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Laboratory Evaluation of Asphalt Concrete Prepared with Over Burnt Brick Aggregate Treated by Zycosoil

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***Abstract*—**Asphaltic concrete for pavement construction in India are produced by using crushed stone, gravels etc. as aggregate. In north-Eastern region of India, there is a scarcity of stone aggregate. Therefore the road engineers are always in search of an optional material as aggregate which can replace the regularly used material. The purpose of this work was to evaluate the utilization of substandard or marginal aggregates in flexible pavement construction. The investigation was undertaken to evaluate the effects of using lower quality aggregates such as over burnt brick aggregate on the preparation of asphalt concrete for flexible pavements. The scope of this work included a review of available literature and existing data, a laboratory evaluation organized to determine the effects of marginal aggregates and potential techniques to upgrade these substandard materials, and a laboratory evaluation of these upgraded marginal aggregate asphalt mixtures. Over burnt brick aggregates are water susceptible and can leads to moisture damage. Moisture damage is the progressive loss of functionality of the material owing to loss of the adhesion bond between the asphalt binder and the aggregate surface. Hence zycosoil as an anti striping additive were evaluated in this study. This study summarizes the results of the laboratory evaluation carried out to investigate the properties of asphalt concrete prepared with zycosoil modified over burnt brick aggregate. Marshall specimen were prepared with stone aggregate, zycosoil modified stone aggregate, over burnt brick aggregate and zycosoil modified over burnt brick aggregate. Results show that addition of zycosoil with stone aggregate increased stability by 6% and addition of zycosoil with over burnt brick aggregate increased stability by 30%.

***Keywords*—**Asphalt Concrete, Over Burnt Brick Aggregate, Marshall Stability, Zycosoil.

I. Introduction

As per the National Highway Authority of India report that, there are 33 lakh km of road network in India which is the second largest road network in the world. Most of them are paved roads either flexible or rigid pavement. At the time of construction both the types of roads requires a huge amount of coarse aggregates, fine aggregates and binder material. Aggregate generally accounts for 92 to 96 percent of Bituminous concrete and about 70 to 80 percent of Portland cement concrete by volume. Aggregate is also used for base and sub-base courses for both flexible and rigid pavements.

Thus aggregate plays a vital role in the construction of roads. The country like India, where massive construction is going on, and a huge quantity of aggregate is required every day either in building or in road construction, there are limited sources of stone and if the present condition continues, in near future, there will be shortage of aggregate for important constructional works. Hence the road developers need a huge quantity of other material as a replacement of those materials which may lead to shortage of materials for construction in the upcoming days. The road industry is therefore looking forward for alternative materials and construction technology, which are environment friendly, energy efficient and cost effective for the construction and maintenance of roads.

Bricks have been used as a construction material all over the world. However, its use as aggregate for asphalt concrete is highly limited to certain parts of the world where naturally available stones are scarce. According to Mazumder et al. approximately 13% of bricks are severely over burnt due to uncontrolled distribution of temperature in the kiln during manufacture [1]. These bricks are considered totally useless in construction. Hence there is a possibility that over burnt brick aggregate could be an attractive alternative material for bases and sub-bases due to its high resistances in abrasion losses.

The water absorption capacity of over burnt brick aggregate is 6.9% which is higher than the standard allowable value of 2%. Zycosoil is a very good anti striping additives and capable to increase the adhesion between asphalt binder and aggregates in presence of water [2]. Asphalt concrete prepared with zycosoil modified over burnt brick aggregate shows a higher strength and stiffness of the mix.

