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Experimental Report on Flexible Pavement by Using Hydrophobic Silica Sand, Zeolite and Steel Mesh

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Abstract

The vision of our project is to reduce global warming, and the mission of the project is to construct flexible pavement without affecting the environment. The agent zeolite was mixed with asphalt mix to reduce carbon dioxide level and increase the strength of the pavement. Hydrophobic silica sand was used in the asphalt mix for the replacement of filler content to reduce porosity. The secondary aim of our project is to reduce the crack in pavement by using steel mesh. The reason behind the steel mesh is to increase the life span of the flexible pavement. Cost expenses of pavement construction and maintenance were compared with our innovative pavement construction as per the CPWD (Central Public Work Department). The aggregate tests such as impact test, abrasion test, crushing test were conducted as per IS- specifications. California bearing ratio and dry density test by core cutter method were identified the soil stability, type of soil which was under the pavement to increase strength. Pavement thickness was calculated for WMM (Wet Mix Macadam) and BC (Bituminous Concrete) by CBR test as per IRC 37-2001. Marshall Stability test, which deals with the stability and flows property of asphalt mix to obtained highly stabilized pavement layers. The IRC (Indian Road Congress) codes of practices were used for the pavement design standards and codes of Indian standards for the test procedures of bitumen.

Keywords: *Global warming, flexible pavement zeolite, hydrophobic silica sand, steel mesh – cracks, life span, cost expenses, CPWD, WMM (Wet Mix Macadam), BC (Bituminous Concrete), Marshall test, IS and IRC Code of practices.*

I. INTRODUCTION

A. Granular sub-base

Laying and compacting well-graded material on prepared sub-grade. Material shall be laid in one or more layers. The material to be used for the work shall be natural sand, gravel, and crushed stone.

B. Wet Mix Macadam

Laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on prepared sub-grade or existing pavement. The thickness of a single compacted Wet Mix Macadam layer shall not be less than 75 mm. Coarse aggregate shall be crushed stone. If crushed gravel is used, not less than 90% by Wt of gravel pieces retained on 4.75 mm sieve shall have at least two fractured faces. If the water absorption value of a coarse aggregate is greater than 2%, the soundness test shall be carried out as per IS- 2386(Part-5).

C. Bituminous concrete (BC)

BC is a Dense Graded Bituminous mix used as a wearing course for heavily trafficked roads. BC mix consists of coarse aggregates, fine aggregates, filler, and binder blended as per Marshall Mix design.

II. PROBLEMS AND SOLUTIONS IN PAVEMENT

A. Problems identified in flexible pavement

- Little less in the strength of the pavement
- Emission of Co_2 during the process of melting bitumen leads to global warming
- Life span is less
- Cracks developed quickly
- Soil erosion under the pavement
- The cost of bitumen is high
- Less soil strength

B. Material used for the solution of problems

Hydrophobic silica sand - The hydrophobic silica sand used 5% filler content in asphalt mix to decrease the porosity of the pavement and as a water repellent.

Aggregate -6mm, 12mm, 20mm, 2.36mm for BC (Bituminous course) grade II, 40mm, and M-sand for WMM (wet mix macadam) were used.

Zeolite - When 30% of zeolite instead of cement used in concrete, it fully absorbs carbon dioxide and achieve better strength. We used only 5% zeolite to increase the strength of flexible pavement and also absorb carbon dioxide.

Steel mesh – 2mm steel mesh is laid under a bituminous course used to reduce the cracks in the flexible pavement and increase the life span.

M-sand – 50% of M- sand used as a mixture with 40mm aggregate to lay down the sub-base course of the flexible pavement that is WMM.

IV. PROPERTIES OF MATERIAL USED

A. *Properties of bitumen*

- Adhesion
- Resistance to Water
- Hardness
- Viscosity and Flow
- Softening Point
- Ductility
- Specific Gravity

B. *Properties of zeolite*

- Methane, CO_2 Absorption
- Not reactive
- Specific gravity 2.3
- Reduce porosity
- Water absorbent
- High compressive strength
- Molecular size 0.5–1.2 nm

C. *Properties of Hydrophobic silica sand*

- Uniform size
- Hard
- Chemically inert
- High melting point
- Filler
- The chemical formula is SiO2
- Contains insulating fibers

D. *Properties of steel mesh*

- The diameter of the wire 2 mm
- Resistance to temperature
- Tensile in nature
- Durable
- Carrying heavy loads

IV. TESTS ON AGGREGATES

A. Impact test

The aggregate impact test is carried out to evaluate the resistance to the impact of aggregates and also determine the toughness of aggregate.

