ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Flexible Pavement Design and Material Characteristics

Avvaru Tharun
M.Tech Student
Department of Civil Engineering,
Nalanda Institute of Engineering and Technology,
Kantepudi, Sattenapalli.

M Srinivas Reddy, M.Tech
Assistant Professor
Department of Civil Engineering,
Nalanda Institute of Engineering and Technology,
Kantepudi, Sattenapalli.

ABSTRACT

A typical flexible pavement consists of a subgrade, sub-base, base course and two layers of asphalt concrete mixes. The flexible pavements in India are designed as per the specifications of the Indian Roads Congress (IRC). In IRC: 37-2012, the pavement is modelled as a multi-layer elastic structure. The stresses and strains are evaluated using linearized elastic theory. The thickness of the pavement layers are selected duly considering the allowable stresses and strains in the pavement layers, including the subgrade.

The main concern related to pavement design is material characterization. For constructing road with superior quality, the highway material should meet the quality requirements and is helpful in providing good strength and longer life of pavements. The highway consists of soil in subgrade, granular material in sub-base/base, and bituminous mixture in binder/surface layer. In the current study, the tests that are carried out for characterizing the soil, granular and bitumen explained clearly. In addition, the allowable limits for selecting such materials are also mentioned.

In India, according to IRC: 37 (2012), pavements are designed to limit rutting and bottom-up fatigue cracking. It provides design templates for six different cross-sections, traffic levels and different subgrade California Bearing Ratio (CBR) values. These templates are designed for an Annual Average Pavement Temperature (AAPT) of 35°C. Traffic is considered in terms of Equivalent Standard Axle Load (ESAL) and here the standard axle is defined as a single axle dual wheel with a load of 80 kN.

IRC: 37 (2012) provides two distress prediction models for rutting based on 80 and 90 percent reliabilities. Resilient modulus (MR) is used as the material property in the design of a pavement for rutting according to IRC: 37 (2012). The IRC method of pavement design provides a constant granular layer thickness for different traffic levels.

The flexibility in changing the design is normally available for the bituminous layers. Using resilient modulus values and subgrade CBR, one should assume thicknesses for bituminous layers and determine stress-strain.

INTRODUCTION
INDIAN ROAD NETWORKS

The total length of Indian roads is about 4.32 million kilometers. India is the second largest country in the world after USA. The details of road networks are shown below.

Road Classifications:

According to Lucknow plan, the roads are classified as,

1. Based on primary basis and,
2. Urban roads

Based on Primary Basis:

Primary systems

i. Express ways
ii. National highways

Secondary systems

i. State highways
ii. Major district roads

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Tertiary systems

i. Other district roads

ii. Village roads

Urban roads:

i. Arterial roads

ii. Sub arterial roads

iii. Collector roads

iv. Local roads

According to Nagpur road plan, the roads are classified as,

1. National highways
2. State highways
3. Major district roads
4. Other district roads
5. Village roads

National Highways:

National highways connects the capital region with important cities of various states, business places, important border places, provides best transportation facilities.

The central government has taken up the development of national highways by making the highways to 4/6 lanes along highly trafficked corridors and upgrading of selected high density corridors. The development of national highways was undertaken by the national highways authority of India.

State Highways:

State highways connects the important places in the state, national highways, business places in state etc. state government will look after the construction & maintenance of state highways. The design specifications are same as national highways.

Major District Roads:

These roads provide the main road connectivity within the districts, connect the state highways, provide important transport facilities, business places etc. These roads are also under the state government. These roads have lower design specifications compared to state highways.

Other District Roads:

These roads provide important connectivity within mandals & Talukas, it connects the major district roads in district, agricultural and market places etc. the state government is responsible for the construction & maintenance of these roads. These roads have lower design specification when compared to Major District roads.

Village Roads:

Village roads connect the other district roads with the villages in rural areas, local market areas, and agricultural places. The state government is responsible for construction &maintenance of these roads.

