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DESIGN OF FLEXIBLE PAVEMENT AND CASE STUDY ON NH365A FROM KODAD TO KHAMMAM

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***Abstract**:* Nowadays it is very important to have a proper road network for the purpose of good transportation. For Few places road network is not available while the traffic is higher and enough. Pavement is generally being constructed and used for the purpose of smooth and comfort moment of the traffic. Flexible pavements will be subjected to load by wheel develop stress particles-to-particles transmit to the lower grades of layers through the granular structure. The pavement is subjected to the wheel loading action on it and the load is to be distributed to a larger area, such that the decrease in stress will occur with respect to the depth. The patch considered in this project is of Kodad to Khammam Road, Telangana. The current condition of the Kodad to Khammam Road is very much disturbed with the presence of uneven undulations as heavy loaded vehicles like moment of trucks took part. Hence, for the purpose of the fulfilment of all the above requirement factors and for the comfort moment of traffic adopted the effective design of flexible pavement. In this paper, we are enclosing the design report Kodad to Khammam Road which includes all the which comes under the project of the pavement construction.

Key words: Design, Flexible Pavement

I. Introduction

Flexible pavement play an important role in design process. There are several layer in flexible pavement such as sub-grade course, sub-base course, base course, and wearing course or surface course. The flexible pavements consist of wearing surface built over a base course and they rest on compacted sub grade. The design of a flexible pavement is based on the principle that a surface load is dissipated by carrying it deep into the ground through successive layer of granular materials. Flexible pavements with asphalt concrete surface courses are used all around the world. The purpose of pavement to provide adequte skid resistance, require surface riding quality, less noise pollution of the pavement structure to reduce the transmitted stresses due to wheel, different layers, their structure function load. The CBR method probably the most widely used method to design the flexible pavement. The CBR method is based on the strength parameter of the materials. Design method is based on the concept of two layer system, consisting of road surfacing, base course and the sub-base as top layer at thickness, and the sub-grade as bottom layer of infinite extent. Pavement performance Shows deterioration of roads with time in it service life, which is dependent on traffic loading, pavement type, structure, strength, and sub grade strength, climate and environment, drainage, initial road condition, and maintenance activities. Flexible pavements are those which are surfaced with bituminous (or asphalt) materials. These types of pavements are called "flexible" since the total pavement structure "bends" or "deflects" due to traffic loads. A flexible pavement structure is generally composed of several layers of materials which can accommodate this "Flexible pavements".

II. LITERATURE REVIEW

Flexible pavements are preferred over cement concrete roads as they have a great advantage that these can be strengthened and improved in stages with the growth of traffic and also their surfaces can be milled and recycled for rehabilitation. The flexible pavements are less expensive also with regard to initial investment and maintenance. Although Rigid pavement is expensive but have less maintenance and having good design period. The economic part is carried out for the design pavement of a section by using the results obtained by design method and their corresponding component layer thickness.

Saurabh Jain, Dr. Y. P. Joshi, S. S. Goliya: This paper discusses about the design methods that are traditionally being followed and examines the "Design of rigid and flexible pavements by various methods & their cost analysis by each method"

D. S. V. Prasad and G. V. R. Prasada Raju: This paper investigates the performance of flexible pavement on expansive soil sub grade using gravel/flyash as sub base course with waste tyre rubber as a reinforcing material. It was observed that from the laboratory test results of direct shear and CBR, the gravel sub base shows better performance as compared to flyash sub base with different percentages of waste tyre rubber as reinforcing material. Cyclic load tests are also carried out in the laboratory by placing a circular metal plate on the model flexible pavements. It was observed that the maximum load carrying capacity associated with less value of rebound deflection is obtained for gravel reinforced sub base compared to flyash reinforced sub base.

Bhrugu Kotak, Parth Zala, Abhijit singh Parmar, Dhaval M Patel, Mittal Patel: through their case study on a road stretch between two points in a rural area which aims at providing cost effective, safe and economical approach leading to less repair and maintenance cost. To achieve their objectives, they used IRC approach of design using traffic data and soil characteristics to provide a economical and long lasting pavement surface design.

