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A LABORATORY STUDY INVOLVING USE OF BRICK AGGREGATE ALONG WITH PLASTIC MODIFIED BITUMEN IN PREPARATION OF BITUMINOUS CONCRETE FOR THE ROADS OF TRIPURA

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ABSTRACT

The present study is to carry out the use of over burnt brick aggregate along with waste plastic modified bitumen in order to minimize the aggregate shortage problem in North-Eastern region of India for the construction of roads. Marshall Method of mix design is considered for deciding the optimum bitumen content to prepare the bituminous mix with such aggregate. 1%, 3%, 6%, 8% and 10% waste plastic by weight of bitumen is added with hot bitumen. The optimum bitumen content is considered before mixing the plastic with bitumen. The stability, Indirect Tensile Strength, Tensile strength ratio, Stripping value of the mix is evaluated. The mix with 8% plastic shows higher stability (increased by 32%) and higher indirect tensile strength (increased by 65%). Tensile strength ratio also increases and it is more than 75%. There is very less stripping observed for the mix modified by 8% waste plastic.

Keywords: oer burnt brick aggregate, waste plastic, modified bitumen, bituminous concrete.

INTRODUCTION

There are very few places in North-East India where rock is available in plenty. So the stone aggregate required in construction may not be available locally. The required material needs to be brought from nearby states or countries like Bangladesh. Hence the engineers in those places are always encouraged to use locally available material. Over burnt bricks are produced by burning the raw materials along with good quality bricks. Due to its distorted shape, over burnt bricks are considered as wastage. But there is a scope of using the over burnt bricks as a source of aggregate for construction. Due to recent development in the North-Eastern region there is a huge demand of construction material especially in preparation of roads. Hence the over burnt brick aggregate can solve the problem of shortage of aggregate in this region.

In bituminous concrete mix, bitumen plays the role of binding the aggregate together due to its adhesive properties. More compatibility of bitumen with aggregate increase the strength of the road prepared with the mix. Water is one of the main reasons for deterioration of the bituminous concrete mix which leads to the early failure of the roads. Use of any anti stripping agents can enhance the properties of the bitumen and indirectly improves the properties of the bituminous concrete mix. It is a common practice to improve the rheological properties of bitumen by adding polymer, rubber etc with the bitumen. Adding of plastic in the form of polymer can enhance the properties of the bituminous concrete mix (R. Vasudevan, 2011).

Plastic in different forms is found to be almost 5% of municipal solid waste, which is toxic in nature. It is a common scenario that plastic bags and other type of plastic packing materials are litters in the roads as well as drains. Due to its non biodegradability it creates stagnation of water and other associated hygiene problems. In order to reduce this problem experiments have been carried out whether this waste plastic can be reused productively in the construction of roads. Waste plastic, when added to hot bitumen can enhance the properties of bitumen. Plastic mix bitumen acts as a very good anti stripping mix.

The brick aggregates are weaker than stone aggregate. Hence brick aggregate mixed with plastic modified bitumen has a scope to be used in road construction. The prepared mix is found to give higher strength, higher resistance to water and better performance over a long period of time. This study mainly highlights the use of waste materials over burnt brick aggregate and waste plastic as a construction material in preparation of roads.

Literature review

Tripua is a North-Eastern state of India, surrounded by Bangladesh in three sides. Here natural stones are not available in plenty. The natural stone aggregate required for the construction field needs to be brought from neighboring places like Assam, Meghalaya and some parts of Bangladesh which is situated at a distance of more than 250 KM. The transportation cost of aggregate for the construction sector is very high. As a result, generation of alternative material to the natural aggregate becomes important and is inevitable in Tripura to fulfill the desired level of demand of aggregate. Bricks are produced by burning the moulded soil which consists of an adequate percentage of clay. Approximately 13% of bricks are severely over burnt due to uncontrolled

distribution of temperature in the kiln during manufacture (Mazumder *et al*.). These over burnt bricks have no use in cement concrete preparation and are considered as wastage.