Important national highways

There are 9 important national highway roads connecting major cities & towns. They are,

NH No	Locations	Length (km)
NH1	Delhi to Amritsar	456
NH2	Delhi to Kolkata	1465
NH3	Agra to Mumbai	1161
NH4	Mumbai to Chennai	1235
NH5	Cuttack to Chennai	1535
NH6	Hajira to Kolkata	1949
NH7	Varanasi to Kanyakumari	2369
NH8	Delhi to Mumbai	1428
NH9	Pune to Vijayawada	841

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Table 1.Details of Indian road networks

SI.No	Type of road	Description of road	Length (km)	Total road length %	Total road traffic carried %
1	NH	Express ways	1000		
		4/6/8 lane: 12% of length	78,200	2%	40%
		Double intermediate lane: 56% of length			
		Single lane: 32% of length			
2	SH	4 lane: 1% of length	132852	4%	40%
		2 lane: 19% of length			
		Single lane: 80% of length			
3	MDR		467876		
4	VR & ODR		2950543		

Andhra Pradesh Road Networks Statistics

The Roads &Building Department of Andhra Pradesh is maintaining 69000 kms of roads which includes National highways, State Highways, Major District roads &rural roads. The lengths of roads in AP are shown below

Table 2 AP road network details

S.no	*Type*	*Length (km)*
1	National highways	4867
2	State highways	10332
3	Major district roads	32359
4	Rural roads	21736

Pavement composition

Sub base course

Sub base course comprises of the materials like natural sand, moorum, gravel, laterite, kankar, brick, crushed stone, crushed slag, and crushed concrete, thereof meeting the prescribed grading and physical grading & physical requirements.

When sub base course consist of various materials then mixing shall be done mechanically, by using a suitable mixer or adopting mix in place method.

Granular sub base course materials confirming to clause 401 of MORTH specifications for road & bridge works are recommended for use.

To say in simple words the sub base materials should have a minimum CBR of20% to 30% for traffic up to 2 msa & traffic exceeding 2 msa respectively. Usually the sub base consist granular or WBM and the thickness should not be less 150mm for less than 150mm for design traffic less than10 msa and 200mm for design traffic of 10 msa and above.

Base Course

The unbound granular bases which comprises the conventional water bound macadam, wet mix macadam or other equivalent granular construction conforming to IRC/MORTH specification's shall be adopted.

The materials to be used in base course are recommended for the minimum thickness of granular base is 225 mm for traffic up to 2msa and 250 mm for traffic exceeding 2 Msa.

Bituminous Surfacing

These surfacing shall consist of wearing course or binder course along with wearing course. It depends upon the traffic data of the particular road. Surface dressing, open graded premix carpet, mix seal surfacing, semi dense bituminous concrete & bituminous concrete are most commonly used wearing courses.

IRC/MORTH specifies that binder course it is desirable upto 5msa. If more than 5msa dense bituminous macadam is recommended.

Pavement distresses

Types of Distress Generally Observed In Site

A flexible pavement are constructed of several layers of natural granular material covered with one or more waterproof bituminous surface layers, and as the name implies, are considered to be flexible. A flexible pavement will flex (bend) under the load of a tyre. The objective with the design of a flexible pavement is to avoid the excessive flexing of any layer, failure to achieve this will result in the over stressing of a layer, which ultimately will Cause the pavement to fail. In flexible pavements, the load distribution pattern changes from one layer to another, because the strength of each layer is different. The strongest material(least flexible) is in the top layer and the weakest material (most flexible) is in the lowest layer.

The reason for this is that at the surface the wheel load is applied to a small area, the result is high stress levels, deeper down in the pavement, the wheel load is applied to larger area, the result is lower stress levels thus enabling the use of weaker materials. Pavement design includes two tasks: (1) mixture or materials design and (2) structure or thickness design. These two tasks cannot be cleanly separated at the design stage; there must be interaction between the tasks. Specifications are the link between mixtures and thickness design. Bituminous pavements exhibit all kinds of distress modes including Rutting, Shoving, Depressions, Cracking ravelling, bleeding etc. Distressed pavement is often a result of a combination of factors, rather than just one root cause.

