IMPROVEMENT IN STRENGTH OF FLEXIBLE PAVEMENT : AN EXPERIMENTAL APPROACH

M.S.Ranadive[1] and A.B.Tapase*[2]

1. Department of Civil Engineering, College of Engineering, Pune (INDIA)
2. Department of Civil Engineering, K.B.P. College of Engineering and Polytechnic, Satara, Maharastra (INDIA)
* E-mail : msrtunnel@yahoo.co.in

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ABSTRACT

Disposal of plastic waste in ecofriendly way is the thrust area of todays research. Overlaying is the only way to solve the problem of pot hole formation, rutting, stripping, etc., of pavements which is time consuming and obstruct flow of traffic. Here the objective is to investigate the effect of plastic waste and concrete as a reinforcement material in bituminous concrete layer of flexible pavement. Number of laboratory tests have been carried out replacing bitumen by plastic waste by few percentage and bituminous mix partially by concrete blocks. The results obtained in laboratory investigation indicates major gain in strength required for road construction with substantial cost saving.

Key Words: Replacement, Plastic coating, Flexible pavement, Bituminous, Plastic waste.

INTRODUCTION

Increased demand due to economic growth has led to the invention of multi-axle heavy trucks which accelerates the transportation of quarry materials, bricks and other such heavy materials has put additional loading than that while designing the flexible pavements. Those factors are the main cause of pavement failure in the form of ruts, cracks, etc. Ruts affect the riding comfort, increase in wear and tear of the vehicles and reduces life of the pavement. The excessive rutting along wheel track causes longitudinal cracking and waviness of pavement surface. Bitumen and bituminous mixes are modified in order to improve the performance of bituminous concrete mixtures. There are two different processes to commercialize the production of bituminous concrete mixes. The wet method involves the use of ready mixed modified bitumen, while the dry process involves adding waste polymers/rubbers (in powder, shredded or granular form) to the aggregate followed by bitumen during mixing process at the hot mix plant[1]. The effect of such modification varies with the chemical nature and the percentage of the modifier used. In general, improvement in resistance to rutting, thermal and fatigue cracking were obtained and therefore, utilization of such waste materials in the highway sector is an effective disposal alternative, which reduces the disposal cost and save the environmental contamination[2]. Consequently, with improved durability and resistance against deformation to conventional bituminous mixes the longevity of the roads is increased[3]. In this work focus has been given on the strength of flexible pavement and disposal of plastic in eco-friendly way. To deal with the problem, attempt is made on use of plastic waste as coating to natural aggregate and small cylindrical concrete blocks as reinforcement in flexible pavement. The strengthening or reinforcing the pavement is worthwhile. Laboratory and field studies reflect the potential of reinforcement in various civil engineering applications. To simulate with the field conditions Marshall stability test with 6-inch (150mm- diameter specimen) is used for experimental work[4-8]. Parameters like stability, flow number, bulk density, percent air voids, percent voids in mineral aggregate are to be checked in testing program.

*Author for correspondence

AIMS AND OBJECTIVES

However, this investigation is an attempt to satisfy the following objectives:

1. To study the effect of plastic waste as an alternative material in bitumen roads as a partial replacement to the weight of bitumen.
2. To study the effect of bituminous mix replacement by specially designed small size concrete blocks as reinforcement by volume.
3. Also to reaffirm and validate the use of large size moulds of 150mm diameter for Marshall stability test.

MATERIAL AND METHODS

Bitumen

The bitumen used in this investigation was provided by Pune Municipal Corporation (PMC), Pune (Maharashtra), India from one of its plant situated in Yerawada, Pune.The bitumen was 60/70-penetration grade and has been widely used in Pune for paving application, it is used as binder in present work and the physical properties of bitumen in comparison to IS: 73, 1992 (8) are given in **Table 1**.

Fine and coarse aggregate

The locally available aggregates were also provided by PMC from its plant at Yerawada, Pune. The physical properties of aggregates used are complied with the ministry of Road Transport and Highways[9].

High density polyethylene (HDPE)

Low density polyethylene (LDPE) and HDPE are been used before in experimental works related to flexible pavements showing positive results related to use of plastic waste in flexible pavements.[1] The polymer coated aggregate bitumen mix perform better for flexible pavements[1]. The results for both dry and wet specimen of 8 percent waste polymer modified bitumen (WPMB) mix show 50 percent enhanced tensile strength compared to conventional mix and more resistance to water damage[2,10].

