



CHAPTER 2 DESIGN STANDARDS

2.1 General

The design of urban roads is dictated by the land availability especially width and connectivity, besides (DP Width), requirements of traffic and economic considerations. It involves geometric standards and type of pavement required. Geometric standards involve parameters such as alignment, horizontal & vertical profile, lateral clearances and requirement of junctions etc.

The design of ROBs and Bridges is dictated by the land availability, requirements of traffic and economic considerations. The design philosophy and standards for such structures are also included in this chapter.

2.2 Design Codes & Standards for Urban/Rural Roads

The Geometric cross section and layout of roads is based on following Indian Codes and Standards supplemented by the International Codes and Standards wherever the former is silent and the design standards developed for the project.

IRC – 2-1968	Route Marker Signs for National Highways (First Revision)
IRC-32-1969	Standard for Vertical and horizontal Clearances of Overhead Electric Power and telecommunication Lines as Related to Roads
IRC-38 – 1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables
IRC-5 4– 1974	Lateral and vertical clearances at Underpasses for Vehicular Traffic.
IRC-58 – 2002	Design Of Rigid Pavements
IRC – 73-1980	Geometric Design Standards for Rural (Non-Urban) Highways
IRC– 86 – 1983	Geometric Design Standards for Urban Roads in Plains
IRC- 92-1985	Guidelines for the Design of Interchanges in Urban Areas
IRC:SP:19-1977	Manual for Survey, Investigation and Preparation of Road Projects
IRC:SP:23-1983	Guidelines for Vertical Curves for Highways
IRC : SP-41-1994	Guidelines for the Design of At-Grade Intersections in Rural & Urban Areas



2.3 Geometric Design Standards

The safety of motorists, pedestrians and bicyclists, efficiency, economy and comfort of vehicle operation are governed by the adequacy of geometric standards. Based on IRC Codes following standards have been recommended.

Table 2.1 – Geometric Design Standards

Item	Parameter	Proposed
1	Roadway Classification	Sub-Arterial
2	Design Speed (kph)	60
3	Carriageway No. of Lanes - Road Lane Width (m) Minimum Median Width (m) Minimum Median Width (m) (4 lane) Footpath Width (m)	4-6Lane 3.50 0.60 1.20 1.20-1.50
4	Minimum Stopping Sight Distance (m)	80
5	Gradient Maximum (%) Minimum (%)	5.0 0.3
6	Vertical Control Minimum 'K' Sag (m) Minimum 'K' Crest (m)	20 20
7	Horizontal Control – Minimum Radius (m)	100
8	Maximum Super elevation (%)	3

Notes:

Minimum intersection turning radius shall be 13 metres.

Super elevation shall be at the rate of 1:100.

2.4 Pavement Design Procedure & Methodology

Pavement design is the process of developing the most economical combination of pavement layers, with respect to thickness and type of material, to protect the soil foundation from the cumulative traffic to be carried during the design life.

Although economics will always be a major factor in the choice between rigid and flexible pavements, and between different pavement materials and designs, other factors such as characteristic behaviour of soil beneath and routine and periodical maintenance of road surface also influence the final design chosen. For example:



- behaviour of soil
- maintenance practice followed
- the expertise of the construction organisation
- presence of public utility services, and
- drainage conditions.

2.4.1 Design Theory

The design method is based on elastic response of the pavement to traffic stresses (i.e. each of the materials in the pavement structure behaves in an elastic manner). The materials in the pavement are characterised by parameters whose values are determined from field and laboratory testing. The method assumes that failure will not occur as a result of permanent deformation of granular or bound materials (and this assumption will be valid as long as good construction procedures are followed, and the pavement is not subjected to very high wheel loads such as can be caused by a very heavily overloaded vehicle). The method also assumes that loss of pavement serviceability can occur due to:

- fatigue of bitumen bound or cemented layers due to repetitions of tensile strains at the bottom of such layers; and/or
- permanent deformation of the subgrade due to repeated vertical compressive strains induced in the subgrade.