Kumar Ravinder : through his investigation on traffic study and structural design of Flexible Pavement using Cemented Base and Sub-base. He used updated design guidelines of IRC: 37-2012 which is a mechanistic-empirical design method and discuss the use of non conventional kinds of materials also in the base and subbase. Through his study, he observed that design of Flexible Pavement using nonconventional layer needs less amount of bitumen and thus reduces pavement thicknesse. The IRC design method can be adopted to know the required pavement thickness due to its easy and practical application. The traffic movement and subgrade soil characteristics need to be studied and required to design a pavement.

A B.Tech project on "Proposal of alignment and pavement design for a newly built up colony": by J.B.S. Bharathi et al In this project an attempt is made to design a model road for a newly built up colony based on the modern principles of pavement design. On the existing alignment of the road, soil samples are collected for the determination of soil characteristics like consistency limits, sieve analysis, C.B.R values, etc. Based on this, the thickness of the pavement (flexible) is designed. The alignment of the road is also designed and fixed by surveying and levelling.

III. METHODOLOGY

Alignment of the road is done by road surveying and details are mentioned in the report. Technical features of the project such as details of right of the way, No. of lanes, carriageway width, shoulder width are clearly mentioned according to the design of the pavement. All the required dimensions of the cross sectional elements of the road are calculated and mentioned accordingly. Traffic survey report on road is made through manual counting of the traffic moments of the road. And a design period of 20 years is assumed based on the design data. Tests are to be conducted on bitumen, aggregates and sub soil for the pavement in the near by treatment plant and results been calculated. Finally design data of the road the road is calculated and design procedure is mentioned. A complete report on road is enclosed in this project.

Materials Used In The Pavement

- Soil
- Aggregates
- Bitumen
- Cement
- Recycled Materials
- Geosynthetics

Material proportions:

Grading for Coarse-Graded Granular Sub-Base Materials

IS Sieve Destination	Percent by Wt passing the IS sieve		
	Grading - 1	Grading - 2	Grading - 3
75.0 mm	100	-	-
53.0 mm	-	100	-
26.5 mm	55-75	50-80	100
9.50 mm	-	-	-
4.75 mm	10-30	15-35	25-45
2.36 mm	-	-	-
0.425 mm	-	-	-
0.075 mm	<5	<5	<5

Grading Requirement for WMM

IS Sieve Destination	Percent by Wt passing the IS sieve
53.00 mm	100
45.00 mm	95-100
26.50 mm	-
22.40 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600 micron	8-22
75 micron	0-8

Gradation Requirements For DBM

Grading	I	II
Nominal aggregate size	40 mm	25 mm
Layer thickness	75-100 mm	50-75 mm
IS Sieve (mm)	Percent Passing	
45.0	100	-
37.5	95-100	100
26.5	63-93	90-100
19.0	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.60	-	-
0.30	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen content percent by wt of total mix	Min 4.0	Min 4.5

Gradation Requirements For BC

Grading	I	II
	50-65 mm	30-45 mm
26.5	100	-
19.0	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	42-58
0.60	15-27	26-38
0.30	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content percent by wt of total mix	5.0 – 6.0	5.0 – 7.0

RECOMMENDED QUANTITIES OF MATERIAL FOR TACK COAT

Type of Surface	Quantity in kg per m 2 area
Bituminous Surface	0.20 to 0.25
Dry and hungry bituminous 0.25 to 0.30 surfaces	0.25 to 0.30
Primed granular surface	0.25 to 0.30
Unprimed granular base	0.35 to 0.40
Cement concrete pavement	0.30 to 0.35

Factors To Be Considered In The Design Of Pavements:

Pavement design consists of two parts:

i. Mix design of material to be used in each pavement component layer
ii. Thickness design of the pavement and the component layer

The various factors to be considered for the design of pavement are:

- Design wheel load
- Sub grade soil
- Climatic factors
- Pavement component material
- Environmental factors
- Special factors in the design of different types of pavements.

