximum temperature warping stress $\sigma_{t,max}$, integrated temperature warping stress, inner stress temperature stress coefficient B_L is same with that of the single-layer plate, which be separately calculated according to formula (B.3.1), formula (B.3.2), formula (B.3.3-1); temperature warping stress coefficient C_L in formula (B.3.3-1) shall be defined in according to B.5.2. The temperature fatigue stress of the lower plate is not required to be calculated and analyzed.

B.5.2 Temperature warping stress coefficient of upper plate C_L should be calculated by formula (B.5.2-1).

temperature stress of doubling plate.

$$D_{b0} = D_{b1} + D_{b2} \quad (\text{B. 6. 3-1})$$

$$\sigma_{bpr} = \frac{\tilde{\sigma}_{bpr}}{1 + D_{b2}/D_{b1}} \quad (\text{B. 6. 3-2})$$

Where: D_{b0} —Bending stiffness of base composite plate ($\text{MN} \cdot \text{m}$);

D_{b1} , D_{b2} —The bending stiffness ($\text{MN} \cdot \text{m}$) of the base and subbase shall be calculated by formula (B.4.1-2) respectively according to the thickness h_{b1} and h_{b2} of the base and subbase and elastic modulus E_{b1} and E_{b2} .

$\tilde{\sigma}_{bpr}$ —Calculate the nominal load stress of the basal composite plate according to formula (B.4.2-2), in which, replace base thickness h_b in formula with base thickness h_{b1} , and replace base plate bending stiffness D_b in the formula with composite plate bending stiffness D_{b0} .

B.6.4 When base is lean concrete or roller compacted concrete, load fatigue stress σ_{bpr} of composite plate base shall be calculated by formula (B.6.3-2). Fatigue stress calculations aren't required for other types of base.

B.7 Calculation flow of concrete slab thickness

1 According to Chapter 3, conduct the combinational design of the carriageway pavement structure, primarily formulate the pavement structure, including the material type and thickness of roadbed, cushion, base and surface layer; according to the recommended cement concrete surface layer thickness range listed Table 4-3 of the Chapter 4, primarily select the concrete slab thickness based on the traffic classifications, road grade, and the selected variation level.

2 Choose the corresponding structural analysis model according to combination conditions of drafting pavement structure.

3 According to calculation flow of concrete pavement thickness shown in the Figure B.7, separately calculate maximum load stress generated by the heaviest axle load of the concrete pavement plate (pavement plate with single-layer plate or double-layer plate), load fatigue stress generated by design axle, and the maximum temperature stress and temperature fatigue stresses generated by maximum temperature gradient.

4 When the product between the plus of the loading fatigue stress with the temperature fatigue stress and the reliability coefficient is less than or nearly equal to the concrete flexural strength standard value, and meanwhile, the product between plus of maximum load stress with maximum temperature stress and reliability coefficient product is less than the concrete flexural strength standard value, i.e. satisfying the formula (3.0.4-1) and (3.0.4-2), the primarily selected thickness can be used as concrete slab calculate thickness.

5 For the lean concrete or compacted concrete base or the lower pavement plate of the double-layer plate, you need to calculate the fatigue stress load and check whether the product between loads fatigue stress and reliability coefficients is less than the flexural strength standard value of its material, i.e. satisfying the formula (3.0.5).

6 If it can not simultaneously satisfy the formula (3.0.4) and formula (3.0.5), you shall reselect concrete pavement plate thickness or (and) adjust the base type or (and) thickness for recalculation, until both satisfy formula (3.0. 4) and (3.0.5).

7 After calculated thickness plus the wear thickness of 6mm, should be rounded up according to 10mm, as the design value of concrete surface thickness.

