Design of Flexible Pavement

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Abstract – The highway plays an important role in development of a country and also improves the living standard of people. The road development programmes envisaged for the country involve large amount of money, man power, materials, and machinery not only for the construction of new roads, but also for the improvement of existing road network. The objective of this project is to provide a pavement design with sufficient information so that the necessary input data can be developed and proper engineering principles applied to design a new flexible pavement. The design is based on Indian Road Congress "guidelines for flexible pavement". These are based on CBR method: in this approach, the pavement thickness is related to the cumulative number of axles to be carried out for different sub grade strengths. Within the rapid growth of traffic, the pavements are required to be design of heavy volume of traffic of the order of 150 Million Standard Axles (MSA). There are so many methods for pavement design but that methods are theoretical. The IRC design criteria are based on CBR method and traffic. So this enables us to design practically. The design is based on IRC 37-200. In this project we discussed about the test and design procedure.

Index Terms – Highway, Flexible Pavement, CBR, MSA.

1. INTRODUCTION

1.1. Role of Transportation:

The evolution and advancements in transportation facilities have been closely linked with the development of human being throughout the history of the world. Transportation contributes to the economic, industrial, social and cultural development of any country. Transportation is vital for the economic development of any region since every commodity produced, whether it is agricultural or distribution. At the production stage, transportation is required for carrying raw materials like seeds, manure, coal, steel, machines, component parts, etc. At the distribution stage, transportation is required from the production centres like the farms and factories to the marketing centres and later to the retailers and to the consumers. Inadequate transportation facilities retard the process of socio-economic and cultural development of the country. Development of adequate transportation system in a country indicates its economic growth and progress in social development.

In the present day concept, the main objective of a good transportation system is to provide safe, economical, efficient transportation facility for the travel of passengers and transportation of goods.

1.2. Role of Transportation for the Development of Rural Areas in India:

About seventy percent of the population of India are living in the rural areas. Therefore developments in urban centres alone do not indicate the overall development of the country. Only with the improvement in transportation facilities in rural areas, there could be faster development of these areas, resulting in overall development of the country. The fertilisers and other inputs for agriculture and cottage industries could reach the rural population easily and the products of the villages can be sold at the nearest market centres for more remunerative prices, resulting in faster economic growth and decreased wastage. By providing improved facilities for education, health care and other social needs. In the villages, the urge for the migration of the population to urban centres decreases, thus helping in balanced development of the country as a whole.

The impacts of rural road connectivity from the recent rural road development programmes in the country are as follows:

- Improvement in transportation services leads to improved access to market centres for the rural producers, better availability of farm inputs at reduced prices.
- Diversification of agricultural produce with improved market access promotes shift in favour of cash crops and commercialization of agricultural activities.
- Diversification of livelihood opportunities with better connectivity enhances employment opportunities in the non-agricultural sectors.
- Improved services with improved road connectivity, inter-alia, enhances access to education, health and financial services.
- Increase in the outreach due to improved rural roads facilities better availability of public services and functionaries in rural areas.

1.3. IMPORTANCE OF ROADS IN INDIA

For the balanced developed of any country, it is essential to provide a well planned road network connecting all the towns and villages. It is necessary to provide good road links between the villages and market centres. The prosperity around the urban areas alone does not reflect the economic and living condition of the people of the country as a whole. Overall economic progress can be achieved, only if reasonably

adequate transport facilities are made available between the villages and other district head quarters and commercial centres. This is possible only by providing a well planned network of all-weather roads in the rural areas which are maintained in good condition. Apart from providing connectivity to the villages, it is also important to develop high quality of major highway system and expressways connecting important urban, industrial and commercial centres.

In general, developing countries have to upgrade the road transportation system to a higher level, both in terms of length and quality so as to meet the demand which is being generated by the development plans. Road development generates considerable employment potential, which is of additional significance to the developing country.

2. SCOPE AND OBJECTIVE OF THE DESIGN

The road pavements are generally constructed on low embankments, above the general ground level or the adjoining land, wherever possible in order to avoid the difficult drainage and maintenance problems. The term road or roadway thus constructed is therefore termed 'highway' and the science and technology dealing with roads is generally called 'Highway Engineering' and 'Highway Technology'.