Design Wheel Load:

Following are the important wheel load factors:

(A) Maximum Wheel Load:

Maximum legal axle load as specified by IRC is 8170kg with a maximum equivalent single wheel load of 4085kg. Total load influences the equality of surface course.

The vertical stress computation under a circular load is based on Boussinesq's theory.

$$\sigma z = P [1 – (z3/(a2 + z2)3/2)]$$

(B) Contact Pressure:

- Tyres pressure of high magnitudes demand high quality of materials in upper layers in pavements, however the total depth of pavement is not governed by tyre pressure.
- Generally, wheel load is assumed to be distributed in circular area but it is seen that contact area in many cases is elliptical.
- Commonly used terms with reference of the tyre pressure are:
  i. Tyre pressure
  ii. Inflation pressure

iii. Contact pressure

- Tyre pressure and inflation pressure mean exactly are the same. The contact pressure is found more than tyre pressure when tyre pressure is less than 7 kg/cm2 and its vice-versa when the tyre pressure exceeds 7 kg/cm2.

Rigidity factor = (contact pressure) / (tyre pressure)
R.F. =1, for tyre pressure is 7 kg/cm2
R.F. <1, for tyre pressure >7 kg/cm2
R.F. >1, for tyre pressure <7 kg/cm2

The rigidity factor depends on the degree of tension developed in the wall of the tyre.

(C) Equivalent Single Wheel Load (ESWL):

- The effect on the pavement through a dual load assembly is not equal to two times the load on any one wheel. The pressure at a depth below the pavement surface is between the single load and two times load carried by any one wheel.

(D) Repetition Of Loads:

- If the pavement structure fails with N1 number of repetitions and P1 kg load and similarly if N2 number of repetitions of P2 kg load can also cause failure of the same pavement structure then P1N1 and P2N2 are equivalent.
- If the thickness required for 106 repetitions is 't', then the pavement thickness required for failure at one repetition is t/4

(E) Elastic Modulii:

- Elastic modulii of different pavement material can be evaluated. Mainly plate bearing test is employed for this purpose.
- If Δ is the maximum vertical deflection of the flexible pavement, then
- $\Delta = 1.5pa/ E_s$
- If rigid circular plate is used instead of flexible plate, then:

$$\Delta = 1.8\ pa/ E_s$$

Where, a= radius of plate P = pressure at deflection
Es= young's modulus of pavement material

Climatic Factors:

The climatic variations cause the following major effects:

i. Variation in moisture content,
ii. Frost action,
iii. Variation in temperature.

Environmental Factors:

The environmental factors such as height of embankment and its foundation details, depth of cutting, depth of subsurface water table, etc.., affect the performance of the pavement.

The choice of bituminous binder and performance of bituminous pavements depends on the variations in pavement temperature with seasons in the region. The warping stresses in rigid pavements depend on daily variations in temperature in the region and in the maximum difference in temperature between the top and bottom of the pavement slab.

IV. Design Of Flexible Pavement

Clearing and Grubbing

• Once the center line is established, level at every 10 mts intervals in longitudinal direction as well as at suitable grid in transverse direction shall be recorded jointly with Engineer before starting the clearing and grubbing oeration.

• All trees, stumps etc. falling within excavation and fill line, will be cut to such depth below ground level that, in no case these fall within 500 mm of the sub grade.

• Site will be cleared from all vegetation such as roots, undergrowth, grasses and other deleterious materials prior to start of the embankment works.

