A Case Study: Analysis of Flexible Pavement Designed

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Abstract— At present, flexible pavement is widely used all over the world, which will result in excess saving in terms of vehicle operating cost and travel time, which has carried on the overall economic feasibility of the project. Transportation plays a significant role in the development of human citizens. Flexible pavement ongoing research about the deflation in the flexible pavement, disintegration, and surface defect which maintains the flexible pavement. At the present time to provide a better road network is necessary but is not available someplace. Noida city center has high traffic, but the road network is not available for it. Which is used by non-daily traffic used to college and other destinations?

Keywords: Road Design, Flexible pavement, CBR, Commercial Vehicles per Day (CVPD), GIM

I. INTRODUCTION

Flexible pavement is the type of pavement that is made up of Bituminous. Which have a low or negligible flexural strength? It consists of wearing surfaces built over a base course, and they rest on compacted subgrade. The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Flexible pavement layers reflect the deformation of the lower layers on to surface layer. Flexible pavement distributes the wheel loads transfer through a set of layers grain to grain. It Consists of subgrade, sub-base course, and base course. Flexible pavements with asphalt concrete surface courses are used all around the world. Various methods are used for the design of flexible pavement. In Group Index Method (GIM), the total thickness of pavement (SUB BASE & BASE surfacing, base and subbase) is determined. Also, the thickness of the sub-base is determined. The CBR method is the best method for the design of flexible pavement. The CBR method is based on the strength parameter of the material and is, therefore, more reasonable than the Group Index Method. North Dakota Method is similar to the CBR method. Pavement thickness is found from the design curve, which is between pavement thickness and cone-bearing ratio.

II. FLEXIBLE PAVEMENT:

Flexible pavements are constructed from Bituminous or unbound material, and the stress is transmitted to the subgrade through the lateral Distribution of the applied load with depth. Flexible pavement is composed of a bituminous material surface course and underlying base and Sub base courses.

Various layers of flexible pavement are given below:

1) Surface course
2) Base course
3) Sub-base course
4) Sub-grade

Fig. 1: Soil sub-grade

III. METHODS OF DESIGN OF FLEXIBLE PAVEMENTS:-

The design of flexible pavements has been based on experience and judgment in the past. But the design methodology has taken rapid strides toward rationality in the past few decades based on an understanding of the stresses and strain in the layers constituting the pavement and the application of the concept of reliability in achieving the desired level of service during the design life of the pavement. Flexible pavement design methods are accordingly either semi-empirical or empirical. In these methods, the knowledge and experience gained on the behavior of the pavements in the past are usefully utilized. The various rear methods used to design flexible pavement:

1) Group Index Method
2) California Bearing Ratio Method
3) Stabile-meter method or California R-Value
4) Triaxial test method
5) Mc-Leod method

IV. GENERAL:

The design method, empirical, and semi-empirical methods are used. Some empirical methods are the ‘group index method’ (based on soil classification and traffic volume), the California R-value method (based on the results of stabile meter tests), and mc Leod's method (based on plate load test results). And semi-empirical methods are the triaxial test and Burmester's (two-layer) method which have been practically superseded by more rational approaches based on long-term road tests on experimental stretches.

V. FUTURES SCOPE:

All the pavement design related information will apply to design of flexible pavements for Expressway (high-speed traffic), National Highways (connect major city of India whether ports), State Highways, Major District Roads, district road, and other categories of roads. Bituminous surfacing and granular base and sub-base courses conforming to IRC standards.

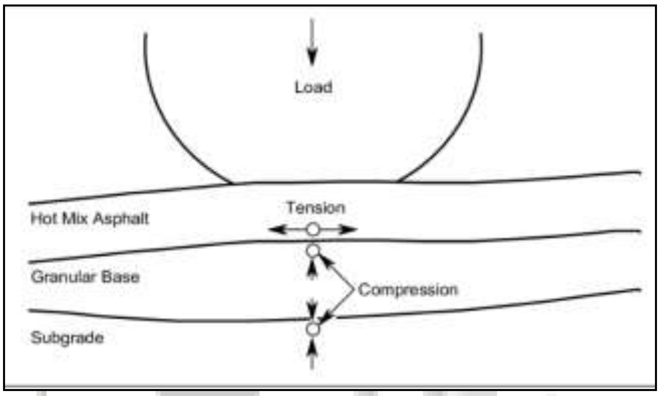
VI. DESIGN CRITERIA:

The flexible pavement has been designed as a three-layer structure, and stresses and strains at critical locations have been calculated using the linear elastic model. To give proper thought to the details of performance, there are three types of pavement distress resulting from the repeated (cyclic) application of traffic loads are considered:

1) At the top of the sub-grade, the vertical compressive strains are acting, which can cause deformation in the sub-grade resulting in permanent deformation at the pavement surface.
2) Pavement deformation within the bituminous layer. In the bituminous layer, the permanent deformation can be controlled by meeting the mixed design requirements.
3) At the bottom of the bituminous layer, the horizontal tensile strain or stresses are acting, which can cause fracture of the bituminous layer

The strains at the critical points are within the permissible limits. Tensile strains are calculated at the bottom of the bituminous layer, and the stiffness of the dense bituminous macadam (DBM) layer with 60/70 bitumen has been utilized in the analysis of flexible pavement.

VII. FAILURE CRITERIA



Tensile and compressive strains in flexible pavements.

Fig. 2: Critical Locations in Pavement

X and Y are the critical locations for tensile strains (t). The Maximum value of the strain is taken for design. The critical location is C, where the vertical sub-grade strain (z) occurs. Since the maximum value of the (z) occurs mostly at critical location C. Fatigue Criteria: flexural fatigue cracking occurs on the bituminous surface of the pavement if the tensile strain at the bottom of the bituminous layer is beyond a certain limit. The relation between the life of the paved road surface and the stiffness of the bituminous layer was found to be as

$N_{f\,=}$ 2.21×10−4× (1/Ex) 3.89× (1/E) 0.854………….. (1)

where,

Nf= it is the allowable number of load repetitions to control fatigue cracking and

E = it is the Elastic modulus of a bituminous layer. The use of equation (1), the fatigue cracking of 20% of the total area

A. *Rutting Criteria:*

The allowable number of load repetitions to control permanent deformation can be expressed as

Nr= 4.1656× (10−8) × (1/Ex) 4.5337

Nr= it is the number of cumulative standard axles to produce rutting of 20 mm.

VIII. DESIGN PROCEDURE:

The design of flexible pavement is based on the execution of current designs, and using an analytical approach, simple design charts and a list of pavement designs are added to the code. In the pavement designs, the CBR values of the given subgrade range from 2% to 10%, and design traffic values range from 1MSA to150MSA for an average annual pavement at the temperature of 35 degrees Celsius. Using the following simple input parameters, the suitable design could be chosen for the given traffic and soil strength:

1) Design traffic in terms of the cumulative number of standard axles (CNSA), and
2) CBR value of sub-grade

IX. DESIGN TRAFFIC:

In the traffic design, the cumulative number of standard axles (8200 kg) is to be carried by the pavement during the design life. The following information is required for the design traffic is:

1) Initial traffic is required for the design of terms of commercial vehicles per day (CVPD)
2) Design life (in number of years)
3) Traffic growth rate during the design life
4) Vehicle damage factor (VDF)
5) Distribution of various traffic over the carriageway.

X. INITIAL TRAFFIC:

It is found out in terms of commercial vehicles per day (CVPD). For the structural design of the flexible pavement, only commercial vehicles(CV) are taken, assuming the burdened weight of four tones or more, and their axle loading will be considered. Estimate of the initial daily average traffic flow for any road should normally be based on 7-day 24-hour classified traffic counts average daily traffic (ADT). In the case of new roads, potential land is required to estimate the initial traffic and traffic on existing routes in the area.

Traffic growth rate:

Traffic growth rates are estimated by

1) Studying the past trends of traffic growth, and
2) By starting with econometric models. If sufficient data is not available, it is assumed that an average annual growth rate of 7.5 percent may be taken.

XI. DESIGN LIFE:

Every civil engineer is required to find out the design life of any civil engineering structure. The design life is defined by the growing number of standard axles that can be carried before the paved area is repaired. Following design life is recommended for the pavement such as national highway, State Highway should be designed for a life of 15 years, Express Highway and urban roads for 20 years and other district, sub-district roads for 10 to 15years.

XII. VEHICLE DAMAGE FACTOR:

It is required for pavement design. The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicles with different axle loads and axle configurations to the number of standard axle-load repetitions. It is defined as (equivalent number of standard axles / commercial vehicle). The VDF varies with the types of road, axle configuration, axle loading, topography, and from place to place. The axle load equivalency factors are used to convert deferent axle load repetitions into equivalent standard axle load repetitions. For these equivalency factors, refer to IRC: 372001. The exact VDF values are found after large field surveys

XIII. VEHICLE DISTRIBUTION:

A sensible evaluation of the Distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load application used in the design. Until reliable data is available, the following vehicle distribution may be assumed for design purposes.