II. Literature Review

Use of brick aggregate in concrete preparation is not new to the Engineers. In Germany during the reconstruction period immediately after the Second World War, it was necessary to satisfy an enormous demand for construction materials and it was necessary to remove the rubble from the destroyed cities. By using these rubbles and demolished aggregates it was possible not only to reduce site clearing costs, but also to meet the need for building materials. Rasel, et al. (2011) mentioned that, due to the scarcity of the natural stone and their high price in Bangladesh, and urged the use of the locally available materials as a coarse aggregate in bituminous mixes for road construction. They have found the Marshall Stability values of 14.0kN, 12.5kN and 12.3kN for fresh stone, fresh brick and waste brick respectively which are greater than the minimum value of Marshall Stability. They also said that, bituminous mixes with fresh brick aggregates and waste brick aggregate satisfy all the requirement of a bituminous binder course for 690kPa (100 psi) tyre pressure having higher optimum

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bitumen content (13% and 12% respectively) [3]. It is found that, distorted bricks have 7-10% less abrasion loss and 6-9% less water absorption than the picked bricks. Distorted bricks have a maximum Los Angeles Abrasion value of 30 which is within limit to use it in base course as aggregate. In 2001, Sobhan and Zakaria [4] investigated the behavior of bituminous macadam mixes with brick aggregate. They used 9 % bitumen content by weight of total mix throughout the study. It was observed that, dense graded picked brick aggregate bituminous mixes were as good as crushed stone aggregate bituminous mixes for use in the base course of bituminous pavement, from the stand point of stability, stiffness, deformation and voids characteristics. Schmidt and Graf, 1972, indicated that dramatic water resistance and with some aggregates a large increase in the dry resilient modulus (M_r) of the hot mixes were produced by adding the cement and lime as a slurry to the aggregate 24 hours before the hot mix was made [5]. Investigation in India and other countries have revealed that properties of bitumen and bituminous mixes can e improved to meet requirements of pavement with the incorporation of certain additives or blend of additives [6]. Nejad et al. (2011) have focused on evaluating of asphalt concrete after addition of nano-material namely Zycosoil [7]. They have found that, zycosoil increases the Tensile strength ratio of the mix by 3-14% and fatigue life by 6-25%. It is found that by adding zycosoil in warm mix asphalt, the water sensitivity and moisture damage can be reduced in a great extent.

III. Objective of This Study

Over burnt bricks may be a useful alternative as a road material. Moreover nano silica material may enrich the properties of the asphalt concrete mix if added in the asphalt concrete in a controlled manner. The objectives of the present investigation are:

1. To make a comparative study of usual aggregate and marginal aggregate in preparation of Asphalt concrete and their effect in the performance.
2. To study the impact of nano materials in properties of asphalt concrete.
3. To study the possibility of using Over Burnt Brick aggregate in asphalt concrete by modifying it with nano materials.

IV. Methodology Planned for the Study

Asphalt concrete is a widely used material throughout the world. To meet the requirement of the present era, more material is required. Aggregate and bitumen are important ingredient materials of asphalt concrete. As there are limited sources of ingredient material, in near future, there will be a shortage of important ingredient materials. An extra material which can enhance the properties of asphalt concrete by modifying the low grade materials, a great amount of material can be saved without compromising with the desired quality. In this study two different types of aggregate has been chosen to prepare the asphalt concrete - one is conventional stone aggregate and the other is crushed over burnt brick aggregate. VG 30 grade of bitumen has been chosen as binder material. Zycosoil has been chosen as nano silica material. Zycosoil is chemically reactive antistrip nanotechnology. Zycosoil reacts with aggregates to form 'asphalt-loving' non-polar hydrophobic aggregate surfaces at HMA processing temperatures. Zycosoil eliminates de-bonding of asphalt mixes caused due to inadequate and incomplete coating, coupled with moisture ingress, to enhance durability of asphalt pavements. In this study, zycosoil was used to modify the aggregate properties. There are different approaches of adding zycosoil in the asphalt concrete mix. It was first added with both the aggregates. Zycosoil is soluble in water. A solution has been prepared by adding zycosoil with water at a ratio of 1kg Zycosoil: 400 liters water and sprayed the mix of 5% by weight of aggregate above the oven dried aggregates. Then both the aggregates, stone and over burnt brick aggregate were separately soaked in the solution for 24 hours. After 24 hours the aggregates were taken out from the solution and kept in room temperature for making them surface dry before use. Same method was followed for stone as well as for over burnt brick aggregate. An asphalt concrete mix has been prepared for Marshall Test and Boiling Test with normal stone aggregate as well as with zycosoil modified stone aggregate. Considering the heavily trafficked road 75 no's of blows were provided on both the faces while preparing the Marshall specimens.