Construction of Embankment

Embankment Construction Operation

Embankment shall be constructed as per the MORTH Specifications, Clause – 305.

a) The limits of Embankment will be marked by fixing batter pegs at regular intervals on both sides of the Embankment layer and working line with white lime.

b) The Embankment will be built sufficiently wider than the designed dimensions so that after proper compaction is achieved up to the toe of the embankment and surplus materials shall be removed / trimmed to get the proper compacted slopes of embankment.

c) The Ground supporting embankment /sub grade shall be compacted as per guidelines given in amended clause 305.3.4. When existing embankment is to be widened and its slopes are steeper than 1 vertical on 4 horizontal, continuous horizontal benches each at least 300mm wide shall be cut into the old slope for ensuring adequate bond with the fresh embankment to be added.

Sub grade Construction

The Samples of existing shoulder material to be collected jointly for conducting laboratory tests for their suitability to use as sub grade material as mentioned in the drawing. If the existing shoulder material or the original ground material do not conform the requirements as per the drawing and specification the same shall be removed and replaced by suitable approved material. If the original ground material or the existing sub grade material as the case may be found conforming the specification and drawing other than compaction the same will be loosened and re-compacted at OMC to 97% of MDD as per I.S. 2720 (Part-8) and tested at specified frequency.

Construction of Granular Sub Base

Before laying of sub-base over already finished sub-grade all the vegetation shall be removed, if any. Light sprinkling of water shall be done as required and rolled with two passes of 8 to 10 ton vibratory roller.The materials of GSB layer shall be Grading V / VI as per Table 400-1 of MORTH. The material shall be brought at site first and dumped in heap in such a way that after spreading and compaction the required thickness is obtained.

Construction of Wet Mix Macadam

Construction operation shall be as per Clause 406.3. Before laying Wet Mix Macadam (WMM) on already prepared GSB/CTB, the shoulder shall be constructed first in order to provide confinement. Material for the wet mix macadam shall be prepared as per mix design in the wet mix plant. Moisture shall be maintained within tolerance range as determined by Mix Design. The mix shall be spread by a paver finisher in full width of a pavement including hard shoulder as per Clause 406.3.4.

Prime Coat/Tack Coat

As soon as the surface preparation as specified in section 6.1.1 has been carried out to the approval of the Engineer, the primer or tack coat will be sprayed at the specified rate. The quantity of binder used shall give complete coverage of the surface with a light trace of run-off in places. The edge of the area to be sprayed will be marked out with a line of string or wire pegged down at intervals not exceeding 15m on straights or 7.5 m on curves.

Construction of Dense Bituminous Macadam

Preparation of base

Before laying of Dense Graded Bituminous Macadam, the base on which it is to be laid shall be prepared in accordance with Clause 501 and 902 as appropriate or as directed by the Engineer. The surface shall be thoroughly swept clean by a mechanical broom and the dust removed by compressed air.

Mixing and Transportation of the Mixture

The material to be used for DBM shall be as per approved Job mix formula, conforming to MORTH Table 500-10. The material shall be prepared in a Hot Mix Plant of adequate capacity. Appropriate mixing temperature shall be maintained as per Table 500-2 of MORTH specifications. The bituminous material shall be transported in clean and covered tippers to the place of laying.

Construction of Bituminous Concrete

The full-scale laying and compaction trials are carried out on BC materials for the permanent works using the plant and methods proposed. The trials are carried out under supervision of the Engineer. The trials are carried out to demonstrate the suitability of the plant, Equipment and work procedures to provide and compact the material to the specified proportions, density and voids content and to confirm that the other specified requirements of the completed asphalt pavement can be achieved. The trial of pavement layer is undertaken ahead of the proposed work to commence full-scale work.