The critical locations for pavement failure are therefore the bottom of bitumen bound or cemented layers (where tensile strains occur) and the top of the subgrade (where compressive strains occur).

2.4.2 Function of Base Course and Subgrade

The base course and subgrade are structural elements of the pavement. In conjunction with the overlying asphalt surface, their purpose is to distribute traffic wheel loads over the whole foundation. To perform this function, we build the base course and subgrade with the necessary internal strength properties.

Asphalt pavement layers have both tensile and compressive strength to resist internal stresses. For example, **Fig 2.1** shows how wheel load (W) slightly deflects the pavement structure, causing both tensile and compressive stresses within the pavement.

Determining Required Pavement Thickness



A significant advance in highway engineering is the realization and demonstration that structural design of

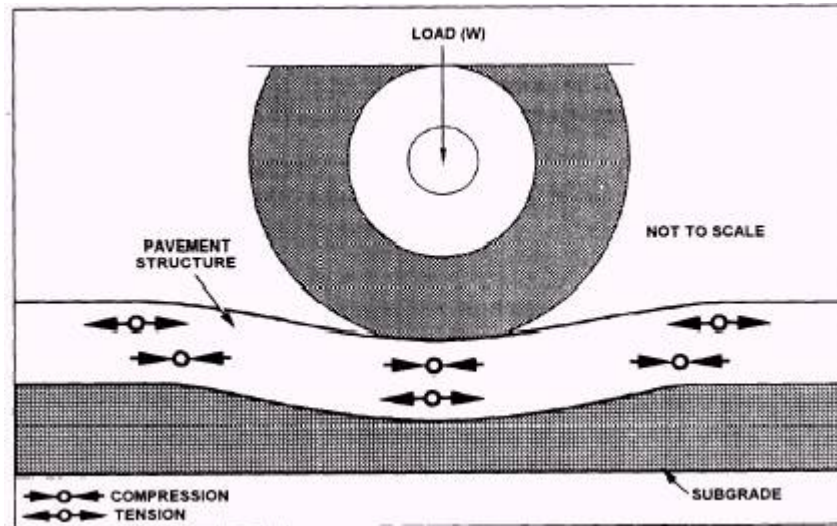


Fig 2.1.-Pavement deflection results in tensile and compressive stresses in pavement structure.

There is no standard thickness for a pavement. Required total thickness is determined by engineering design procedure. Factors considered in the procedure are as follows:

1. Traffic to be served initially and over the design service life of the pavement
2. Strength and other pertinent properties of the prepared subgrade
3. Strength and other influencing characteristics of the materials available or chosen for the layers (or courses) in the total asphalt pavement structure
4. Special factors such free swelling property of existing soil

2.4.3 Design Period

The design period for a pavement depends on the type of road, its location, and the intended usage during and after the design period. Generally the more heavily trafficked the road the more difficult it becomes to perform maintenance or reconstruction.

Design period as per IRC-37 is 15 years for National and State Highways and 20 years for Expressways and Urban roads.



2.4.4 Design Traffic

The design traffic is expressed in terms of the equivalent number of standard axles (ESA) predicted during the design period. Design traffic is dependent mainly on commercial vehicles with car traffic playing only a very minor role in pavement life.

2.4.5 Subgrade Properties and Strength

Several methods for evaluating or estimating the strength and supporting power of a subgrade are in use today, including the following:

- Loading tests in the field on the subgrade itself. For example, the plate bearing test uses large, circular plates, loaded to produce critical amounts of deformation on the subgrade in place.
- Loading tests in a laboratory using representative samples of the subgrade soil. A test commonly used by the Seabees is the California bearing ratio (CBR) test, which is sometimes used on the subgrade in place in the field.
- Evaluations, based on classification of soil by identifying and testing the constituent particles of the soil.