Boiling test was conducted according to ASTM D3625. Aggregate having size of passing 20 mm sieve and retained on 12.5 mm sieve was chosen and 250 gm of such aggregate was oven dried. Aggregate was heated to 150^0C and 14 gm of asphalt was heated to 160^0C and was mixed to prepare the sample. The mix was kept at the room temperature and the temperature of the mix dropped down to 80^0C. After that the mix was boiled for 10 minute and allowed to cool down to room temperature. The average percentage of the mix stripped of asphalt was observed visually [8].

V. Experimental Investigation

Study has been carried out on asphalt concrete mix with and without mixing nano material named zycosoil for modification of aggregate and asphalt mix. There are limited works so far carried out to study the properties of asphalt concrete prepared with nano modified material. An effort has been made in the present work to study the changes in the properties of asphalt concrete due to addition of zycosoil with the ingredient material. An asphalt concrete can be prepared with coarse aggregate, fine aggregate and asphalt. The property of ingredient material influences the properties of the mix. Hence before starting the evaluation of the asphalt concrete, an experimental investigation has been carried out to know the properties of the ingredient material.

A. Properties of Coarse Aggregate

The aggregate was chosen because it has sufficient strength, hardness, toughness, specific gravity and desire shape. Over burnt brick aggregate was also chosen as a marginal material

to study the properties of asphalt concrete with it. The test on aggregate was carried out as per the guideline IS :2386 (III) and (IV) [9], [10]. The properties of normal and modified stone aggregate used in this study are tabulated in Table I.

Ministry of Road Transport and Highways (MoRT&H), 2001 specifies the limiting value of different test result for the properties of coarse aggregate used in the preparation of bituminous concrete. As per MoRT&H (2001), the Impact value of aggregate should not be more than 24%, Los Angeles Abrasion value should not be more than 30%, water absorption should not be more than 2% and Specific Gravity should be within 2.5-3.0 [11]. Aggregate grading that satisfied the requirement of Ministry of Road Transport and Highways (MoRT&H), 2001 specifications was selected for stone aggregate and is tabulated in Table II. Test results shows that the stone aggregate fulfills all the desire properties as per MoRT&H where as in case of Over burnt Brick aggregate results are just on the boundary or less than the desire properties. But it is observed that after adding zycosoil, there is a considerable change in properties of Over burnt Brick aggregates. Impact value reduces by 4.4%, Abrasion value by 6%, Water absorption by 2.4% and Specific gravity increases from 1.94 to 2.15. In case of stone aggregate, there are very little changes in properties.

TABLE I
PROPERTIES OF AGGREGATE (NORMAL AND TREATED)

Test performed	Stone	Stone with Zycosoil	Brick	Brick with Zycosoil
Aggregate Impact value	22.4%	22.2%	29.6%	25.2%
Los Angeles Abrasion value	15.1%	14.8%	32%	26%
Water absorption value	0.96%	0.92%	6.9%	4.5%
Specific Gravity	2.68	2.70	1.94	2.15

TABLE II
GRADATION OF STONE AGGREGATE (FOR ASPHALT CONCRETE)

Sieve in mm	% passing by weight of Specimen	Cumulative % retained	% of aggregate and mineral filler
19	100	00	
13.2	79-100	10.50	Coarse aggregate 38%
9.5	70-88	21	
4.75	53-71	38	
2.36	42-58	50	
1.18	34-48	59	
0.60	26-38	68	Fine aggregate 55%
0.30	18-28	77	
0.15	12-20	84	
0.075	4-10	93	