Different types of distresses in flexible pavement are as follows

Longitudinal Cracking

Cracks that are approximately parallel to pavement centerline are not in the wheel path. Longitudinal cracks are non-load associated cracks. Location within the lane (wheel path versus non-wheel path) is significant. Longitudinal cracks in the wheel path are normally rated as Alligator 'A' cracking.

Fatigue Cracking

A series of interconnected cracks are caused by fatigue failure of the HMA surface under repeated traffic loading. As the number and magnitude of loads becomes too great, longitudinal cracks begin to form (usually in the wheel paths). After repeated loading, these longitudinal cracks connect forming many-sided sharp-angled pieces that develop into a pattern resembling the back of an alligator or crocodile.

Transverse Cracking

Cracks that are predominately perpendicular to pavement centreline and are not located overPortland cement concrete joints. Thermal cracking is typical in this category.

Edge Cracking:

Crescent-shaped cracks or fairly continuous cracks that intersect the pavement edge and arelocated within 2 feet of the pavement edge, adjacent to the unpaved shoulder.It includeslongitudinal cracks outside of the wheel path and within 2 feet of the pavement edge.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Rutting:

Longitudinal surface depression that develops in the wheel paths of flexible pavement undertraffic. It may have associated transverse displacement.

Corrugation:

Transverse undulations appear at regular intervals due to the unstable surface course causedby stop-and-go traffic.

Shoving

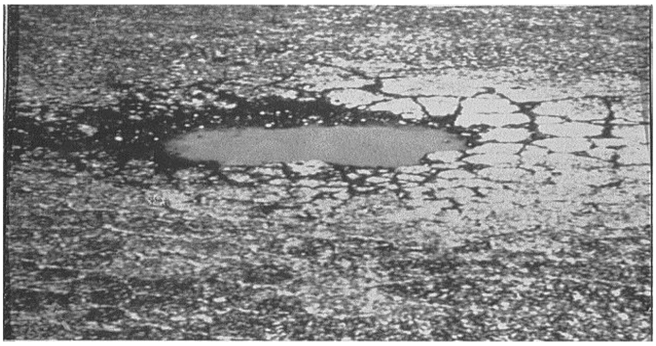
Shoving is a longitudinal displacement of a localized area of the pavement surface. It is generallycaused by braking or accelerating vehicles, and is usually located on hills or curves, or atintersections. It also may have vertical displacement.

Depression

Depression is Small, localized surface settlement that can cause a rough, even hazardous ride to motorists.

Potholes

Bowl-shaped holes of various sizes in the pavement surface. Minimum plan dimension is 150mm.



PATCHING

Patching means portion of pavement surface greater than 0.1 sq. meters that has been removed and replacedor additional material applied to the pavement after original construction.

MATERIAL CHARACTERIZATION

General

It is necessary that a soil survey along and around the road alignment is carried out following the laid down-procedures and that the results of all field and laboratory investigations are made available to the designer. During the soil surveys, the depth and fluctuations of GWT must be recorded. All the representative samples of subgrade soils must be subjected to the simple classification tests (wet sieve analysis, liquid and plastic limits) and the soil group

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

shown against each representative sample, ensuring that atleast 3 samples are taken per kilometre length even if the same soil type continues.

For each soil groups thus identified, atleast one CBR test should be conducted with the soil compacted to the standard proctor density and at a moisture content corresponding to the wettest state considered appropriate to the site conditions.

Subgrade strength evaluation

The Subgrade

As per MORTH specifications for rural roads, subgrade can be defined as a compacted layer, generally of naturally occurring local soil, assumed to be 300mm in thickness, just beneath the pavement crust, providing a suitable foundation for the pavement. The subgrade in embankment is compacted in two layers, usually to a higher standard than the lower part of the embankment. In cuttings cut formation, which serves as the subgrade, is treated similarly to provide a suitable foundation for the pavement. Where the naturally occurring local subgrade soils have poor engineering properties and low strength in terms of CBR, for example in black cotton soil areas, improved subgrades are provided by way of lime/cement treatment or by mechanical stabilization and other similar techniques.