As the pavement design method is based on layered elastic theory it is beneficial to use an elastic modulus for each pavement material and the subgrade. However pavement materials and natural soils do not behave in a perfectly elastic manner and the determination of elastic moduli is difficult. For these reasons the subgrade strength is not specified in terms of elastic modulus but in terms of the more readily determined CBR value. As CBR is dependent on the nature of the soil, its density, and its moisture content, it is important that the determination of CBR is made at conditions under which the material is likely to perform in service. In the present case CBR values are obtained by laboratory tests as well as field tests (DCPT).

2.4.5.1 Special Treatment

Where there are CH or CI soils, a soil swell test may be carried out in areas showing 20 to 40% swell upon wetting, the pavement design will include sub-grade modification with fly ash, lime or other treatment. Soils with swell potential of greater than 40% have been proposed for removal and replaced with non-expansive material. Replacement of existing material with moisture conditioning at 0 to 3% of optimum will only be allowed with the sub-grade will pass a proof roll test.



In the present case, to avoid the effect of up-heaving due to free swelling property of soil, separation layer of 250 mm in new construction and 200 mm in existing road strengthening has been proposed.

2.4.6 Drainage of Subgrade

Pavement and subgrade moisture conditions exert a major influence on the performance of roads. In pavement design it is important to be able to recognise ways by which moisture may enter the pavement or subgrade and to determine measures needed to control moisture movement.

Moisture changes usually result from one or more of the following effects:

- seepage from higher ground near the road pavement;
- fluctuations in water table level;
- infiltration of water through the surface of the road pavement and shoulders; and
- transfer of moisture in liquid or vapour states.

In the present case, drainage layer (GSB-II) of 200 mm thick has been proposed for effective drainage.

2.5. Design Methods

The choice of materials of pavement depends upon the traffic and drainage system in the area besides, life-cycle cost, funds availability. A variety of pavement design methods are available for all types of pavements. Here design of flexible and rigid pavements and two types of pavement design method have been considered.

- empirical methods (e.g. based on the California Bearing Ratio strength test for soils) and
- theoretical methods.

2.5.1 Flexible Pavement Design

There are two major approaches to flexible pavement design:

- empirical methods, and
- theoretical methods.

Empirical methods are based mainly on evidence gained from observation of existing roads e.g. observing what works and what doesn't. The California Bearing Ratio Method



of pavement design, for example, uses a series of relationships between subgrade strength (CBR) and pavement thickness derived by examining a large number of pavements that have been built in the past. However the method has limitations when existing relationships have to be used in environments with different materials, environmental conditions or traffic loadings to those for which the relationships were developed.

In the present case laboratory, CBR values have been found to be at large variance, from those of field CBR calculated with DCP Test. To avoid future problems, DCPT CBR results have been adopted to calculate the crust thickness.

Theoretical methods attempt to combine structural theory (usually theory of elastic behaviour) with a knowledge of the behaviour of road materials and foundation soils under repeated loading, to develop a pavement thickness by analysis. The theoretical approach uses laboratory and field testing to determine material properties which are then used in the analysis process. The theoretical approach has limitations in the material behaviour theories which must be used (e.g. analysis of any system other than a multi-layered elastic structure is very difficult, and yet a multi-layered elastic system does not mirror the real world), and the testing available to determine material properties (e.g. for accurate analysis an elastic modulus established under dynamic repeat loading with variable load amplitudes is required, but such testing is extremely expensive).

The CBR Method of Pavement Design for multi layer pavements of granular material is recommended by IRC 37-2001 "Guidelines for the Design of Flexible Pavements" and the same has been used. Procedure for the same is given below:

Step 1: To find out initial traffic of commercial vehicles per day by conduction traffic volume count

Step 2: To determine traffic growth factor by studying the past trends of traffic growth

Step 3: Design life of Pavement

Step 4: To find out Vehicle Damage Factor to convert the number of commercial vehicles of different axle loads and axle configuration to the number of standard ale load repetition. It may be obtained by conducting axle load survey.

Step 5 : To find out distribution factor of traffic over the carriageway



Step 6: To determine design traffic in cumulative number of standard axles (msa) by following formula.

$$N = 365 \times [(1+r)^n - 1] \times A \times D \times F / r$$

Where,

N is the cumulative number of standard axles to be catered for in the design in terms of msa.