In the foregoing paragraphs, the need and the status of road transportation have been discussed. It is therefore logical to discuss the science of highway engineering which answers the questions as how highways are planned and designed and how are they constructed and maintained.

In the nutshell, it may be said that the Highway Engineering deals with various phases like traffic and transportation studies and analysis, planning of road net-work, alignment, design of road geometrics, materials, pavement design, construction and maintenance, highway traffic operation, safety, regulation and administration. Appropriate investigations, economic and financial analysis are essential before planning a road project. Environmental and social impact assessment studies and roadway aesthetics are also needed. Special problems such as alignment, design and construction of roads in high altitudes and difficult terrains also form part of highway engineering studies.

The surface of the roadway should be stable and non-yielding, to allow the heavy wheel loads of road traffic to move with least possible rolling resistance. The road surface should also be even along the longitudinal profile to enable the fast vehicles to move safely and comfortably at the design speed. At high moisture contents, the soil becomes weaker and soft and starts yielding under heavy wheel loads, thus increasing the resistance to traction. The earth road may not be able to fulfil any of the weather changes. Therefore a pavement consisting of superior and stronger materials is laid over the prepared earth surface which could fulfil the above requirements.

The objective of laying a pavement is to support the wheel loads and to transfer the load stresses through a wider are on the soil subgrade below. Thus the magnitude of stresses transferred to the subgrade soil through the pavement layers is considerably lower than the contact pressure or compressive stresses directly under the wheel load applied on the pavement surface. The reduction in the wheel load stress due o the pavement depends both on its thickness and the characteristics of materials used in the different pavement layers placed over the soil subgrade. A pavement layer material is considered more effective or superior, if it is able to distribute the wheel load stress through larger area per unit thickness of the layer.

Depending on the vertical alignment and the environmental conditions of the site, the pavement may be constructed over an embankment, cut or almost at the ground level itself. It is always desirable to construct the pavement well above the maximum level of the ground water or the highest water table to keep the sub grade soil relatively dry even during monsoon season.

3. MATERIALS & THEIR PROPERTIES

1. Soil

2. Aggregates

3. Bitumen

3.1 SOIL

Soil is an accumulation or deposit of earth material, derived naturally from the disintegration of rocks or decay of vegetation that can be excavated readily with power equipment in the field or disintegrated by gentle mechanical means in the laboratory.

Figure 1: Showing the Soil

The supporting soil beneath pavement and its special under courses is called sub grade. Undisturbed soil beneath the

pavement is called natural sub grade. Compacted sub grade is the soil compacted by controlled movement of heavy compactors.

3.1.1 Desirable Properties

The desirable properties of sub grade soil as a highway material are

- Stability
- Incompressibility
- Permanency of strength
- Minimum changes in volume and stability under adverse conditions of weather and ground water
- Good drainage
- Ease of compaction

3.2 AGGREGATES

Aggregates generally occupy 65- 80% of a concrete's volume. Aggregates are inert fillers floating in the cement paste matrix for concretes of low strength. The strength of aggregates do not contribute to the strength of concrete for low strength concrete. The characteristics of aggregates impact performance of fresh and hardened concrete.

Figure 2: showing the aggregates

Natural aggregates are formed by the process of weathering and abrasion, or by artificial crushing a larger parent mass. Thus, many properties of the aggregate depend on the properties of the parent rock, e.g. chemical and mineral composition, petro graphic classification, specific gravity, hardness, strength, physical and chemical stability, pore structure, colour, etc. in addition, there are other properties of the aggregate which are absent in the parent rock: particle shape and size, surface texture and absorption. All these properties may have considerable influence on the quality of fresh or hardened concrete.

3.3 BITUMEN

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost.