Punith and Veeraragavan[11] used reclaimed PE as asphalt modifiers.They found that the basic test properties indicated that the addition of PE content to neat asphalt reduces the penetration and ductility values, whereas increases in softening point and specific gravity values were observed with the addition of PE modifier. A PE content of 5% by weight of asphalt is recommended for the improvement of the performance of asphalt cement.

Sinan and Emine[12] tried to investigate the possibilityThe possibility of using various plastic wastes containing High Density Polyethylene (HDPE) as polymer additives to asphalt concrete. From the work done it is observed that waste HDPE-modified bituminous binders provide better resistance against permanent deformations due to their high stability and high Marshall Quotient (MQ) and it contributes to recirculation of plastic wastes as well as to protection of the environment.

The potential use of pyrolisis LDPE as a modifier for asphalt paving materials[3]. Five different blends including conventional mix were subjected to binder testing such as rheological tests, as well as to some other tests related to the homogeneity of the system. Research results indicate that modified binders showed higher softening

Table 1: Physical properties of 60/70 penetration grade paving bitumen[9]

S/N	Properties tested	Unit	Results	Specification limits as per IS:73,1992 (India)
1	Penetration (25^0 C; 0.1 mm)	mm	68	50-70
2	Softening point	(^{0} C)	46.50	46-54
3	Ductility (25^0 C)	(cm)	79.33	>75
4	Flash point	(^{0} C)	240	175, minimum
5	Specific gravity	(g/c m^3)	1.03	>0.99

Table 2: Physical properties of aggregates used[10]

S/N	Properties tested	Unit	Results	Specification limits for Bituminous concrete (BC), as per MoRTH (2001)
1	Los Angeles abrasion value	(Percent)	16.76%	30% (max)
2	Aggregate impact value	(Percent)	13.60%	24 (max.)
3	Combined flakiness and elongation indices	(Percent)	14.00%	30 (max.)
4	Water absorption	(Percent)	1.30%	2 (max.)
5	Specific gravity (CA)	(g/c m^3)	2.68	2-3
6	Specific gravity (FA)	(g/c m^3)	2.66	2-3

point and caused a reduction in percentage loss of weight due to heat and air (i.e. increase durability of original asphalt). Recycled plastics composed predominantly of polypropylene and low-density polyethylene can be incorporated in plain bituminous concrete mixtures[13]. High density polyethylene (HDPE) plastic carry bags in shredded form were used in this work.

Details of reinforcement

The reinforcement material should be such as it should improve properties of sample. Number of concrete blocks were tried in laboratory to reach the final size and shape. Out of which small circular cylindrical sample of size 40mm diameter and 25mm height have recorded good compressive strength greater than 25mpa compare to other blocks of different size and shapes. The mix proportion for preparing cement concrete blocks is 1:1:1:1 (cement: sand: coarse aggregate: filler) with W/C ratio 0.45. Blocks kept in water for curing for at least 7 days. After curing it should be kept out of water for at least 24 hours before the tack coat is applied to it.

Experimental set up

Most asphalt technologist believes that fundamental changes must be made in the composition of hot mix asphalt and its testing methods. Though, there are many methods being followed, the basic principle behind them is to arrive at the optimum binder content, given the gradation selected and the mechanical properties desired. Here the specimen used is prepared as per ASTM D1559[4] which is cylindrical 150mm diameter compacted with automatic Marshall compactor on either side with 75 number blows. The extent of the experimental program is as discussed below. Overall, 84 specimens were prepared for different percentage of bitumen content ranging from 4.5 %, 5%, 5.5% and 6%. Also the specimen were prepared by varying percentage of bitumen replaced by plastic waste in the range of 5 to 20 % and replacing bituminous mix by concrete blocks as reinforcement. Each time three tests were conducted for particular mix to get more accurate results.

Instead of using standard Marshall mould, modified cylindrical mould of 150mm diameter is used. Here, automatic compactor equipped with 9.979 kg weight constructed to provide a free fall of 45.7cm is used with the help of compaction plate in this work. To simulate with the field conditions the specimen is loaded axially[6-8].

Mix design

The gradations adopted for mix are taken as specified by "Manual for Construction and Supervision of Bituminous works" MoRTH; India[10] is given in **Table 3**. Here mix design is to be made for bituminous concrete layer of flexible pavement with different percentage of bitumen content, plastic waste and reinforcement blocks as replacements. Nominal size of the specimens is 150 mm diameter by 75 mm in thickness.