A is the initial traffic in the year of completion of construction in terms of number of commercial vehicles per day.

D is the lane distribution factor.

F is the vehicle damage factor.

n is the design life in years.

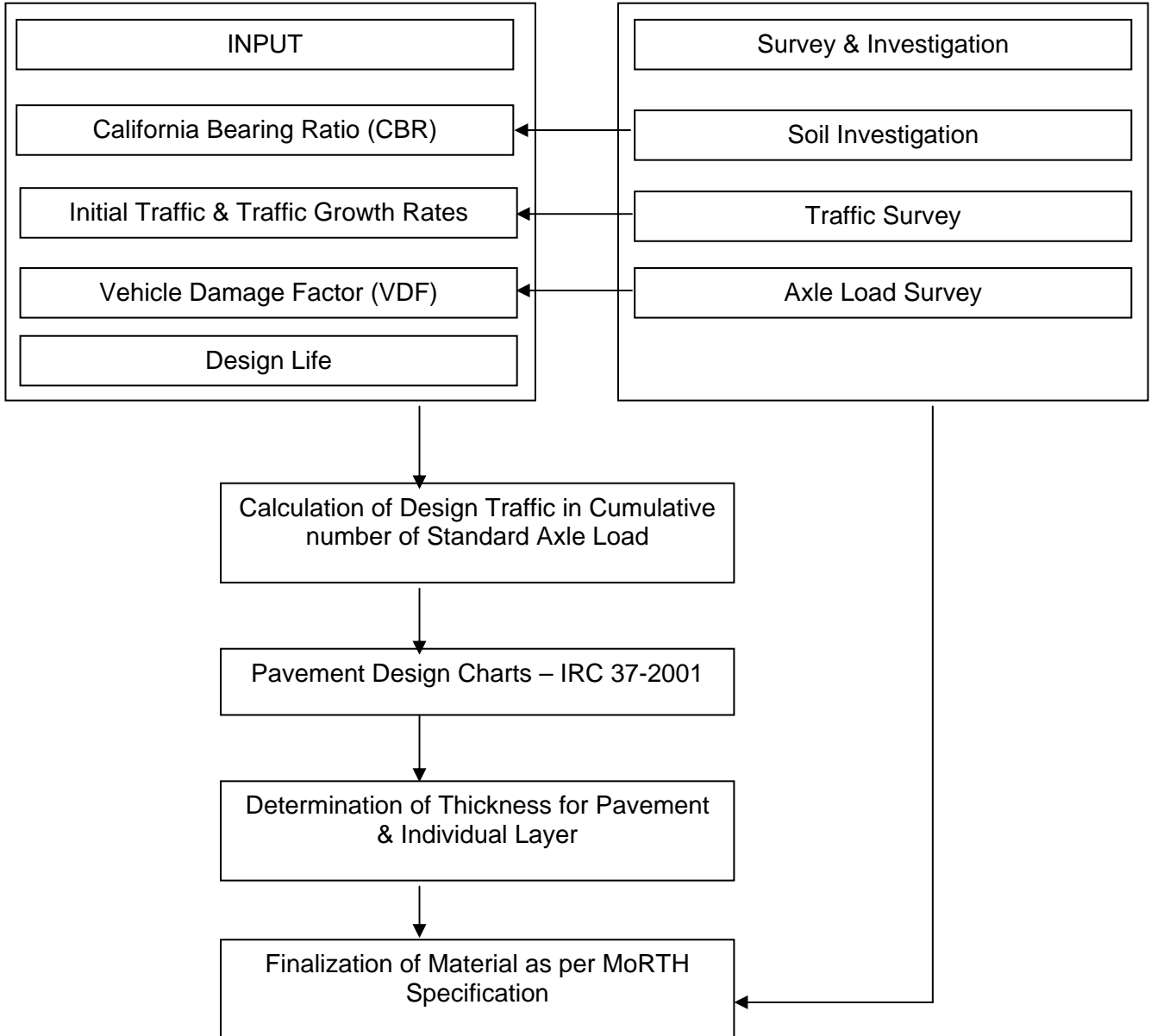
r is the annual growth rate of commercial vehicles (for 3.5%, $r = 0.035$)

Step 7 : To determine total pavement thickness and crust composition by charts/graphs with respect to CBR and cumulative number of standard axles.