XIV. SINGLE LANE ROADS:

A single-lane road is a road that permits two-way traffic. The width of the road depends on the terrain and the volume of traffic on the road. The design should be based on the total number of commercial vehicles in both directions.

XV. TWO-LANE SINGLE CARRIAGEWAY ROADS:

A single-carriageway is a road with four lanes arranged within one carriageway with no central reservation to separate opposing flows of traffic. The design should be based on 75% of the commercial vehicles in both directions.

XVI. FOUR-LANE SINGLE CARRIAGEWAY ROADS:

The design should be based on 41 % of the total number of commercial vehicles in both directions.

XVII. DUAL CARRIAGEWAY ROADS:

The design of dual two-lane carriageway roads should be based on 75 % of the number of commercial vehicles (CV) in each direction. For dual three-lane carriageway and dual four-lane carriageway, the distribution factor will be 60 %and 45 %, respectively.

XVIII. PAVEMENT THICKNESS DESIGN CHARTS:

In the pavement thickness design, the design of pavements to carry traffic in the range of 1 to 10 MSA, use chart one, and for traffic in the range ten up to 150 MSA, use chart IRC: 37 2001. Design curves associate road density with a growing number of standard axles that must be carried over the design life to separate. Sub-grade CBR values ranging from 3 % to 10 %. The design charts will give the total thickness of the pavement for the pavement thickness design. Complete thickness consists of less granular foundation, granular foundation, and bituminous origin. Every layer of pavement layers is designed which is based on the recommendations given below and the subsequent tables. (WBM) or wet mix macadam (WMM) or equivalent proof in most texts. The materials should be of good quality with a minimum thickness of 225 mm for traffic up to 2 MSA and150mmfortrafficexceeding 2MSA. This guideline follows analytical designs and developed a new set of designs up to 150 MSA in IRC: 37 -2001.

CBR 9% AND 10%				
S.No.	Total Pavement Thickness (mm)	Pavement Composition		
		Bituminous Surfacing		Granular Base (mm)
		Wearing Course(mm)	Binder Course	
1	375	20 PC		225
2	425	20 PC	50 BM	225
3	450	20 PC	50 BM	250
4	475	25 SD BC	50 DBM	250
5	540	40 BC	50 DBM	250

Chart 1:

XIX. BITUMINOUS SURFACING:

It is the topmost layer of flexible pavement. Different type of bituminous surfaces is:

1) Prime coat: it is the first application of low viscosity liquid bituminous material over an existing porous surface like the WBM base course.
2) Tack coat: the application of bituminous material over an existing impervious pavement surface that has already been treated by a prime coat.
3) Seal coat: seal coat is mainly applied on the impervious surface of the bituminous pavements as a top coat. It is desirable to use bituminous macadam (BM) for traffic up to o 5 MSA and dense bituminous macadam (DBM) for traffic more than 5MSA.

XX. PAVEMENT COMPOSITION:

Sub-base materials comprise natural sand, gravel, Laterite, brick metal, crushed stone, etc. The sub-base material should have a minimum CBR of 20 % and 30 % for traffic up to 2 MSA and traffic exceeding 2 MSA, respectively. Sub-base usually consists of granular or WBM and the thickness should not be less than 50mm for design traffic less than10MSA and 150mm for design traffic of 10 MSA and above.

XXI. DESIGNED:

A. *Formula of Million Standard Axles:*

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

Where,

N = cumulative number of standard axles to be catered during the design period in terms of MSA.

A = initial traffic in the year of completion of construction in terms of CVPD.

D = lane distribution factor.

F = design life in years. R = annual growth rate of commercial vehicles.

Design the pavement for the construction of a new bypass with the following data:

1) Single lane carriageway
2) Initial traffic in the year of completion of construction=350 CVPD (sum of both directions)
3) Traffic growth rate=6.5%
4) Design life=16years
5) Vehicle damage factor based on axle load survey=2.5 standard axle per commercial vehicle
6) Design CBR of sub-grade soil=4%.

B. *Designed details:*

1) Distribution factor=0.75
2) $N = 365\times (1+0.065)16-1)/\ 0.065\times 350\times 0.75\times 2.5$
   $=64084215.54$
   $=6.4$ MSA
3) Total pavement thickness for CBR 9 & 10% and design traffic 6.4MSA from IRC: 37:2001 chart 1 =550 mm
4) Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC: 372001).
   a) Bituminous surfacing=25mm SDBC +70mm DBM
   b) Road-base=250mmWBM
   c) Sub-base=315mm granular material of CBR not less than30%

The design procedure of pavement given by IRC to determine with the help of the CBR value, million standard axle concept, and vehicle damage factor. Traffic distributions along the lanes are taken into account. The design traffic is found using a growth rate (r).

