Section 5

Pavement Design

SECTION 5

PAVEMENT DESIGN

5.1 General

5.1.1 The existing roads in the States are generally flexible pavements and their capacity augmentation by way of widening and strengthening would therefore generally be by provision of flexible pavements only.

5.1.2 Situations may, however, also arise where the Government may require provision of cement concrete pavement depending upon specific site conditions. Such a requirement shall be specified in Schedule-B of the Concession Agreement and indicated as a deviation in Schedule-D of the Concession Agreement. The minimum design and maintenance requirements for cement concrete pavement shall be specified by the Government and Schedule-K of the Concession Agreement shall be modified accordingly.

5.1.3 Design of new pavement sections or widening and strengthening of existing pavements shall take into account all relevant factors for assuring reliable performance that satisfies the specified minimum performance requirements.

5.1.4 The pavement condition and other data furnished by the Government are based on preliminary investigations. The Concessionaire shall undertake the necessary soil, material and pavement investigations and traffic volume and axle load studies in accordance with the good industry practice for preparing detailed designs.

5.1.5 The materials, mixes and construction practice shall meet the requirements prescribed herein and MOSRTH Specifications / IRC Specifications, unless specified otherwise.

5.1.6 Where problematic conditions such as expansive soils, swamps or marshes, flooding, poor drainage, etc. are found to exist, adequate measures shall be adopted to deal with such site conditions.

5.2 Method of Design of Flexible Pavement

The design of flexible pavement is covered in two parts namely, new pavements, and widening and strengthening of existing pavements. New pavements shall be designed in accordance with the method prescribed in IRC:37 or any other international standard method/guideline for pavement design, subject to the condition that the overall pavement composition shall not be less than the minimum requirement specified in IRC:37. Strengthening of existing pavements shall be designed on the basis of the procedure outlined in IRC:81, except where specified otherwise.

5.3 Method of Design of Rigid Pavement

Rigid pavement shall be designed for a period of not less than 30 years, in accordance with the method prescribed in IRC:58.

5.4 Design of New Pavements

5.4.1 *Flexible Pavement - Design Period and Strategy*

(i) Pavement shall be designed for a minimum design period of 15 years. Stage construction shall be permissible subject to the requirement specified in para (ii) below.

(ii) Alternative strategies or combination of initial design, strengthening and maintenance can be developed by the Concessionaire to provide the specified level of pavement performance over the operation period, subject to satisfying the following minimum design requirements;

(a) The thickness of sub-base and base of pavement section is designed for a minimum design period of 15 years and the initial bituminous surfacing for a minimum design period of 8 years.

(b) The pavement shall be strengthened by bituminous overlay, as and when required, to extend the pavement life to full operation period. Strengthening in stages for not less than five years at a time can be done. The thickness of bituminous overlay shall be determined on the basis of IRC:81.

5.4.2 *Rigid Pavement - Design Period and Strategy*

(i) The stage construction shall not be permitted in case of rigid pavement. The pavement shall be constructed in 10 m width (7 m carriageway plus 2X1.5 m rigid shoulders).

(ii) The Pavement Quality Concrete (PQC) shall be designed as per para 5.3.1, based on a flexural strength of 4.5 MPa. The PQC shall rest over Dry Lean Concrete (DLC) sub-base of 150 mm thickness.

(iii) The DLC will be of M10 concrete (7 days' strength) as prescribed in IRC:SP:49. DLC will be extending beyond the PQC (including that in shoulder, if any) by 1m on either side.

(iv) A properly designed drainage layer (GSB) of thickness 150-200 mm shall be provided. The drainage layer shall be properly designed so that a drainage coefficient of 20 m per day is obtained.

(v) The construction of rigid pavement should normally be done by Slip-form Paver. Stringent quality control is absolutely essential for long term performance of the rigid pavement and therefore, the same should be executed with utmost quality control and as per procedure laid down in IRC:15.

(vi) The details of axle load surveys, for trucks only, shall be used in computing stress ratios as per IRC:58.

5.4.3 *Pavement Performance Requirements*

i) The pavement structure shall be capable of giving the specified performance over the entire operation period.

ii) The new pavement surface shall satisfy the following standards:

a.	Roughness In each lane measured by calibrated BI	Not more than 2000 mm/km for each lane in a km length
b.	Rutting, cracking or any other distress	Nil

(iii) During the operation period, the pavement surface roughness or any structural/functional distress shall not exceed the values specified in Schedule-K of the Concession Agreement. Any treatment in the form of renewal/overlay carried out or required to restore/correct/improve the riding quality or any distress shall be of such thickness and specification that will restore the riding quality to 2000 mm/km.