Fig. 2.2 shows the flowchart of design procedure for the same



Fig 2.2 Flow Chart of Flexible Pavement Design for New Carriageway (IRC 37-2001)



2.5.2 Rigid Pavement

IRC 58-2002 “Guidelines for the Design of Plain Jointed Rigid Pavements for Highways” is used for design of rigid pavement of new carriageway/widening. Procedure for the same is given below:

Step 1: To stipulate design value for the various parameters.



Step 2: To decide types and spacing between joints.

Step 3: To select trial design thickness of pavement slab.

Step 4: To compute the repetitions of axle loads of different magnitudes during the design period.

Step 5 : To calculate the stresses due to single and tandem axle loads and determine the cumulative fatigue damage (CFD).

Step 6: If the CFD is more than 1.0, select a higher thickness and repeat the steps 1 to 5.

Step 7: To compute the temperature stress at the edge and if the sum of the temperature stress and flexural stress due to highest wheel load is greater than the modulus of rupture, select higher thickness and repeat the steps 1 to 6.

Step 8: To design the pavement thickness on the basis of corner stress if no dowel bars are provided and there is no load transfer due to lack of aggregate inter-lock.

2.6 Overlay Design on Rigid Pavement

In the present case, a road length of about 21 kms with Cement Concrete surface is available in Nanded city. Looking at the CBR value of soil beneath, it is essential to strengthen/rehabilitate Cement Concrete Pavement.

IRC: SP 17 "Recommendations About Overlays On Cement Concrete Pavements" has been refereed for design of overlay on rigid pavement. Procedure for the same is given below:

Step 1 : To find out length of crack in m per 10 sqm. from pavement condition survey analysis.

Step 2 : To find the category of road as per crack condition of pavement and decide type of overlay.

Step 3 : To determine thickness of overlay.

The following formula is used for determining the thickness of concrete un-bonded overlay.



$$H_o = \text{SQRT} (H_m^2 - C H_e^2)$$

Where H_o – Thickness of Overlay mm
 H_m - Thickness of Monolithic Slab
 H_e – Thickness of existing concrete pavement
 C - Pavement Condition Factor

2.7 Overlay Design on Existing Bituminous Pavement

IRC 81-1997 “Guidelines for Strengthening of Flexible Road Pavement using Benkelman Beam Deflection Technique” is used for design of overlay on existing pavement. Procedure for the same is given below:

Step 1 to step 6 as given in para 1.2.1 is same.

Step 7 : To record dial gauge readings, temperatures etc by conducting Benkelman Beam Deflection Survey (BBD).

Step 8 : To determine moisture content of soil samples collected during BBD survey.

Step 9 : To determine temperature variation factor.

Step 10 : To determine moisture content factor from graphs given in IRC 811997.

Step 6 : To determine characteristic deflection by the following formula.

$$D_c = X + 2 \sigma \quad \text{for Major Arterial Roads}$$

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$$\text{Mean Deflection } x = \frac{\sum_{i=1}^n x_i}{N}$$

Where,

X Individual Deflection, mm
 x Mean Deflection, mm
 n Deflection Measurement
 σ Standard Deviation.
 D_c Characteristic Deflection