Appendix C

Stress analysis of Concrete Slab with Asphalt Top Surface Layer

C.1 Load Stress Analysis

C.1.1 Critical load position of concrete slab with asphalt top surface layer is the middle part of longitudinal edges of the slab. Load fatigue stress σ_{pr} generated by design axle load P_s at the critical load position p_s , shall be calculated according to formula (B.2.1). Of which, methods of determining the stress reduction factor, load fatigue stress factor and integrated factor are identical to the methods used for the concrete slab without asphalt top surface layer.

C.1.2 The load stress p_s and the maximum load stress p_m generated by design axle load P_s and the heaviest axle load at the critical load position of the concrete slab with asphalt upper surface shall be separately calculated according to the formula (C.1.2-1) and formula (C.1.2-2).

$$\sigma_{psa} = (1 - \xi_a h_a) \sigma_{ps} \quad (\text{C.1.2-1})$$

$$\sigma_{pma} = (1 - \xi_a h_a) \sigma_{p,max} \quad (\text{C.1.2-2})$$

Where: σ_{psa} —Load stress generated by design axle load P_s at the critical load position of concrete slab with asphalt top surface layer (MPa);

σ_{pma} —The maximum load stress generated by the heaviest axle load at the critical load position of concrete slab with asphalt top surface layer (MPa);

ξ_a —Coefficient can be obtained from Figure C.1.2;

h_a —Asphalt top surface layer thickness (m);

σ_{ps} —Load stress generated by design axle load P_s at the critical load position of concrete slab without asphalt top surface layer (MPa) shall be calculated according to formula (B.2.2-1);

$\sigma_{p,max}$ —The maximum load stress generated by the heaviest axle load P_m at the critical load position of concrete slab without asphalt top surface layer (MPa) shall be calculated according to formula (B.2.6);

C.2 Temperature stress analysis

C.2.1 Determine the maximum temperature stress according to Formula (C.2.1-1) and

V_c —Concrete Poisson's ratio, generally can be 0.15-0.18;

g_{td} —The maximum equivalent strain difference between pavement and bottom when no restriction is applied, the calculation shall be according to formula (D.0.1-3);

α_c —Concrete linear expansion coefficient ($1/^\circ\text{C}$) can be selected according to Table E.0.3-2;

T_g —The maximum negative temperature gradient ($^\circ\text{C}/\text{m}$) between the top surface and underside of cement concrete surface course can be selected by reference to 1/4-1/3 of the maximum positive temperature gradient in the area (look up in Table 3.0.10);

β_h —Correction coefficient of temperature gradient thickness when concrete pavement thickness is not equal to 0.22m shall be calculated according to formula (D.0.1-4);

ε_∞ —The maximum concrete shrinkage strain when no restriction is applied can be approximately calculated according to formula (D.0.1-5);

a_1 —Curing condition coefficient, when curing in water or covered by linen, $a_1=1.0$; when curing agent is adopted, $a_1=1.2$;

w_0 —Unit consumption of water for concrete (N/m^3);

k_1 —As for the coefficient related to the climatic region and the minimum air humidity, when the highway is located in Region II, IV and V of highway natural division, $k_1=0.4$; when in Region III, VI and VII, $k_1=0.68$;

C —Warping stress coefficient can be calculated according to formula (B.3.3-2) of Appendix B, $t=1.29/r$;

r —Radius of relative stiffness of surface slab (m);

α_{cg} —The maximum bond stress between concrete and reinforcement shall be approximately calculated according to formula (D.0.1-6);

c_1 —The cementation-slip coefficient between concrete and reinforcement is calculated according to Formula (D.0.1-7); due to an unknown quantity L_d is included in the formula, the iteration method needs to be adopted for the calculation, which first assumes $L_d=L_{ds}$, and then calculates c_1 and corresponding L_d ; if $|L_d - L_{ds}| < 0.005$, the calculation is over; or else, suppose that , and repeat the calculation till the requirement is met;

ε_s —The maximum total strain of concrete in the reinforcement embedment depth shall be calculated according to formula (D.0.1-8);

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