Fig. 1

B. Abrasion test

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works.

Fig. 2

C. Crushing test

The ultimate goal is to measure resistance to crushing under gradually applied crushing load.

Fig. 3

TABLE I
Test results of aggregate
IS CODE 2386- PART 4 (1963)

Tests conducted	The value ranges as per CPWD for road	Results
Impact test **IS CODE 2386-PART 4 (1963) pg No:13**	Less than 10% exceptionally strong and 10% to 30% satisfactory	8.2 % (12mm) 7.28 % (20 mm)
Abrasion test **IS CODE 2386-PART 4 (1963) pg No:19**	Maximum 40% for base course and max 30% for bituminous layer	16.24% (20 mm) 15.08% (40mm)
Crushing test **IS CODE 2386-PART 4 (1963)pg No:7**	Less than 10% strong and Greater than 35% weak	18.4% (12mm) 16.4% (20mm) 15.3% (40mm)

V. TEST ON BITUMEN WITHOUT USING ADMIXTURES

A. Specific gravity test

The ratio of the mass of a given volume of the substance to the mass of an equal volume of water, the temperature of both is being specified.

Fig. 4

B. Softening point test

The temperature at which the substance attains a particular degree of softening under the specified condition of the test.

Fig. 5

B. Penetration test

The penetration of a bituminous material is the distance in tenths of a millimeter that a standard needle will penetrate vertically into a sample of the material under standard conditions of temperature, load, and time.

Fig. 6

C. Viscosity test

The property of a fluid by which it resists flow due to internal friction, and one of the methods by which it is measured, is by determining the time taken by 50 cc of the material to flow from a cup through a specified orifice under standard conditions of test and at a specified temperature.

Fig. 7

D. Ductility test

The ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before breaking when a briquette specimen is pulled apart at a specified speed and at a specified temperature.

Fig. 8

TABLE II
Test results of bitumen without using admixtures

Tests conducted	The value ranges as per CPWD for road	Results
SPECIFIC GRAVITY **IS: 1202-1978 (page No:19)**	0.97 - 1.02	0.98
SOFTENING POINT **IS : 1205 – 1978(page No:37)**	35 - 75^0 C	55^0 C
PENETRATION **IS : 1203 – 1978(page No:27)**	20 - 225mm (consistency)	70mm
VISCOSITY **IS : 1206 (Part I)-1978(page No: 39)**	10 – 140 seconds	84 seconds
DUCTILITY **IS : 1208- 1978 (page No:71)**	Min 75 centimetres	79.6cm

VI. TEST ON BITUMEN WITH ADMIXTURES SUCH AS HYDROPHOBIC SILICA SAND AND ZEOLITE

TABLE III
Test results of bitumen with using admixtures

Tests conducted	The value ranges as per CPWD for road	Results
SPECIFIC GRAVITY **IS: 1202-1978 (page No:19)**	0.97 - 1.02	0.998
SOFTENING POINT **IS : 1205 – 1978(page No:37)**	35 - 75^0 C	57^0 C
PENETRATION **IS : 1203 – 1978(page No:27)**	20 - 225mm (consistency)	64mm
DUCTILITY **IS : 1208- 1978 (page No:71)**	Min 75 centimetres	83.2 cm
VISCOSITY **IS : 1206 (Part I)-1978(page No: 39)**	10 – 140 seconds	87 seconds

VII. FIELD DENSITY OF SOIL BY CORE CUTTER METHOD

Volume of core cutter (Vc) = 1021 cm^3
Empty weight of mould (Wc) = 976 gm
{Weight of core cutter + Wet soil (Ws)} = 2460 gm
Weight of wet soil (Ws-Wc) = 1484 gm

Water content (W %)

Initial weight = 18gm
After oven drying weight = 16.9 gm
Weight of water = 1.1 gm

= weight of water / Oven dried soil x 100

= 1.1/ 16.9 x 100
The water content of soil = 6.5%

Fig. 9

Bulk density of soil, γb

Bulk density of soil, γ**b = Ws – Wc / Vc**
= 1484 / 1021
= 1.45 g/cm^3

Dry density of soil, γd

Dry density of soil, γd = γb / (1+w)
= 1.45 / (1+0.065)
= 1.36 g/cm^3
The maximum dry density of soil is 1.36 g/cm^3

VIII. CALIFORNIA BEARING RATIO TEST FOR SUBGRADE SOIL (IS: 2720 - Part 16)

Need and scope of CBR test

- CBR is the measure of the resistance of a material to penetration of a standard plunger under controlled density and moisture conditions.
- The test consists of causing a cylindrical plunger of 50 mm diameter to penetrate component material at 1.25 mm/minute.
- The loads for 2.5mm and 5mm are recorded. This load is expressed as a percentage of standard load value at a respective deformation level to obtain CBR value.