The subgrade, whether in cutting or in embankment, should be well compacted to utilize its full strength and to economize on the overall pavement thickness. The current MORTH specifications for rural roads require that the subgrade should be compacted to 100% maximum dry density achieved by the standard proctor test. The material used for subgrade construction should have a dry unit weight of not less than 16.5 KN/m3.

Subgrade strength

The insitu subgrade strength of an existing road will be determined in terms of CBR value obtained on representative subgrade soil samples remoulded to the insitu density at the field equilibrium moisture content, observed after the recession of the rainy season. If, for some reason, it is not found possible to determine the field moisture content immediately after the recession of monsoon, the 4 day's soaked CBR value of the remoulded subgrade soil samples, compacted to field density, may be determined. When the alternative of carrying out DPC tests is adopted, salient details are provided in the modified below, which relates to strength of the subgrade in terms of CBR at insitu moisture and density.

Subgrade strength classes

In order to use the design catalogue, the subgrade is divided into the following classes:

Table 3 Subgrade classes

Quality of subgrade	class	Range (CBR %)
Very Poor	S1	2
Poor	S2	3-4
Fair	S3	5-6
Good	S4	7-9
Very Good	S5	10-15

Where the CBR of subgrade soil is less than 2, the economic feasibility of replacing 300mm subgrade with suitable soil needs to be explore and, if found feasible, the pavement should then the designed based on CBR value of the improved subgrade, alternatively, a capping layer of thickness not less than 100mm of modified soil (with CBR not less than 10) should be provided.

Traffic estimation

Composition of rural traffic

It is not only the traffic volume but also its composition that plays an important role in determining the pavement thickness and composition. There is a wide variety of vehicles plying on rural roads, half or even more of the total number being non motorized mostly bicycles and animal drawn carts.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Among the motorized vehicles, the two wheeled motor cycles constitute a sizable proportion followed by tractors/tractor-trailers, jugads, pick-up vans, jeeps and cars. Heavy commercial vehicles (HCV) like full-sized trucks and buses are relatively very few in number, their proportion out of the total may be as low as 5%, sometimes even lower.

The number of medium commercial vehicles (MCV) like tractor-trailers and medium-sized trucks is generally much higher than the number of HCV. Even though the number of animal drawn carts is on the decline, these are still sizable in number. The number of tractors/tractor trailers is gradually on the increase, while the number of motor cycles is increasing rapidly.

For the purpose of pavement design, the large number of bicycles, motor cycles and pneumatic tyred animal drawn carts are of little consequences and only the motorized commercial vehicles of gross laden weight of 3 tones and above (i.e. HCV and MCV) are to be considered.

A procedure has also been suggested to evaluate and consider the effect of solid wheeled carts (SWC) in computing the design traffic for pavement design.

Traffic growth rate

some of the simple methods for estimating the traffic growth rates are given below:

Trend analysis

The past trend of growth is analyzed and the rate established by fitting a relationship of the type Tn =T0(1+r)n where n is the number of years, T0 is the traffic in zero year, Tn is the traffic in the nth year and r is the rate of growth in decimals. The future rate of growth can be fixed equal to or higher than the past rate depending on socio-economic considerations and future growth potential of the region where the road is located. Local enquiries in this regard are often very useful.

Econometric model

The traffic growth rate can also be estimated by establishing econometric models,

Recommended growth rate

In the absence of any specific information available to the designer, it is recommended that an average annual growth rate of 6% over the design life may be adopted.

Design life

While selecting the design life of a pavement it must be borne in minds that at the end of the design life, the pavement will not have to be reconstructed all over again. It only means that at the end of design life, it will only need to be strengthened, so that it can continue to carry traffic satisfactorily for a further specified period. It is necessary to carry out proper condition surveys atleast once a year, so that the nature and rate of change of condition will help identify as to when the pavement will require strengthening. A design life of 10 years is recommended for purpose of pavement design for flexible pavements. This design life of 10 years is recommended to ensure that neither the strengthening will need to be carried out too soon nor will the design for a very long design period be unduly expensive by way of high initial investment required.