Moreover it creates problem for the brick manufacturers disposing those wastage. Hence crushed over burnt brick aggregates are of particular interest because their use can considerably reduce the problem of prevention of natural aggregates, minimizing aggregate transportation costs and to reduce the waste disposal problem. Mazumder, *et al*. 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 for using it in base course as aggregate. Rasel, *et al*. explained that, due to the scarcity of the natural stone and their high price in Bangladesh, urges the development of the locally available materials used as a coarse aggregate. They observed a Marshall stability 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 according to standard of Bangladesh. Conceicao et al. investigated that bricks are the highly porous ceramic material and have high water absorption. The compactive effort influences the resistance to permanent deformation characteristic of those materials prepared with brick aggregate. Debieb and Kenai reported a decrease in strength varying from 20% to 30% for both coarse and fine crushed bricks depending on the degree of substitution. Lanham *et al*. observed that, dense graded picked brick aggregate bituminous mixes with higher percentage of bitumen content were also good as compared to crushed stone aggregate bituminous mixes for use in the base course of bituminous concrete pavement. Thus the literature supports the use of burnt brick aggregate as an alternative aggregate in road construction. Use of plastic in road construction is not new. There are several roads prepared in Chennai using waste plastic. The performance of those roads is better than other roads (R. Vasudevan *et al*.). Mixing of 6% plastic with bitumen by weight of bitumen can improve the properties of bituminous mix. The stability increases by 12%, ITS increases by 29% and the mix shows no stripping (A.U. Ravi Shankar). Use of waste plastic in bituminous mixes improves properties and performance of roads. It can also be used in rural road construction (P.K. Jain).

Plastic waste scenario

Plastics are user friendly and the use of plastic is increasing significantly. In India, the per capita plastic consumption is 6-7 kg per annum (CPCB, 2009). As per Central pollution Control Board (CPCB) reports, India generates 56 lakh tones of plastic waste annually. The use of plastic in the form of carry bags, bottle, cups etc. is constantly increasing. About 60% of the total plastic is collected and recycled. Nearly 50 to 60 % of the total consumed plastics are being used in the packing purposes. Once used, the plastic bags are thrown out. The problem with plastics is that they do not easily degrade. Burning of plastic generates dangerous gases. Thus the management of waste plastic becomes a vast challenge to the engineers now a day. The characteristic of plastic encourages the engineers to use it as a road material. The plastic like High density Polyethylene (HDPE) is of tough and flexible character. Similarly Low density Polyethylene (LDPE) is moisture proof and inert. Polypropylene is stiff and heat resistant (Jain P.K., 2012). Use of plastic in road construction helps in waste management along with such properties which is an added advantage.

Objective of the present study

The over burnt bricks are considered as waste material for the brick industries. Similarly plastic carry bags are considered as solid waste once used. In order to solve the issue of shortage of stone aggregate in road construction and to solve the issue of disposal of plastic, a laboratory investigation is planned. The study includes the use of over burnt brick aggregate and waste plastic as an ingredient of bituminous concrete. The objective of the present investigation is given below:

- To study the physical and mechanical properties of over burnt brick aggregate as road material.
- To evaluate the performance of bituminous concrete prepared with waste over burnt brick aggregate.
- To evaluate the properties of bituminous mix prepared with waste plastic modified bitumen.
- To evaluate the indirect tensile strength and moisture susceptibility properties of bituminous concrete mix prepared with over burnt brick aggregate and plastic modified bitumen.

METHODOLOGY

The over burnt bricks collected from a local kiln at Agartala, Tripura, India. The over burnt bricks are available in distorted shapes. In some of the cases, 3-4 bricks get clubbed together and cannot be separated from each other easily. The bricks are broken in the sizes around 75mm manually and then put in the crusher to break further to get the desired size of the aggregate. The gradation of aggregate is followed as mentioned in MoRT&H 2013 for preparation of bituminous concrete mix. The gradation of aggregate is presented in Table-1. The waste plastic carry bags are collected from the surrounding places of Agartala. The bags are cleaned by washing and then dried. These are shredded in small pieces passing 4.75mm sieve and retaining on 2.36mm sieve. The bitumen is heated and then 1%, 3%, 6%, 8%, 10% shredded plastic by weight of bitumen is mixed with the molted bitumen. The plastic modified bitumen is added with the hot aggregate and test specimen was

prepared. Different laboratory tests were performed to evaluate the mix prepared with over burnt brick aggregate with plastic modified bitumen.

Table-1. Gradation of aggregate for bituminous concrete.