Steps for sample preparation for control mix with different bitumen content

(a) Oven dried aggregate for approximately 12

hours at around 105^0 C to 110^0C was separated into the individual specified sizes by dry sieving.

(b) Individual aggregates were recombined to the correct proportions for approximately 3000 gm specimens according to mix design[6-8].

(c) The aggregates were thoroughly mixed on mixing pan.

(d) Then after the hot bitumen as per trial percent (say 4.5% of total mix weight) is mixed with aggregate at temperature of 160^0C.

(e) After properly mixing aggregate with bitumen the mix was filled in a mould at a time and compaction plate was placed on which 75 numbers of blows were given on either sides of sample with the help of automatic compactor.

Table 3 : Mix design for bituminous concrete

S/N	Sieve size	Cumulative percentage passing					Blending percentage					Actual result	Permissible as per MORTH 2001 grading-1
	mm	20 mm	12.5 mm	10 mm	6 mm	Girit	20 mm	12.5 mm	10 mm	6 mm	Girit		Table No. 500-18
							25%	10%	10%	10%	45%		
1.	26.5	100	100	100	100	100	25	10	10	10	45	100	100
2.	19	91.5	100	100	100	100	22.88	10	10	10	45	97.88	79-100
3.	13.2	9.0	100	100	100	100	2.25	10	10	10	45	77.25	59-79
4.	9.5	1.7	75.5	78.2	100	100	0.425	7.55	7.82	10	45	70.80	52-72
5.	4.75	0.2	5.6	7.3	70.5	98.8	0.05	0.56	0.73	7.05	44.5	52.89	35-55
6.	2.36	-	1.1	0.4	7.3	71.7	-	0.11	0.04	0.73	32.27	33.21	28-44
7.	1.18	-	-	-	1.2	47.8	-	-	-	0.12	21.51	21.63	20-34
8.	600	-	-	-	0.3	34.4	-	-	-	0.03	15.48	15.51	15-27
9.	300	-	-	-	0.1	22.10	-	-	-	0.01	9.99	10	10-20
10.	150	-	-	-	-	11.60	-	-	-	-	5.22	5.22	5-13
11.	75	-	-	-	-	7.4	-	-	-	-	3.33	3.33	2-8

Sample preparation for different percent of bitumen replaced by plastic waste

All the steps up to (c) were carried out as mentioned earlier in 3.6.1. than the steps from (d) were followed as mentioned below:

(d) Before mixing hot bitumen at nearly about 170^0 C with natural aggregates at 160^0 C, the shredded plastic waste as trial percent (say 5 %, 10%, 15 %, 20%) was manually sprinkled onto the natural aggregate. Plastic gives the hot aggregate a uniform oily-looking coating of molten plastic, to which the molten bitumen adheres very well.

(e) Required quantity of bitumen as per trial percent was added to the sample. Mix it thoroughly at temperature of 160^0C.

(d) Same procedure was repeated for filling the sample in the mould as mentioned earlier.

Steps for sample preparation with 9.20% of volumetric replacement of bituminous mix by concrete blocks as reinforcement

All the steps up to (c) were carried out as mentioned earlier in 3.6.1. than the steps from (d) were followed as mentioned below:

(d) Here 9.20% of total volume of mix was replaced by concrete blocks as reinforcement in the sample.

(f) Filling of mould: Add the concrete blocks randomly into the mix and fill the mould at a time and place the compaction plate on which 75 number of blows are given on either sides of sample with the help of automatic compactor.

Combine replacement of percentage of bitumen by plastic waste and volumetric replacement of bituminous mix by concrete blocks as reinforcement