5.5 Design Traffic

5.5.1 The design traffic shall be estimated in terms of cumulative number of standard axles (8160 kg) to be carried by the pavement during the design period.

5.5.2 Estimate of the initial daily average traffic flow shall be based on atleast 7 days', 24 hour classified traffic counts. IRC:9 may be used as guidance for carrying out the traffic census.

5.5.3 Any likely change in traffic due to proposed improvement of the facility and/or future development plans, land use, shall be duly considered in estimating the design traffic.

5.5.4 Traffic growth rate shall be established for each category of commercial vehicles to be considered for design of pavement. For traffic projections, the procedure outlined in IRC:108 may be followed. The Concessionaire shall adopt a realistic value of the rate of traffic growth, provided that annual rate of growth of commercial vehicles shall not be assumed as less than 5 per cent.

5.5.5 Axle load surveys shall be carried out to estimate the vehicle damage factor (VDF) for each category of commercial vehicles. The axle load equivalency factors recommended in Annexure-2 of IRC:37 shall be used for converting different axle road repetitions into equivalent standard axle load repetitions. VDF values so determined shall be used for estimating design traffic in standard axles. Provided that if the Concessionaire envisages the possibility of controlling the severity and incidence of overloading with better enforcement of legal load limits as also of increase in the proportion of Multi Axle Vehicles over the years, it may, at it own risk and cost adopt a lower VDF value than that determined on the basis of the Axle load spectrum survey.

5.5.6 Lane distribution factors given in IRC:37 shall be adopted.

5.5.7 For rigid pavements Equivalent Damage Ratio (EDR) shall be adopted as given in IRC:58.

5.6 Subgrade

The subgrade, whether in cut or fill, shall meet the following requirements:

(i) Subgrade material shall conform to the requirements laid down in Section 4. Expansive clays and other unsuitable soils shall not be used for subgrade construction. The material used in subgrade shall have dry density of not less than 17.5 kN/cu.m.

(ii) The thickness of subgrade shall not be less than 500 mm.

(iii) The subgrade shall be compacted to atleast 97% of the maximum dry density achieved with heavy compaction in accordance with IS: 2720 (Part 8).

(iv) The soaked CBR value of remoulded subgrade soil samples at the specified dry density and moisture content shall not be less than 7% (average of atleast 3 specimens), unless specified otherwise.

5.7 Pavement Components and Materials

(i) The pavement construction materials for sub-base, base and bituminous surfacing shall conform to the requirements prescribed herein and the MOSRTH / IRC Specifications, unless specified otherwise.

(ii) Where several materials will adequately serve as component within the pavement

structure, such as a sub-base or a base course, the Concessionaire shall have the option of using any of the materials/specifications. It is important that good engineering practice and product quality requirements are not abandoned for the sake of effecting cost reduction.

If any material which is not specified here or included in MOSRTH / IRC / PWD Specifications is proposed to be used, the proposal supported with authentic standards and practice shall be communicated to the Independent Engineer for review and comments, if any.

5.7.1 *Sub-base*

(i) Sub-base shall be of any of the following types:

(a) Granular sub-base conforming to clause 401 of MOSRTH Specifications. Sub-base material shall have minimum soaked CBR value of 30%.

(b) Cement treated soil sub-base conforming to clause 403 of MOSRTH Specifications.

(c) Water Bound Macadam conforming to IRC:19.

(d) Wet Mix Macadam conforming to IRC:109.

(ii) Frost susceptible materials shall not be used in the sub-base.

(iii) From pavement drainage considerations, the granular sub-base should be extended over the entire formation width. The granular sub-base shall be of proper design and grading to perform satisfactorily as the drainage layer. In cuttings, granular sub-base shall be at least 300 mm above the invert level of the drain.

(iv) Where modification of granular sub-base grading given in Clause 401 of MOSRTH Specifications is considered necessary to improve its drainage properties, the PI, Compaction and Strength criteria shall be fully satisfied, besides drainage efficacy. Further where required, depending upon the gradation of the sub-base material and subgrade soil, an appropriate filter layer of soil/aggregate or geo-textile shall be incorporated between the sub-base and the subgrade to prevent clogging of sub-base. The proposal shall be communicated to the Independent Engineer for review and comments, if any.