Sieve in mm	% passing by weight of Specimen	Cumulative % passing	% of aggregate and mineral filler
19	100	100	Coarse aggregate 38%
13.2	90-100	89.5	
9.5	70-88	79.0	
4.75	53-71	62.0	
2.36	42-58	50.0	Fine aggregate 55%
1.18	34-48	41.0	
0.60	26-38	32.0	
0.30	18-28	23.0	
0.15	12-20	16.0	
0.075	4-10	7.00	
			Mineral filler 7%

STUDY OF MATERIAL PROPERTIES

The properties of the ingredients material is studied individually. The various standards are followed to study the physical and mechanical properties of the materials used in the study.

AGGREGATE

Crushed over burnt brick aggregate is used in this study as aggregate. The gradation of those aggregates complied with the Ministry of Road Transport and Highways (MoRT and H, India) requirements. The aggregate is tested as per BIS guidelines. As per MoRT and H (2013), 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. The tested properties of stone aggregate and OBBA are presented in Table-2.

Table-2. Properties of over burnt brick aggregate.

S. No	Test performed	Test Results
1	Aggregate Impact value	29.6%
2	Los Angeles Abrasion value	32%
3	Water absorption value	6.6%
4	Specific Gravity	1.89%

BITUMEN

VG-30 grade bitumen has been used as binder to prepare the bituminous concrete. The properties of bitumen used in this study are presented in Table-3 and compared with the standard values mentioned in IS: 73, 1992.

Table-3. Properties of bituminous.

S. No.	Test performed	Test result
1	Specific Gravity	22.4%
2	Penetration	15.1%
3	Softening Point	0.96%
4	Ductility	2.64

MINERAL FILLER

Mineral filler consists of finely divided mineral matter such as rock dust, slag dust, hydrated lime, hydraulic cement, fly ash, loess, or other suitable mineral matter. Mineral fillers should have 100 percent of the particles passing 0.60 mm, 95 to 100 percent passing 0.30 mm, and 70 percent passing 0.075 mm. In this study, stone dust has been used as mineral filler. The properties of stone dust used in this study as mineral filler are listed in Table-4.

Table-4. Properties of stone dust.

S. No.	Test performed	Test result
1	Specific Gravity	2.7
2	Bulk Density (kN/m^3)	18.1

PLASTIC

Waste plastic is collected from the domestic areas. It is used in the shredded form. The size of the

shred used in this study which passes 4.75mm sieve. The plastic was collected and washed properly. After drying the plastic bags were shredded and sieve through 4.75mm. Properties of shredded plastic are provided in Table-5.

Table-5. Properties of plastic.

S. No.	Test performed	Test Result
1	Melting Temperature	135^0C
2	Softening Temperature	105^0C
3	Ignition Temperature	250^0C

PROPERTIES OF BITUMINOUS CONCRETE MIX

The properties of bituminous concrete mix are evaluated by Marshall Test. The performance of the prepared mix is evaluated by Indirect Tensile Strength test and by Stripping value test.

MARSHALL MIX DESIGN

Marshall Test, a stability test is applicable to hot-mix design of bitumen and aggregates. In this present study, Marshall Test is performed with over burnt brick and stone aggregate mix. The Marshall method is used to determine the Optimum Bitumen Content (OBC). Standard values of Marshall test results and Tensile Strength Ratio (TSR) as specified by MoRT and H is presented in Table-4. The standard gradation of aggregates in preparation of the test specimen, followed in this study as per MoRT and H is presented in Table-6.

Table-6. Design criteria as per MoRT and H.

Test performed	Minimum stability (at 60^0C)	Flow (mm)	Compaction level (both side)	Air void	VMA (minimum)	VFB	Marshall quotient (kN/mm)	Tensile strength ratio (minimum)
Results	9kN	2-4	75	3-5%	10%	65-75%	2-5	80%

Test specimens have been prepared and tested in the laboratory according to MoRT and H guidelines. From the test results, the relationship between Marshall Stability, Flow value, Bulk density, Air Void (VA) and Voids Filled with Bitumen (VFB) with varying percentages of bitumen content for brick aggregate have been evaluated. Marshall Samples are prepared with the brick aggregate along with normal and plastic modified bitumen. The Marshall specimens were prepared by adding 7.5%, 8%, 8.5%, 9% and 9.5% bitumen (by weight of aggregate) into the hot aggregate. The optimum bitumen content to prepare the mix is found as 8.5% for over burnt brick aggregate. Different percentage of plastic is added to the optimum bitumen content and test samples are prepared. Three identical specimens for each percentage were prepared and the average value is reported. Test results obtained in the laboratory are listed in Table-7.