V. TESTS CONDUCTED ON DESIGN OF FLEXIBLE PAVEMENT

Liquid Limit

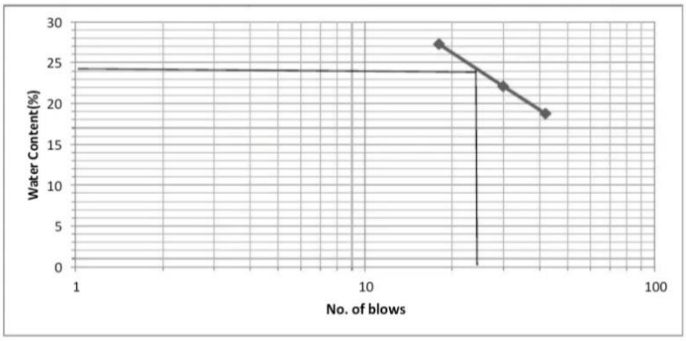
The water content at which measurable shearing strength is first apparent is called liquid limit and make the boundary between liquid state and plastic state. If the water content of the soil is steadily reduced further below the liquid limit soil volume and plasticity decreases.

Observations & calculations

Weight of soil sample taken = 150gm.

S.No	Description	Sample 1	Sample 2	Sample 3	Sample 4
1	Weight of empty can, w1	10	10.5	11	11
2	Weight of the can + weight of dry soil, w2(g)	24	29.5	30	28
3	Weight of can + weight of dry soil, w3(g)	21	26	27	26
4	Water content, w(%)	27.27	22.1	18.75	13.33
5	No. of blows as observed, n	18	30	42	65

Graph



Graphical Representation of Liquid Limit Test

From graph

Water content corresponding to 25 blows=24%

Therefore,the liquid limit is 24%.

Plastic Limit

It is water content below which the soil stops behaving as a plastic material. It begins to crumble when rolled into threads of 3 mm diameter.

At this water content, the soil loses its plasticity and passes a semi solid state.

Observation & Calculations

The Plastic Limit (average of 3 determinations) = 11.85%

Plasticity Index

Plasticity index is the main property that is to be determined for a soil before using the soil to any type of work. Generally for gravel it can be allowed upto 18 or 20.

But for highway construction it should be less than this is the difference of liquid limit and plastic limit. So there is no further experimentation for this.

Plasticity index of soil, IP = 24 – 11.85 = 12.15%

Free Swell Index

This parameter gives the swelling property of the soil.

Free Swell Index (F.S.I) = ((Va-Vk)/Vk)*100

Observation & Calculation

Sl.N0	Determination No	1	2
1	Mass of dry soil passing 425µ (gm)	10	10
2	Volume of water in 24hrs swell (cc)	13	13
3	Volume of kerosine after 24hrs (cc)	10	10
4	Free swell index ((Va-Vk)/Vk)*100 (%)	30	30
5	Average (%)	30%	

California Bearing Ratio Test

This is a penetration test developed by the California Division of Highways, as a method for evaluating the stability the stability of soil sub grade and other flexible pavement materials. The test results have been correlated with flexible pavement thickness requirements for highways and air fields. The CBR test may be conducted in the laboratory on a prepared specimen in a mould or in situ in the field.

Determination	1	2	3
weight of container (W0)	11	10	11
weight of container + wet soil (W1)	15	16	17.5
Weight of container + dry soil (W2)	14.5	15.4	16.9
Weight of water(w1-w2)	0.5	0.6	0.6
Weight of oven dry soil (W2-W0)	3.5	5.4	5.9
Water content W=(W1-W2\W2-WO) x 100	14.28	11.11	10.16

The Standard Load Values	**Standard Load (kg)**	**Unit Standard Load**

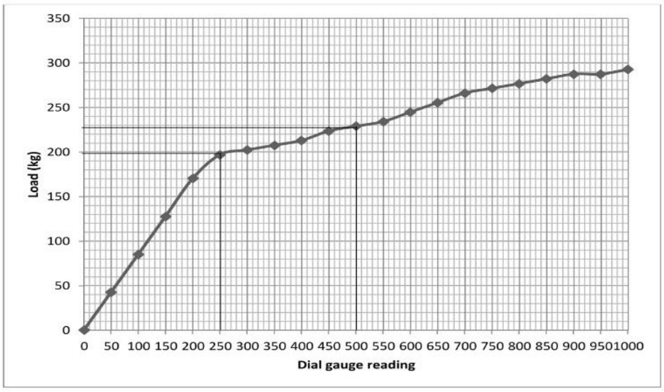
Penetration (mm)		(kg/sq.cm)
2.5	1370	70
5.0	2055	105
10.5	2630	134
10	3180	162
12.5	3600	183