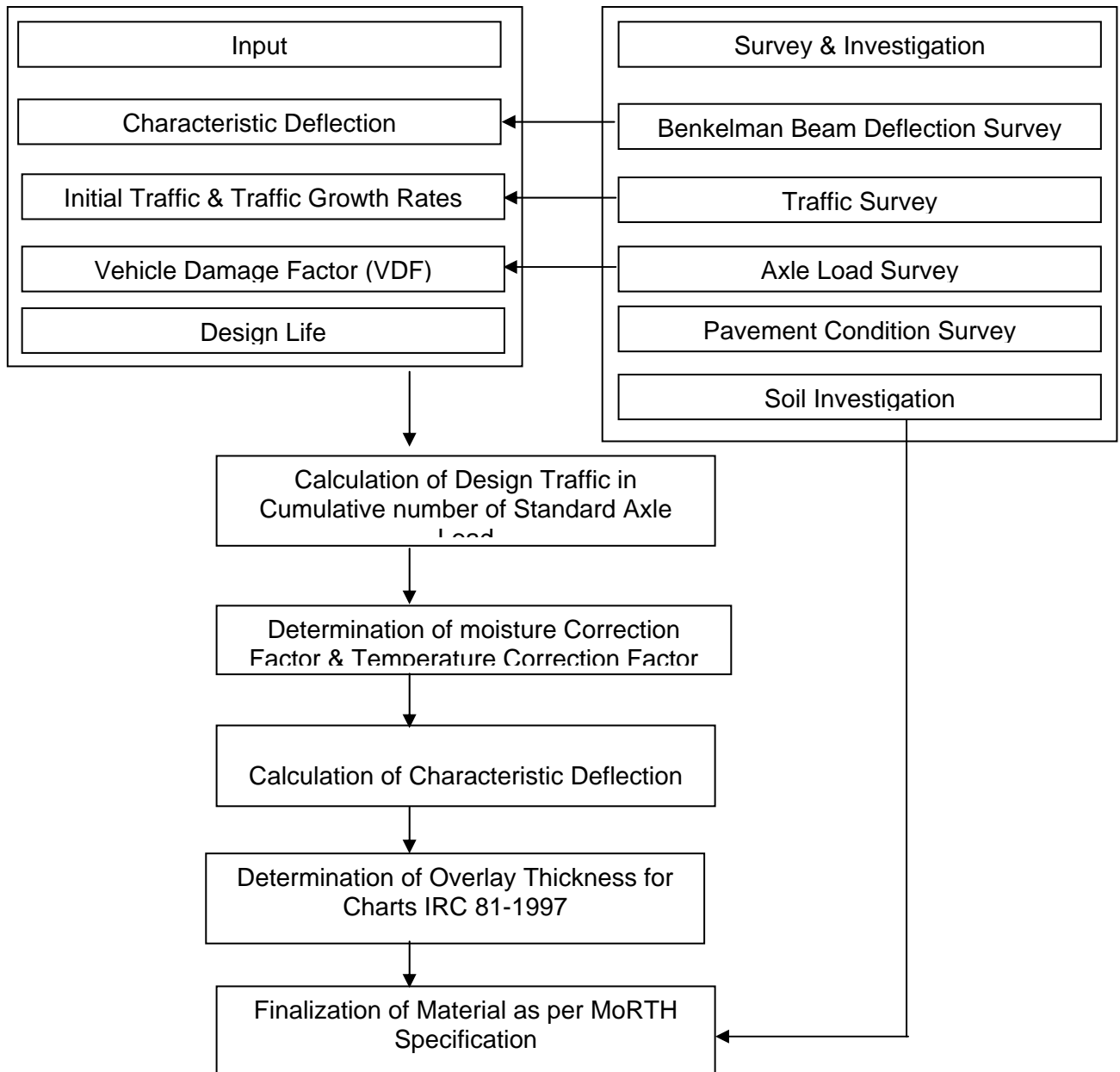
Step 7 : To determine overlay thickness from Fig 9 of IRC 81-1997 in terms of bituminous macadam construction.

Step 8 : To Convert thickness in to DBM/AC following formula is used.

1 cm of Bituminous Macadam = 0.7 cm of DBM/AC

Fig. 2.3 shows the flowchart of design procedure for the same.