5.7.2 *Base Course*

(i) Base course material and construction shall conform to any of the following types:

(a) Water Bound Macadam for base course conforming to IRC:19.

(b) Wet Mix Macadam for base course conforming to IRC:109.

(c) Crusher Run Macadam Base conforming to the requirements of Clause 410 of MOSRTH Specifications.

(d) Any other superior base material like Bituminous Macadam conforming to Clause 504 of MOSRTH Specifications can be used in combination with the granular base.

(ii) The granular base shall be primed with a prime coat of low viscosity liquid bituminous material of appropriate type conforming to MOSRTH Specifications/BIS specifications, preparatory to the superimposition of bituminous treatment or mix.

5.7.3 *Bituminous Surfacing*

(i) The bituminous surfacing shall be either a wearing course or a binder course with a wearing course depending upon the design traffic.

(ii) Bituminous surfacing materials and thicknesses shall satisfy the requirements of the IRC:37. The suggested surfacing materials and thickness are desirable minimum from functional and structural requirements.

(iii) The specifications for the bituminous materials and mixes shall satisfy the specified minimum requirements, as per the relevant MOSRTH Specifications. The design of mixes shall be done by Marshall method.

(iv) For the design of mixes, use of refusal density criterion can be adopted.

(v) The grade of bitumen/modified bitumen shall be selected by the Concessionaire keeping in view the traffic, rainfall and other environmental conditions.

5.8 Performance Evaluation

(i) Pavement performance evaluation shall be done by the Independent Engineer in accordance with tests based on good industry practice.

(ii) Roughness in each lane for full length shall be measured by calibrated BI periodically.

(iii) The structural evaluation of the pavement shall be made by taking deflection measurements every 5 years, in accordance with the procedure given in IRC: 81, unless needed earlier for stretches exhibiting severe distress during the operation and maintenance period.

5.9 Widening and Strengthening of Existing Pavement to Two Lane / Two Lane Plus (with Paved Shoulders)

5.9.1 The requirement of strengthening (overlay thickness) for the existing pavement shall be assessed as per the procedure laid down in IRC: 81. The pavement thickness in the widened portion shall be kept equal to the thickness of the existing pavement plus the thickness of the overlay as assessed above, unless specified otherwise. The overlay on the existing pavement and widened portion shall be uniform in thickness and composition. It shall be ensured that the thickness of the bituminous surfacing in the widened portion shall not be less than the equivalent thickness of bituminous surfacing over the existing pavement.

5.9.2 The pavement shall be widened symmetrical to the existing centerline or on one side only depending on the placement of the existing road within the right of way. This aspect may be decided in consultation with the Independent Engineer, in case not specified in the relevant schedule of the Concession Agreement.

The earthwork in subgrade in widened portions and shoulders shall be compacted to atleast 97% of the maximum dry density obtained by heavy compaction (IS: 2720, Part 8).

5.9.3 Before strengthening treatment is prescribed, a detailed pavement condition survey and evaluation shall be carried out in accordance with IRC: 81 to determine:

(i) The extent of distress and nature of deficiency in the existing pavement structure, and

(ii) Whether any special treatments e.g. provision for remedying reflection cracking, pavement internal drainage, subgrade improvement/ reconstruction, or rectification of any other deficiencies are warranted.

5.9.4 Before implementing the strengthening treatment, the existing pavement surface profile

shall be checked and if found deficient, shall be corrected by providing a suitable profile corrective course or by milling and recycling. The profile corrective course shall meet the following requirements:

(i) The profile corrective course shall not form part of the overlay thickness.

(ii) Where the maximum thickness of profile corrective course is not more than 40 mm, it shall be constructed as an integral part of the overlay course. In other cases, the profile corrective course shall be constructed as a separate layer.

(iii) Where it is to be laid as integral part of the overlay/strengthening course, the profile corrective course material shall be of the same specifications as that of the overlay/strengthening course.

5.9.5 Necessary corrective measures to treat the identified deficiency vide paras 5.9.3 and 5.9.4 above, shall be taken along with strengthening of the pavement.