Figure 3: Showing the Bitumen

Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementitious substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

4. TESTS ON MATERIALS &THEIR RESULTS

4.1 Wet Sieve Analysis

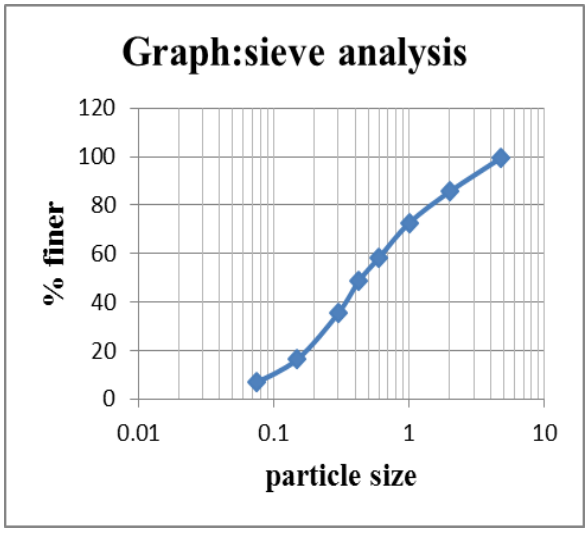
Figure 4: showing the wet sieve analysis

Table no-1: Showing the fines fractions

sieve size	weight retained in gms	% retained	cumulative % retained(N)	% finer(100-N)
4.75mm	6	0.6	0.6	99.4
2.00mm	138	13.8	14.4	85.6
1.00mm	130	13	27.4	72.6
600µ	143	14.3	41.7	5803
425µ	97	9.7	51.4	48.6
300µ	132	13.2	64.6	35.4
150µ	90	9	73.6	26.4
75µ	96	9.6	83.2	16.8
Pan	168	16.8	100	0

Graph:

The graph is plotted between the particle size and %finer.



Graph-1: showing the wet sieve analysis of soil

From graph:

D10=0.029,

D30=0.12,

D60=0.61

Uniformity coefficient (Cu) = D_{60}/D_{10}

= 0.61/0.029

= 21.03

Coefficient of curvature (C_c) = $(D_{30})^2/D_{60}*D_{10}$

= $(0.12)^2$/0.61*0.029

= 0.81

Uniformity coefficient (C_u) = 21.03,

Coefficient of curvature (C_c) = 0.81.

Also Cu >6 and Cc is not in between 1 to 6,

The plasticity index(Ip) value is greater than 7

4.2 California Bearing Ratio

The California bearing ratio (CBR) is a penetration test for evaluation of the mechanical strength of natural ground, sub grades and base courses beneath new carriageway construction. It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

Figure 5: showing the California bearing apparatus

Table no-2: Showing the loading values of the soil

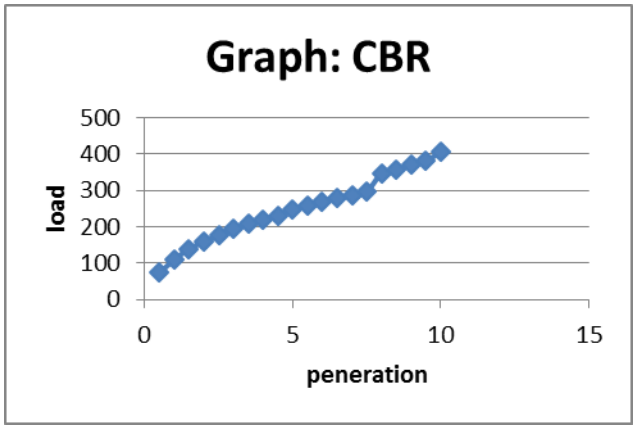
S.no	Strain gauge reading	Strain(mm)	Proving ring reading	Load (kg)
1	50	0.5	3.6	73.68
2	100	1	5.4	110.52

3	150	1.5	6.8	139.18
4	200	2	7.8	159.65
5	250	2.5	8.6	176.02
6	300	3	9.5	194.44
7	350	3.5	10.2	208.77
8	400	4	10.8	221.0
9	450	4.5	11.3	231.28
10	500	5	12.2	249.7
11	550	5.5	12.7	259.94
12	600	6	13.2	270.17
13	650	6.5	13.7	280.41
14	700	7	14	286.55
15	750	7.5	14.5	296.78
16	800	8	17	347.95
17	850	8.5	17.4	356.14
18	900	9	18.1	370.47
19	950	9.5	18.7	382.75
20	1000	10	19.8	405.26