Mineral Filler 7%

Unlike the first class bricks, the over burnt bricks get distorted after over burning in the kiln. It appears black and the original size changes to a different form. Using heavy hammer and laboratory crusher, over burnt bricks were broken to desired sizes and aggregates were prepared. Fig. 1 shows a stag of such over burnt bricks. During compaction, brick aggregate showed more breakage and so percentage of finer material produced during compaction was more with respect to the stone aggregate. Hence a modified grading of brick aggregate was chosen considering the higher percentage of coarse aggregate in the mix. The modified grading is listed in Table III.

TABLE III
GRADATION OF BRICK AGGREGATE (FOR ASPHALT CONCRETE)

Sieve in mm	% passing by weight of Specimen	Cumulative % retained	% of aggregate and mineral filler
25	100	00	Coarse aggregate 44%
19	80-100	10	
9.5	60-80	30	
4.75	48-65	44	
2.36	35-55	58	Fine aggregate 52%
0.60	19-30	75	
0.30	13-23	82	
0.15	7-15	89	
0.075	0-8	96	

Mineral Filler 7%

B. Properties of Asphalt

The physical properties of the asphalt used in this study are tabulated in Table IV. The test performed as per IS: 1202, 1203, 1205 and 1208 [12] - [15].

TABLE IV
PROPERTIES OF ASPHALT

Test performed	Specific Gravity	Penetration	Softening Point	Ductility
Test Result	0.99	83 mm	47^0C	92 mm

Fig. 1 Over Burnt Bricks

TABLE V
PROPERTIES OF CEMENT (OPC)

Test performed	Normal Consistency	Initial Setting Time (minute)	Final Setting Time (minute)	Specific gravity	Compressive Strength (N/mm^2)
Test Result	30	100	265	3.02	48.5

C. Mineral Filler

Stone dust and Ordinary Portland Cement (OPC) was used in this study as mineral filler. A total of 7% filler consisting of 5% stone dust and 2% cement was used to prepare the material. The plasticity index of stone dust used in this study has been 3.6. The cement used in this study was Ordinary Portland Cement. The properties of cement used in this study are tabulated in Table V. The test is performed as per IS:4031 [16]-[20].

VI. Evaluation of Asphalt Concrete Mix

Asphalt concrete mix has been evaluated by Marshall Stability Test and Boiling Test. Marshall Stability Test provides the strength of the mix in terms of strength and stiffness and Boiling Test provides the water susceptibility of the mix. Marshall Specimens were prepared by providing 75 no's of blows on each faces of specimen to simulate the heavily trafficked condition. Table VI provides the standard Marshall properties required for Dense Graded Bituminous Macadam layers.

TABLE VI
Standard Marshall Properties for Dense Graded Bituminous Macadam (MoRT&H)

Minimum Stability in 60^0C (kN)	9
Flow (mm)	2-4
Compaction Level (both side)	75
% Air-voids	3-6
% Voids in Mineral Aggregate (VMA)	12-14
% VFB	65-75

A. Marshall Stability Test for Stone Aggregate

TABLE VII
Marshall Test Result of Stone and Treated Stone

Types of aggregate	Stone	Stone (with zycosoil)
OBC (%)	5.0	5.0
Bulk Density (gm/cc)	2.42	2.49
Marshall stability (kN)	18.5	19.6
Flow .01 mm	3.15	3.00
% Va	3.85	3.95
% VMA	13.28	14.35
% VFB	71.0	72.2
Marshall Stiffness kN/mm	17.75	18.21

From Table VII, it is observed that the stability of asphalt concrete with stone is 18.5kN whereas with zycosoil treated stone the value is 19.6kN. Moreover flow value gets reduced by 0.15mm, Marshall Stiffness increased by 0.46kN/mm.