XXII. SITE SELECTION

1) Total length of Road=500 m
2) Road Width=3.7 m

3) After the selection of the alignment or final centerline of the road, investigation for soil and other materials is required for the suitability of the pavement.
4) Construction of the road pavements starts in respect of the likely sources and the availability and suitability of required materials of road pavement.
5) They are site selection for the flexible pavement In Noida city center. Locate the Noida Road.
6) Mostly use the road for a school bus, college bus, other job categories, and other staff there is no traffic problem

XXIII. SITE SURVEY:

A. *Topographic Survey*

It measures and identifies the exact location and specifications of natural and human-made features within an area of land. An investigation was conducted, and a temporary benchmark was established. Levels for cross-sections have been taken at every 12 m intervals at a different location.

B. *Traversing.*

In traversing the survey, the directions and lengths of the survey lines are measured with the help of an angle measuring instrument and tape or chain, respectively, and a temporary benchmark was established.

C. *Leveling.*

It is used to establish or verify or measure the height of specified points relative to the datum. All leveling for establishing benchmark is carried out having an accuracy of +5 and -5 mm/km. We started the work by assuming a subjective level. Leveling work is carried over using a technical instrument named AUTO LEVEL by taking an initial benchmark of 224.34 m from the standard railway mean sea level of the Noida city center, Noida.

D. *Auto Level.*

An Auto Level is similar to the dumpy level, with its telescope fixed to the Tri-branch. It is used in surveying with a vertical staff to measure height difference and to transfer measure and set height.

E. *Soil Tests:*

From the soil and material investigations, the CBR values are found to be more than10%. From the quarry and borrow are investigations, the good quality material required for the construction is available.

Fig. 3: Collection of Soil Sample from the Site

The dry density of soil:

For the determination of the dry density of soil, we will adopt the oven-dry method, and this method is used to determine the water content in the soiled oven drying method as per IS: 2720 (Part8)–1983. The water content (w) of a soil sample is equal to the mass of water divided by the mass of solids.

Water content (w) = (Ww/Ws)

Calculation (1): Fig4.Weight of soil

Weight of core cutter with soil=2.650Kg

Weight of soils stored in the core cutter;

= (weight of soil with core cutter)-(weight of core cutter without soil)

= (2.650)-(0.974)

=1.650 Kg

The measured dimension of core cutter are given below,

Height of core cutter=13cm

Diameter of core cutter = 10 cm

Thickness of core cutter=5mm

Weight of steel rammer = 9kg

Volume of core cutter (Vc) = area x height = 1021cm^3

Sr.no.	Observation and calculations	Determination 1	Determination 2	Determination 3
1.	The volume of the core cutter in (cm^3)	1021	1021	1021
2.	Weight of core cutter (Wc) in gram	974	974	974
3.	Weight of core cutter + wet soil (Ws) in gram	2650	2674	2660
4.	Weight of wet soil (Ws -Wc) in gram	1676	1700	1686
5.	Bulk density (Yb) = (Ws–Wc/Vc), gram/cm^3	1.64	1.66	1.65
6.	Water content (w) in % by oven drying method to find out.	12.42	11.95	12.85
7.	Dry density (Yd) = (Yb/1+w), gram/cm^3	1.46	1.48	1.46

Average dry density (Yd) = 1.46 gram/cm^3

XXIV. CONCLUSIONS:

Design of flexible pavement as per IRC-37:2001 and quality control methods for construction of fully approach control express highway as ORR.

The main observations and conclusions are given below:

Grade: 500 mm.
GSB: 200 mm.
WMM: 250 mm
DBM: 50 mm
BC: 50 mm.
Average dry density = 1.46g./cm^3

1) For the above design, the material properties of the aggregate and bitumen methodology are as per the standards of ISO 9001:2008 code Quality control methods.
2) Quality management used in the project as per the guidelines of network methods (Gantt charts, bar charts, milestone charts, critical part method, and program evaluation review technique).
3) Tests are conducted as per the IS code and are within the permissible limits.
4) Quality control of the project contains material, and the design procedure given by IRC makes use of the CBR value, million standard axle concepts, and vehicle damage factor. The traffic distributions along the lanes are taken into account. The design is designed to design traffic that is achieved using growth.

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