All the steps up to (c) were carried out as men-

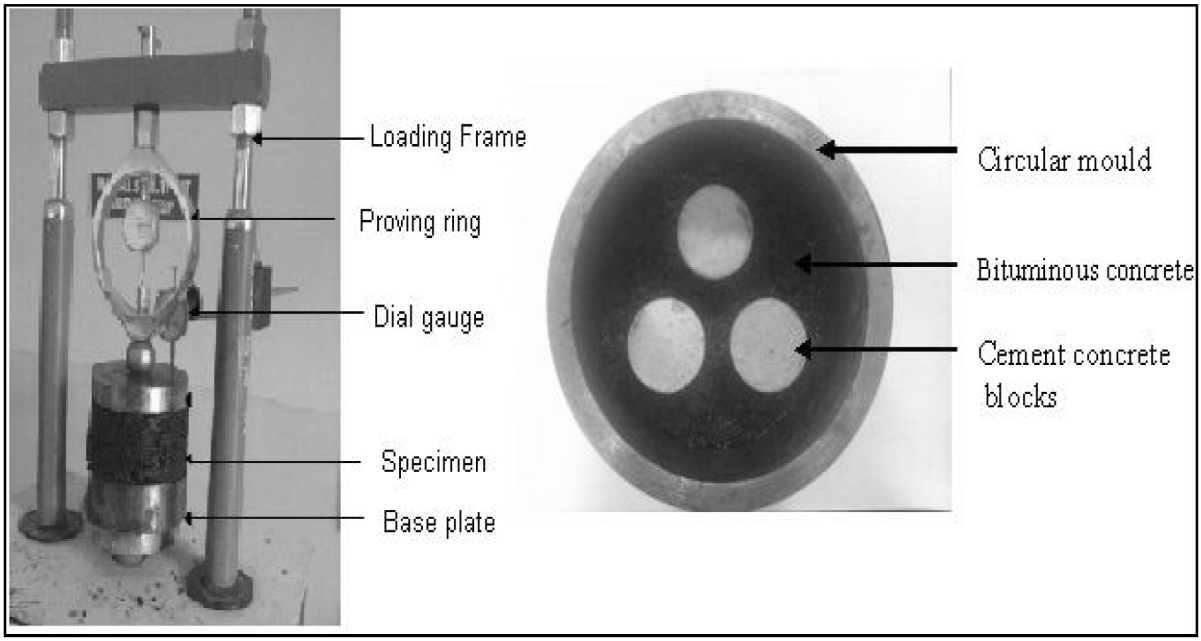

Fig. 1: Blocks and Loading arrangements

tioned earlier in 3.6.1. than the steps from (d) were followed as mentioned below:

(d) Before mixing hot bitumen at nearly about 170 o C with natural aggregates at 160 o C, the shredded plastic waste as trial percent was manually sprinkled onto the natural aggregate at this temperature plastic gives the hot aggregate a uniform oily-looking coating of molten plastic, to which the molten bitumen adheres very well, with the plastic actually dissolving in the bitumen to an extent of only about 2% to increase the viscosity of the binder.

(e) Here 9.20% of total volume of mix is replaced by concrete blocks as reinforcement in the sample, so reduce that much amount from the mix.

(f) Filling of mould: Add the concrete blocks randomly into the mix & fill the mould at a time and place the compaction plate on which 75 number of blows are given on either sides of sample with the help of automatic compactor.

The moulds were kept in room temperature for least 10 hours so that they can be handled manually. Then the samples were removed out from the mould carefully.

RESULTS AND DISCUSSION

Experimental results from tests performed on bituminous concrete specimens to know the stability, flow value, bulk density, per cent air voids, and per cent V.M.A. are presented maximum density of compacted specimen is observed at 5.5% bitumen content for all cases **(Fig. 2).** Bulk density varies in the range of 2.25gm/cc to 2.38gm/cc.

It is observed that 9.20 percent volumetric replacement of bituminous mix by concrete blocks shows more air voids compared to control mix but when it is mixed with aggregates coated with plastic waste it shows percent air voids within permissible range. Minimum air voids are observed in specimens with 5.5% bitumen content for all cases **(Fig. 3)**.

Percent V.M.A. is more in case of reinforcement as compared with control mix and other results. Minimum 15.72% at 4.5% bitumen content with control mix and maximum 20.04% at 6.0% bitumen content with 9.20 percent volumetric replacement of bituminous mix by concrete blocks arrangement case is observed **(Fig. 4)**.

Stability is maximum in case of 10 percent bitumen replaced by plastic waste **(Fig. 5)**.Also flow shows good results in case of 10 percent bitumen replaced by waste plastic **(Fig. 6)**.