CBR value is calculated by the formula,
CBR = [(Load sustained by specimen at defined penetration level)/(Load sustained by sustained crushed stone at same penetration level)]*100

Observations & Calculations

S.NO	Penetration (mm)	Proving Ring Reading	Load on plunger(kg)
1	0.5	0.8	42.56
2	1.0	1.6	85.12
3	1.5	2.4	127.68
4	2.0	3.2	170.24
5	2.5	3.7	196.84
6	3.0	3.8	202.16
7	3.5	3.9	207.48
8	4.0	4.0	212.8
9	4.5	4.2	223.44
10	5.0	4.3	228.76
11	5.5	4.4	234.08
12	6.0	4.6	244.72
13	6.5	4.8	255.36
14	7.0	5.0	226.0
15	7.5	5.1	271.32
16	8.0	5.2	276.64
17	8.5	5.3	281.96
18	9.0	5.4	287.28
19	9.5	5.4	287.28
20	10.0	5.5	292.60

CBR2.5 = (196.84/1370)*100 = 14.36%
CBR5.0 = (228.76/2055)*100 = 11.13%
Graph



The CBR value of soil sample = 14.36%.

Penetration Test On Bitumen

The penetration test measures the consistency and stability of pure bitumen, oxidized bitumen(blown bitumen), and the residue of emulsion bitumen.

Relevant Indian Standard for Penetration Test on Bitumen:

IS 1203-1978 Edition 2.2 (1989-03): Methods for Testing Tar and Bituminous Materials

Observtion & Calculations

Actual test temperature = 25°C

	Test 1	Test 2	Test 3
Pentrometer dial reading			
(a) Intial	200	264	333
(b)Final	264	333	407
Penetration value	64	69	74

Mean penetration value = 69

Ductlity Test

breaking when a briquette specimen of the materials is pulled at a specified speed and at specified temperature

Observations & Calculations

Bitumen grade = S65

Test temperature. C = 27

(a)In Air = 30

(b)In water bath before trimming = 60

(c)In water bath after trimming = 100 to 120

Details	Sample - 1	2	3
(a)initial reading	0	0	0
(b)final reading	76.8	75.8	76.6
(c)ductility = (b -a)cm	76.8	75.8	76.6

Ductility value = (76.8 + 75.8 + 76.6)/3

= 76.4mm

Bitumen Softening Point Test

The determination of softening point helps to know the temperature up to which a bituminous binder should be heated for various road use applications.

Observation & Calculation

	1	**2**	**3**
Temperature when the boil touches bottom , °C	46	47	49

Average = (46 + 47 + 49)/3

Softening Point Of Bitumen = 47.3 °C.

VI. Conclusions

Construction of flexible pavement for Kodad to Khammam NH365A road is followed the specified design data. CBR value for soil sub grade used for the road construction is under allowable limit i.e., 14.36%.Tests required for the materials used in the construction are tested in treatment plant and adequate results have been obtained. Traffic survey for Kodad to Khammam NH365A road is made through manual counting and allotted a design period of 15 years for the pavement. According to design of pavement, the each layers has: following thickens are SUB GRADE , GSB , WMM , DBM, BC 500mm, 250mm, 250mm, : 75mm, 45mm. For the above design, the meterial and aggregate tests conducted according to IS code and they are within design limits. Finally, a complete general report for Flexible Pavement Design of Four laning of NH-365A from Kodad (Design Km 0.00/Existing Km 185.00 of NH-65) to Khammam (Design Km 31.800/Existing Km 29.400) (Design Length = 31.800 Km) is written considering all the steps involved in construction. Acknowledgement :Thank to the contractors who is executed the work and supported.

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