Fig 2.3 Flow Chart of Overlay Design for Existing Carriageway (IRC 81-1997)





2.8 Design Standards for Structures

The structural design shall be based on Indian Codes and Standards for Roads supplemented by the International Codes and Standards wherever the former are silent.

IRC: 5-1998	Standard Specifications and Code of Practice for Road Bridges (Section I), General Features of Design (Sixth Revision), 1993
IRC: 6-2000	Standard Specifications and Code of Practice for Road Bridges, Section II, Loads and Stresses, 1994
IRC: 18-2000	Design Standard for Pre-stressed Concrete Road Bridges (Post Tensioned Concrete)
IRC:21-2000	Standard Specifications and Code of Practice for Road Bridges
IRC: 24-1984	Standard Specifications and Code of Practice for Road Bridges, Section V, Steel Road Bridges 1984
IRC: 45-1998	Recommendations for Estimating the Resistance of Soil below the Maximum Scour level in the Design of Well Foundations of Bridges, 1992
IRC: 78-2000	Standard Specifications and Code of Practice for Road Bridges, Section VII, Foundations and Substructure (First Revision), 1994
IRC: 83-1996	Standard Specifications and Code of Practice for Road Bridges, Section IX, Bearings, Part I Metallic Bearings, 1994 and Part II Elastomeric Bearings 1991.
IRC: SP 64 - 2005	Guidelines for the Analysis & Design of Cast-in-place Voids Slab Superstructure.
IRC: SP 65 – 2005	Guidelines for the Design & Construction of Segmental Bridges.
IRC: SP 66 – 2005	Guidelines for the Design of Continuous Bridges.
IS 875 – 1993	(Part 3) – 1987 Code of Practice for Design



	Loads (Other than earthquake) for Buildings and Structures, Part 3, Wind Loads (Second Revision) Fourth Reprint, November 1993
IS: 1893 – 2000	Criteria for Earthquake Resistant Design of Structures (Fourth Revision), June 1986.
IS 2911	(Part I / Section 1, 2, 3 and 4) Code of Practice for Design and Construction of Pile Foundations, Part I, Concrete Piles.
IS 2911	(Part III) 1980 Code of Practice for Design and Construction of Pile Foundations, Part 4, Load Test on Piles.
IS 2911	(Part IV) 1985 Code of Practice for Design and Construction of Pile Foundations, Part 4, Load Test on Piles.

2.9 Design Loads

The structure shall be designed for various loads as per IRC 6-2000 as described below.

Dead Load of Superstructure
Superimposed Dead Loads
Vehicular Live Load
Braking force
Active Earth Pressure
Earth Pressure due to L.L., Surcharge on backfill
Centrifugal force
Bearing Friction
Wind force
Earthquake force
Collision Load

Density for different materials to be considered for design -

Prestressed Concrete	-	2.6 T/m ³
Reinforced Concrete	-	2.5 T/m ³
Plain Cement Concrete	-	2.4 T/m ³
Wearing Coat	-	2.2 T/m ³
Soil (Dry)	-	1.8 T/m ³



Soil (Saturated) - 2.1 T/m³

The particular loading applicable to the project are enumerated below:

For all the structures, vehicular live load shall be considered as per the provisions of IRC: 6 - 2000 as applicable for different widths of carriage ways.

For overall movement of the bridge, the temperature difference of $\pm 25^{\circ}\text{C}$ shall be considered as per provisions in IRC: 6 - 2000. The distribution of temperature difference between top & bottom deck is considered according to the Fig. 10 shown in IRC: 6 - 2000.

Wind Loads : Full wind force on live load and structure, applied perpendicular to the structure, or 65% wind force perpendicular to traffic direction and 35% wind force parallel to traffic direction on live load and structure whichever produces the worst effect shall be considered.

Earthquake Load: Structures will be designed for Zone III according to IRC - 6, soil foundation factor $\beta = 1.0$ (bearing piles on rock) and importance factor $\lambda = 1.5$. Horizontal Seismic Coefficient for longitudinal and transverse direction will be calculated using the provisions published in Journal - 'INDIAN HIGHWAYS' of January 2003 amendments to IRC provision of seismic forces (Cl. No. 222). Earthquake load thus calculated shall be applied in the longitudinal or transverse direction; whichever produces the maximum effects.