Fig. 10

Table IV
Standard load values

Penetration (mm)	Standard load (kg)	Unit standard load (Kg/cm^2)
2.5	1370	70
5	2055	105
7.5	2630	134
10	2180	162
12.5	3600	183

Observations

Weight of soil taken = 10 kg

Area of plunger = 19.64 cm^2

Proving ring calibration factor = 2.5

Specific gravity of soil = 2.667 (Granular soil)

Optimum moisture content = 7.3 %

Tabule V
(Dry density of soil = 1.36 gm/cm^3)

Penetration (mm)	Proving ring dial reading	Corrected load [factor - 2.5](kg)	Unsoaked CBR %
2.5	62	155	11.3
5	72	180	8.75

California bearing ratio at 2.5 mm penetration = 11.3%

California bearing ratio at 5 mm penetration = 8.75 %

California bearing ratio of sub grade soil = 11.3 %

IX. CALCULATION OF PAVEMENT THICKNESS

Data

CBR value of sub grade soil = 11.3 %

Design life of pavement = 15 years

Annual growth rate = 7.5 %

Number of cumulative vehicles as per last count = 277 CVPD

Initial traffic = 298 CVPD

Distribution factor = 1

Vehicle damage factor = 3.5

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

Where, N = cumulative number of standard axles to be catered in design (MSA)

A = initial traffic (CVPD)

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

Where, P = number of commercial vehicles as per last count

x = Number of years between last count

D = Distribution factor

F = Vehicle damage factor

n = design life in years

r = Annual growth rate of commercial vehicles

$$N = 365 \frac{[(1+0.075)^{15-1}]}{0.075} \times 298 \times 1 \times 3.5$$

$= 9.96 \text{ MSA} \simeq 10 \text{ MSA}$

For 11.3% CBR value and design traffic 10 MSA as per IRC 37, 2001

Total thickness of the pavement = 500mm

Pavement composition =450mm (WMM), 50mm (BC)

X. MARSHALL STABILITY TEST ON ASPHALT MIX

The goal of the Marshall Test

- The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute.
- The load is applied to the specimen till failure, and the maximum load is designated as stability.
- During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading.
- The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded.

Table VI
Specification of aggregate selection (BC course grade II)

Sieve size mm (Retained)	Weight of aggregate in gm	Percentage of retained (%)
19	120	1.5
13.2	240	19.04
6.7	240	19.04
2.36	540	42.85
Zeoilte powder	30	2.38
Silica sand	30	2.38
Bitumen	60	4.76
Total weight	1260	100

Specimen prepared as per this procedure

- Approximately 1200gm of aggregates and filler is heated to a temperature of 175°C to190°C.
- Bitumen is heated to a temperature of 121°C to125°C with the first trial percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates).
- The heated aggregates and bitumen are thoroughly mixed at a temperature of 154°C to 160°C.
- The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side at a temperature of 138°C to 149°C.
- The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm.
- Vary the bitumen content in the next trial by +0:5% and repeat the above procedure.

Fig. 11

Fig. 12

Table VII
Different weights of specimen

Bitumen content	Weight of specimen in the air (gm)	Weight of specimen in water (gm)	Weight of specimen in SSD (gm)
3.76	1246	741	1249
4.76	1247.6	742.3	1251
5.76	1248.6	743.6	1253
Average	1247.6	742.3	1251

Specific gravity of specimen / bulk density (Gm)

$= Wa / (Wa – Ww)$

$= 1247.6 / (1247.6 -742.3)$

$= 2.46$

Flow value of 4.76% bitumen = 2.90mm

Stability of 4.76% bitumen = 530 kg

CONCLUSION

- We conclude our project with the maximum stability of asphalt, which is 530 kg, and the minimum flow was 2.90mm.
- The steel mesh was provided after the laying of wet mix macadam to reduce crack and increase the life span of pavement.
- Pavement thickness was calculated depends upon the CBR value.
- The estimated pavement thickness = 500mm.
- The optimum bitumen content of 4.76% was obtained for maximum stability and minimum flow.
- The field density of subgrade soil found by the core cutter method was 1.36 g/cm^3.
- Hydrophobic silica acts as a water repellent to drain water to the side of the pavement.

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