5.9.6 Any stretches in which the pavement is damaged/deteriorated to such an extent that the use of Benkelman Beam method may not result in a realistic assessment of the strengthening treatment, pavement in such stretches shall be designed using the design procedure for new pavements.

5.9.7 Where an existing pavement is built over an untreated expansive/black cotton soil subgrade, its improvement/strengthening/ widening shall be treated separately. Such stretches shall require reconstruction with provision of adequate measures such as replacement or treatment of expansive subgrade and shall be designed as new pavement in accordance with the procedure specified in para 5.4 and IRC:37. Such stretches shall be specified in Schedule-B of the Concession Agreement.

5.9.8 No granular layer shall be provided over an existing bituminous surfacing. Where it is envisaged to strengthen grossly deficient existing road with a granular base layer in addition to the bituminous overlay, the requirements specified in paras 5.10.6 and 5.10.7 shall apply.

5.9.9 *Paved Shoulders*

(i) Paved shoulders shall be constructed, where specified.

(ii) The width of paved shoulders shall be 1.5 m unless specified otherwise.

(iii) The paved shoulders shall be constructed in layers, each matching the thickness of the adjoining pavement layer. The work shall be carried out in accordance with Clause 407 of MOSRTH Specifications.

(iv) Where the existing pavement is to be widened to two lanes with paved shoulders, the pavement layers in the main carriageway and in the paved shoulder width shall be laid and compacted together.

(v) If the thickness of the existing paved shoulders, if any, is less than the thickness of the adjacent pavement, the paved shoulders shall be re-constructed to the new pavement thickness.

(vi) The overlay on the main carriageway pavement and on the paved shoulders shall be uniform in thickness and composition.

5.9.10 *Granular Shoulders*

Material for granular layer on shoulders shall be well graded natural sand, moorum, gravel,

crushed stone or combination thereof, conforming to Clause 401 of MOSRTH Specifications and having soaked CBR value of not less than 30%. The granular layer shall be compacted to at least 98% of the maximum dry density for the material determined as per IS: 2720 (Part 8).

5.10 Design of Strengthening Treatment (Overlay)

5.10.1 IRC:81 shall be followed for design of strengthening treatment. The guidelines provide the method for determining the characteristic deflection using Benkelman Beam and then working out the overlay thickness for the design traffic.

5.10.2 The characteristic deflection for design purpose shall be determined by the following formula:

$$D_C = \bar{X} + 2\sigma$$

Where, D_C = Characteristic Deflection (mm)

$\bar{X}$ = Mean Deflection (mm) (determined on the basis of individual deflection corrected for temperature and seasonal variation)

σ = Standard Deviation

5.10.3 *Design Period and Minimum Requirements*

(i) Pavement strengthening shall be done for a design period of 10 years or equal to the operation period, whichever is more. Strengthening in stages shall be permissible subject to the requirements given in para (ii) below.

(ii) The Concessionaire shall ensure the following requirements as a minimum for design of strengthening measures:

(a) Initial strengthening for a design period of not less than eight years.

(b) Subsequent overlay at the end of the initial design period, or earlier, if the surface roughness exceeds the value specified in Schedule-K of the Concession Agreement or if any structural distress is observed. The overlay shall be designed to extend the pavement life for at least five years at a time.

(c) The riding quality of the pavement shall be measured periodically and if the roughness exceeds the specified value, the pavement strength shall be evaluated based on current deflection measurements and traffic projections for the next five years, at least. In case any strengthening treatment is required, the same shall be implemented, otherwise the wearing course be renewed by providing a minimum 25 mm thick bituminous surfacing conforming to the existing wearing course specifications.

5.10.4 *Design Traffic*

The design traffic shall be estimated in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design period as per the procedure described in para 5.5 of this Section.

5.10.5 The thickness of bituminous overlay shall be determined on the basis of the characteristic deflection and the design traffic as per the procedure outlined in IRC:81. The guidelines give the thickness of overlay required in terms of bituminous macadam. The thickness of bituminous overlay for pavement strengthening shall not be less than 50 mm.