The aspect of stage construction is especially relevant to very low volume roads (design traffic is less than 0.1 MSA) which are initially designed and constructed as all-weather gravel roads. After monitoring their performance and the growth in volume and composition of traffic over 5 years or so, can be suitably strengthened and black topped where necessary. Suitably postponing the metalling and black-topping of gravel roads can go a long way in connecting more of the unconnected habitations within the same investment.

The aspect of possible upgradation of a rural road to a higher category road at a future date must be kept in view, especially ensuring proper compaction of

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

subgrade which serves as the very foundation of a pavement.

Distribution of commercial traffic over the carriageway

Distribution of commercial traffic in each direction and in each lane is required for determining the total equivalent standard axle load applications to be considered in the design. In the absence of adequate and conclusive data, the following distribution may be assumed until more reliable data on placement of commercial vehicles on the carriageway lanes are available:

(i)Single-lane roads

Traffic tends to be more channelized on single-lane roads than two-lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.

(ii) Two-lane single carriageway roads

The design should be based on 50 per cent of the total number of commercial vehicles in both directions. If vehicle damage factor in one direction is higher, the traffic in the direction of higher VDF is recommended for design.

(iii) Four-lane single carriageway roads

The design should be based on 40 per cent of the total number of commercial vehicles in both directions.

(iv) Dual carriageway roads

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

Where there is no significant difference between traffic in each of the two directions, the design traffic for each direction may be assumed as half of the sum of traffic in both directions. Where significant difference between the two streams exists, pavement thickness in each direction can be different and designed accordingly.

For two way two lane roads, pavement thickness should be same for both the lanes even if VDF values are different in different directions and designed for higher VDF. For divided carriageways, each direction may have different thickness of pavements if the axle load patterns are significantly different.

Computation of design traffic:

The design traffic in terms of the cumulative number of standard axles to be carried during the design life of the road should be computed using the following equation:

$$N = \frac{365 \times \left[(1+r)^n - 1\right]}{r} \times A \times D \times F$$

Where,

N = Cumulative number of standard axles to be catered for in the design in terms of msa.

A = Initial traffic in the year of completion of construction in terms of the number of Commercial Vehicles Per Day (CVPD).

D = Lane distribution factor

F = Vehicle Damage Factor (VDF).

n = Design life in years.

r =Annual growth rate of commercial vehicles in decimal (e.g., for 5 per cent annual growth rate, r = 0.05).

The traffic in the year of completion is estimated using the following formula:

$$A = P(1+r)^x$$

Where,

P = Number of commercial vehicles as per last count.

x = Number of years between the last count and the year of completion of construction.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

PAVEMENT DESIGN

Traffic data required

Average daily traffic = 418

Average Annual Daily Traffic (AADT) = T + (1.2 n T t) / 365

Here T= 209

n=1 observed from previous studies & local enquiries

t=75

Average Annual Daily Traffic (AADT) = T + (1.2 n T t) / 365

= 209 + (1.2×1×209×75)/365

=260. Nos

AADT assuming an initial growth rate of 6% = (AADT×(1.06)^2)

= 260×1.06^2

= 293 Nos.

From the above AADT traffic count data, proportions of MCV and HCV are,

MCV	41Nos	Laden medium commercial vehicle
MCV	38Nos	Un-laden medium commercial vehicle
MCV	0Nos	Over laden medium commercial vehicle
HCV	3Nos	Laden heavy commercial vehicle
HCV	0Nos	Un-laden Heavy commercial vehicle
HCV	0Nos	Over laden heavy commercial vehicle

CONCLUSIONS

The study area is vatticherukuru, mandal road connecting mandal headquarters with Guntur town.

From the analysis the road condition was average. But based on traffic growth & subgrade strength of soil it will be good if the new road is constructed by removing present road. The pavement thickness to be maintained was analysed and confirmed as 425mm.