B. Marshall Stability Test for Over Burnt Brick Aggregate

In Marshall Test, it has been observed that with 5-7% bitumen content, brick aggregate was not coated properly and as a result the Marshall specimen broke down easily. As the brick aggregate is porous and the specific gravity of the brick aggregate is low (sp. Gravity 1.94), the surface area of the brick aggregate is more and more bitumen is required for proper coating.

TABLE VIII
Marshall Test Result of Brick and Treated Brick

Types of aggregate	Brick	Brick (with zycosoil)
OBC (%)	7.5	8.5
Bulk Density (gm/cc)	2.02	2.19
Marshall stability (kN)	12.0	15.6
Flow .01 mm	3.80	3.60
% Va	3.90	4.05
% VMA	21.0	22.6
% VFB	79.0	80.3
Marshall Stiffness kN/mm	8.73	9.31

From Table VIII, it is observed that the stability of asphalt concrete with brick aggregate is 12.0kN whereas with zycosoil treated brick aggregate there is a considerable increase in stability up to 15.6kN. Moreover flow value gets reduced by 0.2mm, Marshall Stiffness increased by 0.58kN/mm. Test results also indicate that the stability and flow values for over burnt brick aggregate is less than stone aggregate but they are in permissible limit. It is also seen that the optimum bitumen contents are different for different mix types. OBC for brick aggregate is double of that for stone aggregate. Result shows that the unit weight and Marshall Stabilities of the compacted specimen for all aggregate types, increase initially with an increase in asphalt content, reach a maximum value and then decrease.

Result shows that the voids of the mix with over burnt brick aggregate decreases with an increase in bitumen content. It is seen from the Table VIII that the % of voids in the total mix at OBC satisfies the limiting value (3 to 6%).

In order to prevent permanent deformation of the mix under high stress, the Marshall stiffness (ratio of stability value to flow value) should not be less than 2.1kN/mm i.e., 1.2 times the tyre pressure. It is seen from the last column of Table VIII that the Marshall stiffness for all mix types are much above the required value 2.1kN/mm.

C. Boiling Test for Asphalt Concrete Mix

Boiling test of Asphalt concrete mix was conducted to know the properties of the mix considering the moisture susceptibility. The test was performed for both normal and treated stone aggregate as well as over burnt brick aggregate. The Stripping value of conventional and modified Asphalt concrete is tabulated in Table IX.

TABLE IX
Stripping Value of Asphalt Concrete prepared with Normal and Treated Stone and Brick aggregate

Type of the Mix	Stripping (%)
Asphalt Concrete with Stone	4
Asphalt Concrete with Treated Stone	0
Asphalt Concrete with Brick aggregate	6
Asphalt Concrete with Treated Brick aggregate	1

Results show that there is a considerable decrease in the stripping percentage for both the concrete prepared with stone or over burnt brick aggregate when treated with zycosoil. The stripping value should be less than 10% for the bituminous concrete [12]. Result shows that for all the mixes, the results

satisfy the limiting value. Moreover, addition of zycosoil improves the properties of the mix when moisture susceptibility is taken into consideration.

VII. Conclusion

On the basis of the experimental results of this study, the following conclusions are drawn:

- By using zycosoil as a coating over aggregates the properties of aggregate improve. This shows that weak aggregates can be used in Asphalt concrete construction by modifying the aggregate by zycosoil treatment.
- The use of over burnt brick in the bituminous mixes requires higher amount of bitumen binder compared to the conventional mix because of the high porosity and roughness of the brick aggregate.
- Over burnt bricks are suitable for the Asphalt Concrete mixes as coarse aggregate from the consideration of aggregate properties if treated by zycosoil.
- Zycosoil coated over burnt brick may also be used in Dense Bituminous Macadam of high volume road.
- Moisture susceptibility of the Asphalt concrete get reduced if the aggregate used in it is treated by zycosoil.

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