Moisture content = (weight of wet soil – weight of dry soil)/weight of dry soil

= ((0.056-0.050)/0.050)*100

=12%



Graph-2: showing the CBR value of soil

CBR= (test load/standard load)*100

2.5mm penetration , CBR=(176.02/1370)*100=12.84%

5.0mm penetration , CBR=(249.7/2055)*100 =12.15%

Dry density=1.164 gm/cc

Water content=12%

CBR value at 2.5mm penetration= 12.84%

CBR value at 5.0mm penetration=12.15%

4.3 BITUMEN TESTS

- Penetration test
- Softening point
- Flash point test
- Fire point test
- Ductility test

4.2 AGGREGATE TESTS

- Abrasion test
- Shape test
- Specific gravity and water absorption
- Impact test
- Crushing test

5. DESIGN OF PAVEMENT THICKNESS

5.1. DESIGN OF FLEXIBLE PAVEMENT BY USING CBR VALUE OF CUMULATIVE STANDARD AXLES(CSA):

$N=(365*((1+r)^n-1)/r)*A*D*F$

Where,

N = cumulative no of standard axles (msa)

A = Initial traffic

D = lane distribution factor

F = vehicle damage factor

n = design life in years

r = annual growth rate of commercial vehicles

Design:

n = 20 years

A = 4000cvpd

CBR value of sub grade soil = 12%

F = 3 (standard axles per commercial vehicles)

D = 0.75 (for two lane carriage way)

r = 8%

$N = (365*((1+r)^n-1)/r)*A*D*F$

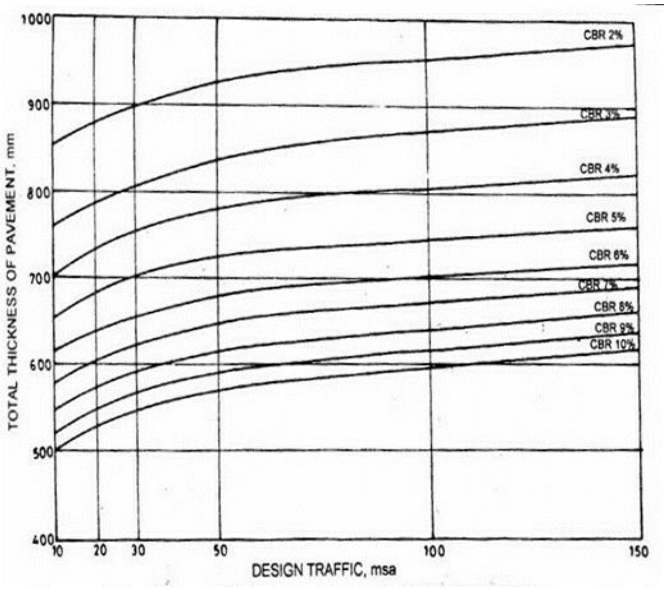
$N = (365*((1+0.08)^{20}-1)/0.08)*4000*0.75*3$

$N = 150msa$

For the design of pavement to carry traffic in the range of 10-150msa. Using the pavement thickness chart.

From design the CBR value is 12%

Cumulative number of standard axles is 150msa



Flexible pavement thickness design chart

From IRC37:2001 chart =650mm

Granular sub-base = 200mm

Granular base = 250mm

Dense bituminous macadam = 150mm

Bituminous surface = 50mm

6. CONCLUSIONS

- From the C.B.R method of pavement Design, the Design thickness of pavement is 650mm.

The Pavement Is To Be Layered As Follows:

- The granular sub-base is to be compacted with the soil at 12% moisture content to a thickness of 200mm.
- The granular base course is to be well compacted with 50-100mm size of coarse aggregates to a thickness of 250mm.
- The dense bituminous macadam layer is to be well compacted with 20mm size of coarse aggregates to a thickness of 130mm and the Bituminous prime coat of 20mm is to be applied.
- The bituminous surface course is compacted with 12.5mm size of aggregates mixed with bitumen to a thickness of 50mm.

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