Collision Loads on Pier: Collision loads of 100 Tonnes parallel and 50 Tonnes transverse to the carriageway shall be considered for the piers located at junctions / road crossings etc. according to IRC: 6 - 2000 Table 7. For additional safety, a reinforced concrete wall 1.0 m high with sand in-fill cushion shall be provided around the periphery of the piers of obligatory spans.

Centrifugal Force: In the curved decks, the effects of centrifugal force as specified in IRC 6 : 2000 in the deck, bearings and substructure shall be included.

Load combinations: Load combination Groups I to VII shall be considered in accordance with IRC 6 - 2000.



2.10 Durability Aspects for Structures

Durability considerations require the use of dense concrete with lower water / cement ratio and higher cover to reinforcement. The following important concrete durability aspects shall be covered in the specification.

Aggregates shall be substantially free from chloride or sulphate contamination. The percentage of chloride ions and sulphates in fine and coarse aggregates, and in the concrete mix shall be limited.

Aggregates shall be sound & durable to resist attack in aggressive environment. Water absorption and soundness in sulphate solutions shall be limited.

Aggregates shall be of proper elongation and flakiness to permit workable concrete within tight water / cement ratios.

Cement must be selected suitable to its purpose such as using blended cement when chlorides are high in the ground.

Water for mixing concrete and curing shall be substantially free from contamination with chlorides and sulphates.

Using admixtures to achieve workability and high quality mix.

Concrete mix shall be designed to obtain workable concrete with low water / cement ratio to produce dense and less permeable concrete.

Concrete shall be placed and properly compacted as soon as possible to avoid plastic and thermal cracks.

Curing is important to achieve strong concrete with a hard, durable, and impermeable surface.

Provision of adequate concrete cover to reinforcement.

Provision of protection to steel reinforcement with anticorrosive treatment.

Use of Mild steel liners to bored piles.

Provision of protective coating to exposed concrete surfaces and to buried concrete surfaces.

Using un-reinforced concrete where it is an acceptable alternative to reinforced concrete.

In the design, attention shall be given to avoid unnecessary complicated details, such as exposed concrete features which may collect sand or dust, pipes or utilities being built into concrete, bundling of reinforcements and the use of unsealed joints etc. Rounded profiles at corners and rounded concrete sections shall be as much as practicable. Construction joints will be given particular attention and provided as often as necessary.



2.11 Lighting

Lighting design has been based on the guidelines stipulated in the National Electrical Code (Part-5) and the recommendations of the International Commission on Illumination (CIE).

The following standards and rules have also taken into consideration while detail engineering:

IS: 1913 General and Safety requirements for light fittings.

IS: 1944, 1970 Code of practice for lighting public thoroughfares.

IS: 3528 Water proof electric lighting fittings

IS: 1239 M.S. Tubular and other wrought steel pipe fittings

IS: 2713 Manufacture of steel tubular poles

IS: 2149 Luminaries for street lighting

IS: 3043 Code for practice for earthing

Indian Electricity Act and Rules

2.12 Landscaping

Landscaping is one of the important aspects in urban design. It has significant transportation and economic advantages:

Safety – Formal rows of trees change the road's visual character. Used in conjunction with kerbs and footpath, trees help to calm traffic.

Way finding – Roadside trees or group of trees, lighting can also serve as landmarks and even alert drivers of an upcoming turn in the road. Landscaping in a traffic island or roundabout makes the feature more recognisable to approaching drivers.

Variety – Monotony causes driver inattention. Trees and amenities create attractive visual interest that give the road a distinctive identity and provide seasonal interest.

Environment - Trees absorb pollutants and storm runoff, reduce air conditioning needs in the summer, and can help block winter winds.

Business Vitality – People enjoy and are attracted to an environment with trees, landscaping and other pedestrian amenities.