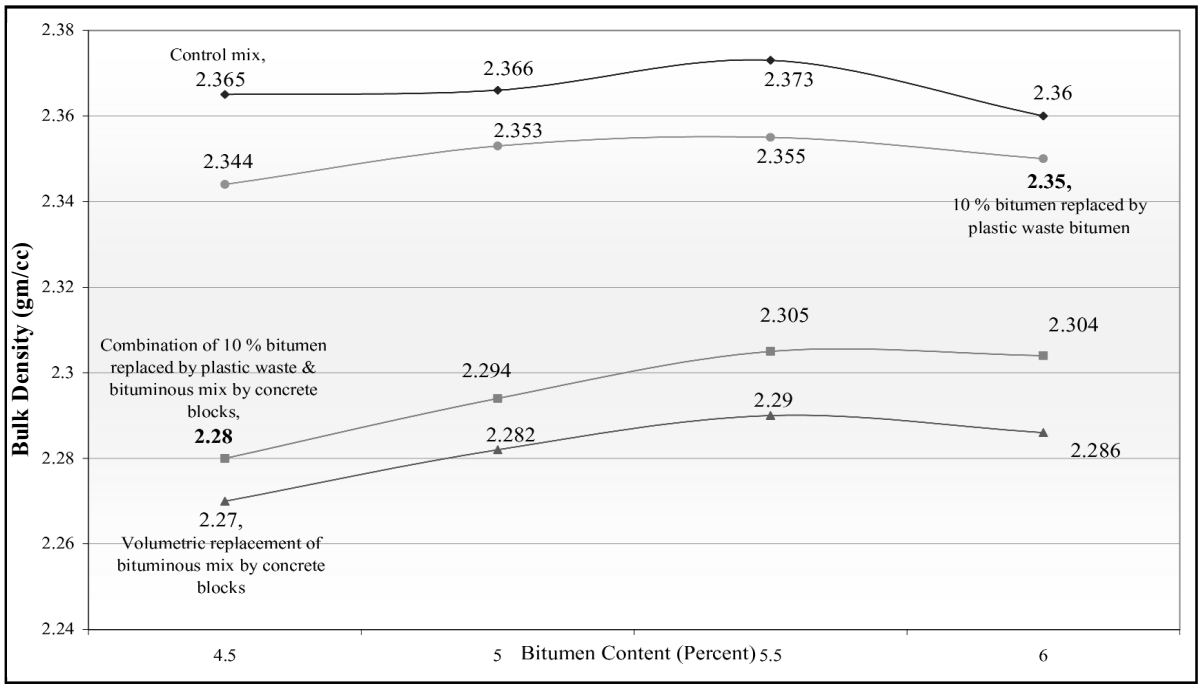

Fig. 2 : Bulk Density (gm/cc) Vs Bitumen content (Percentage) for all Cases

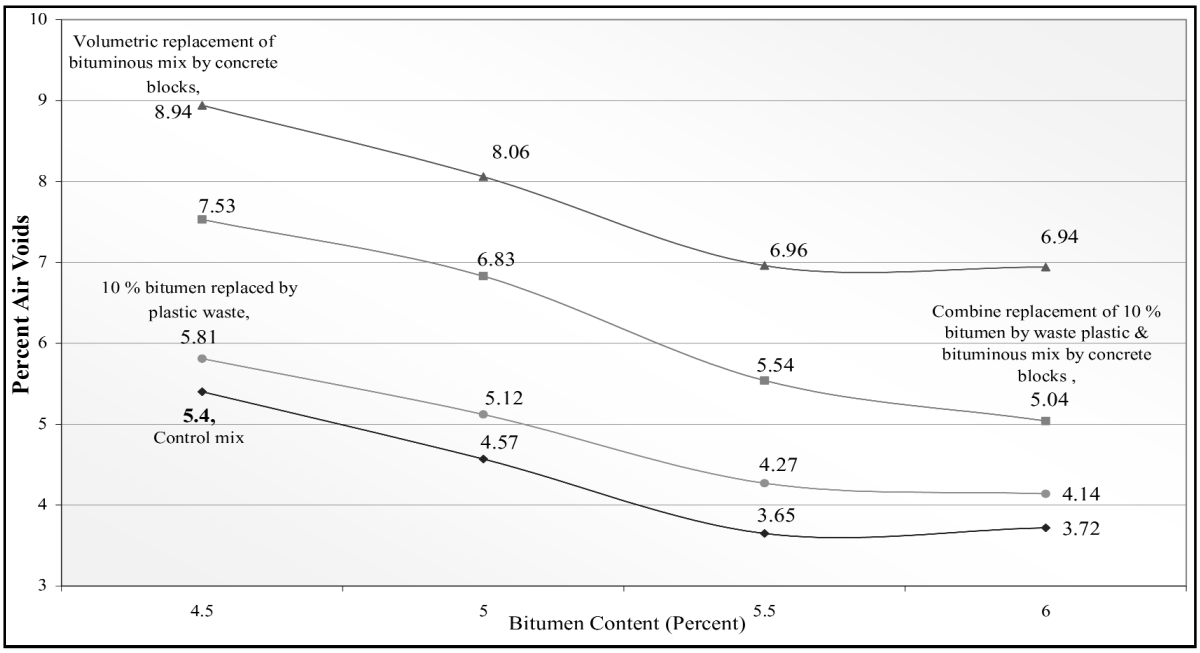

Fig. 3 : Percent air voids Vs Bitumen content (Percentage) for all cases

CONCLUSION

Based on the experimental study following important conclusions are drawn

- From the study it is observed that the ten percent of bitumen can be replaced by plastic waste in bituminous layer having 5.5 percent optimum bitumen content. Cost reduction in bitumen is nearly about 8.00 percent when the bitumen is replaced by 10 percent plastic waste.