Table-7. Marshall test results on different aggregate.

Properties		Bituminous mix with different percentage of plastic in the mix				
		1%	3%	6%	8%	10%
Unit weight (kN/m^3)		23.0	23.35	23.55	23.70	22.85
Marshall stability (kN)		9.65	10.85	12.15	12.75	11.00
Flow (mm)		3.20	3.45	3.60	3.65	3.70
% VA		3.16	4.05	4.25	4.75	4.80
% VMA		16.45	17.88	18.96	20.20	20.29
% VFB		71	72.2	74.3	74.6	75.1
Marshall quotient (kN/mm)		3.02	3.15	3.38	3.49	2.97

From Table-7, it is observed that, the stability of the mix increases with the increase in dosage of plastic in bitumen. At 8% plastic dosage to hot bitumen value reaches to the highest of 12.75kN. Marshall Quotient value is also within the limit for this mix. Hence 8% of

plastic is considered as the most suitable dosage for further performance study.

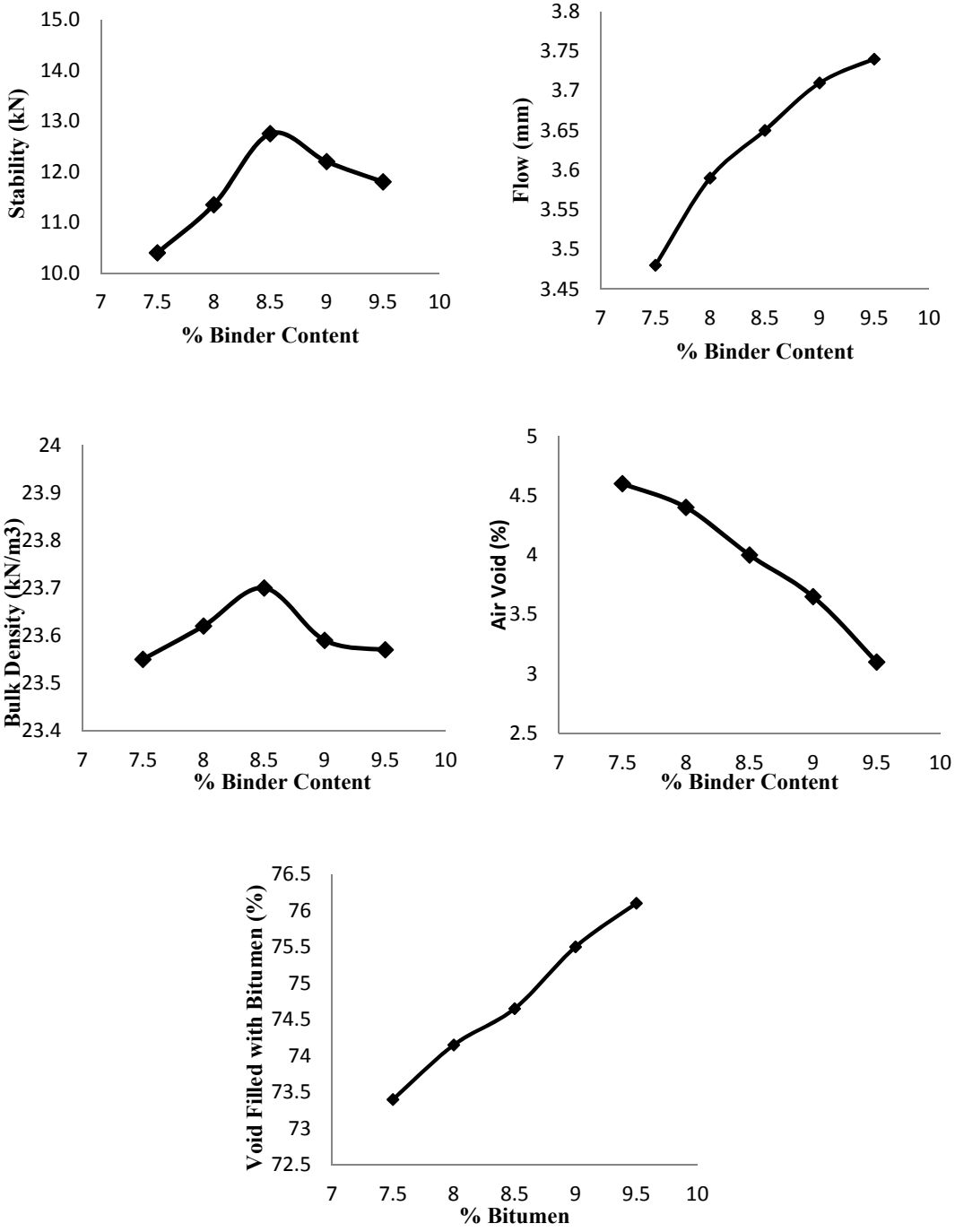

Figure-1. Volumetric properties of bituminous concrete mix (adding 8% plastic with bitumen) at binder content versus: stability, flow, air voids, bulk density and voids filled with bitumen.

Indirect Tensile Strength Test

The Indirect Tensile Strength (ITS) test is used to evaluate the tensile strength properties of bituminous concrete which can be used to assess the fatigue behaviour. The standard procedure as per ASTM D 6931 is followed to prepare the sample for the test as well as to measure the failure loads. The IT'S provide a measure of the tensile strength of the bituminous mixes. The test is conducted on the conditioned and unconditioned samples. The Indirect Tensile Strength of the mix with different percentage of plastic modified bitumen are tabulated in Table-8.

Table-8. Indirect tensile strength test results.

S. No.	Percentage of plastic in bitumen	The indirect tensile strength (N/mm^2)		Tensile strength ratio (%)
		Unconditioned	Conditioned	
1	1	0.68	0.43	63.23
2	3	0.74	0.50	67.57
3	6	0.84	0.60	71.43
4	8	1.12	0.88	78.57
5	10	1.28	1.03	80.46

Stripping value test