5.10.6 The overlay, so determined for the existing pavements in terms of Bituminous Macadam can be modified to provide for other compositions, including the combination of granular layers of WBM/WMM and bituminous treatment. The equivalent overlay thickness can be determined using the following equivalency factors as per Clause 7.4 of IRC: 81;

100 mm of BM = 150 mm of WBM/WMM

100 mm of BM = 70 mm of DBM/SDBC/BC

5.10.7 The type of material to be used in overlay construction will depend upon several factors such as design traffic, thickness, condition and type of existing bituminous surfacing and convenience of construction. If it is proposed to strengthen an existing weak pavement structure with granular construction followed by bituminous surfacing, the following requirements shall be satisfied:

(i) The existing bituminous surfacing shall be completely removed by scarifying / milling before laying WBM/WMM layers. It will be ensured that the underlying layer is not disturbed.

(ii) If the thickness of the scarified/milled layer is 40 mm or more, the existing pavement thickness shall be made up by increasing the overlay thickness correspondingly.

(iii) The thickness and composition of bituminous surfacing over the granular layer shall conform to the recommended surfacing and thickness in para 4.2.3 (Bituminous Surfacing) of IRC:37.

5.10.8 *Bituminous Mix for Overlay*

The specifications for the bituminous mixes for the overlay shall be as specified for bituminous surfacing for new pavement sections vide para 5.7.3 of this Section.

5.10.9 *Pavement Performance Requirements and Evaluation*

The strengthened pavement shall satisfy the minimum standard and maintenance requirements specified for new pavement sections in para 5.4.3 of this Section and Schedule-K of the Concession Agreement.

The performance measurement and evaluation will be done as per the procedure described in para 5.8 of this Section.

5.11 Construction, Workmanship and Quality of Work

All materials, construction operations, workmanship, and the surface finish of the quality of completed construction for all pavement works including subgrade, sub-base, base course, bituminous surface courses for new pavements and for widening and strengthening works shall conform to the specified requirements and specifications and comply with the relevant provisions of Section 900 of the MOSRTH Specifications.

5.12 Premature Distress

Notwithstanding the minimum design, specifications and standards specified in the preceding paras for new pavements and strengthening of existing pavements, if the pavement shows premature distress in the form of cracking, rutting, patching, loss of camber or any other structural or functional distress, necessary remedial measures by strengthening/ resurfacing shall be undertaken after proper investigation for conforming to the minimum requirements prescribed in Schedule-K of the Concession Agreement.

5.13 Detailed Design Report

The new pavement design and strengthening proposals formulated on the basis of the detailed investigations and studies shall be communicated to the Independent Engineer for review and comments, if any. The proposal shall be accompanied by Data Collection, Data Evaluation and Design Reports.

5.13.1 *Data Collection Report*

The data collection report shall include:

(i) Soil investigation data for new pavements as per Table 13.2 of IRC: SP:19. Report shall include OMC-Dry density relationship with heavy compaction and soaked CBR values, in addition to other data and information as per the prescribed proforma.

(ii) Test values of aggregate for pavement courses as per Tables 13.3 and 13.4 of IRC:SP:19. All tests as per requirements of MOSRTH Specifications shall be reported in addition to the tests and information included in the above mentioned Tables.

(iii) Classified traffic counts in Proforma 1 of IRC:SP:19.

(iv) Axle load surveys and VDF values for each category of commercial vehicles as per Proforma 4 of IRC:SP:19.

(v) Estimation of traffic growth and traffic projections for pavement design.

(vi) Pavement condition data in the Proforma given in Table 2 of IRC:81.

(vii) Pavement roughness data measured by Bump Integrator as per IRC:SP:16.

(viii) Pavement Deflection Data measured by Benkelman Beam as per the procedure detailed in IRC:81. Pavement deflection data shall be recorded in the prescribed Proforma vide Table 3 of IRC:81.

The deflection data shall be accompanied with the characteristics of the subgrade soil covering type of subgrade soil, field moisture content (at the time of deflection survey), average annual rainfall in the area, and pavement temperature at the time of deflection survey.

(ix) Any other relevant information required by the Independent Engineer for review and comments, if any.

5.13.2 *Data Evaluation Report*

The report shall inter alia cover:

(i) Data evaluated - soil characteristics and subgrade strength, pavement distress, pavement deflection, riding quality, skid resistance, drainage aspects, etc.

(ii) Pavement deficiencies, drainage and constraints.

(iii) Any other relevant details.

5.13.3 *Detailed Design Report*

The Concessionaire shall furnish the detailed design of the preferred solution along with any special treatment proposed for adoption. Any departures from the specifications, stated herein, shall be supported with authentic standards and specifications and accepted practice.