Stripping value test conform the binding strength of bitumen to a particular type of aggregate. IS: 6241-1971 is followed to complete the test. 200gm of clean, oven dried aggregates passing 20mm sieve and retained on 12.5mm sieve is heated to 150^0C and mixed with 5% bitumen by weight of aggregate which is preheated to 160^0C before the preparation of mix. It is tested by immersing bitumen coated aggregate in water for 24h at 40^0C. When the bitumen coated aggregate is immersed in water then water penetrates into the pore and voids of the aggregate, resulting in the peeling of bitumen. After a period of 24h, the stripping is observed and the percentage of stripping is noted. The results of the mix with different percentage of plastic modified bitumen are tabulated in Table-9.

Table-9. Stripping value test results.

S. No.	Percentage of plastic in bitumen	Stripping (%)
1	1	5.5
2	3	4
3	6	3
4	8	1
5	10	1

It is observed that the Stripping value is least for the mix with 8% and 10% plastic modified bitumen. It satisfies the acceptable value (as per Table-5). Hence bituminous concrete with 8% and 10% plastic modified bitumen shows a better binding strength with brick aggregate even when subjected to worst moisture content.

STUDY OUTPUT

Following outputs are observed in the present study:

a) Use of over burnt brick aggregate in road construction can ease the problem of waste management in brick factories.
b) The over burnt brick aggregates are useful alternative for the stone aggregates at places where stone aggregate is not available in plenty.
c) Use of plastic in road preparation can solve the problem of waste management in the society.
d) The stability of the bituminous mix increases with the increase in percentage of plastic in bitumen. It is 32% higher for the bitumen with 8% plastic than the bitumen with 1% plastic.
e) Mixing of more percentage of plastic in bitumen can lead to decrease in stability as there is a chance of formation of cavity.
f) Mixing of plastic in bitumen can increase the tensile strength ratio of the mix. It is 78.57% for the mix with bitumen having 8% plastic and 63.23% with bitumen having 1% plastic. It is 15.34% higher and indicates better resistance to moisture damage.
g) With the increase in percentage of plastic the water damage decreases in the mix. It is 82% lesser for the mix containing bitumen with 8% plastic than the bitumen with 1% plastic.
h) Optimum percentage of plastic to be mixed with bitumen when added with over burnt brick aggregate is 8%.

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