- Percent material cost reduction is 10.36% of

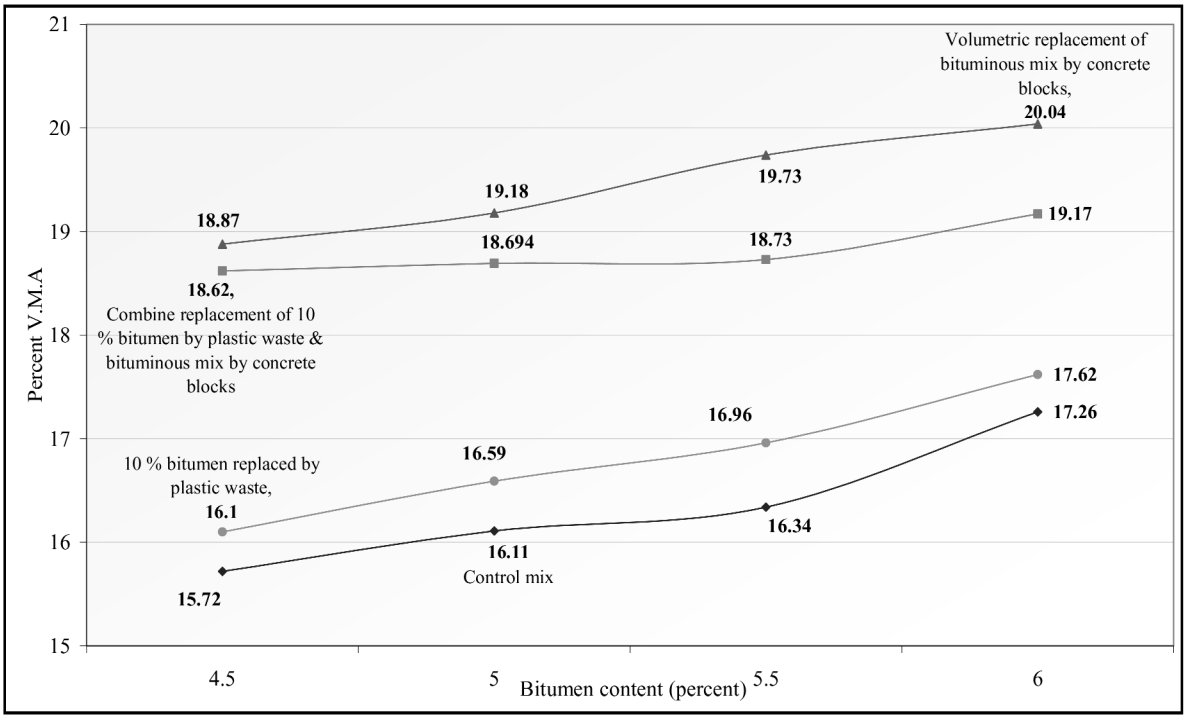

Fig. 4 : Percent V.M.A Vs Bitumen content (Percentage) for all cases

total material cost when there is 9.20 percent volumetric replacement of bituminous mix by concrete blocks and 10 percent bitumen by plastic waste, also percent cost reduction is around 4.63 % of total project cost.

- Considering stability as main parameter, it is observed that at 5.5 percent bitumen content with 10 percent bitumen replaced by plastic

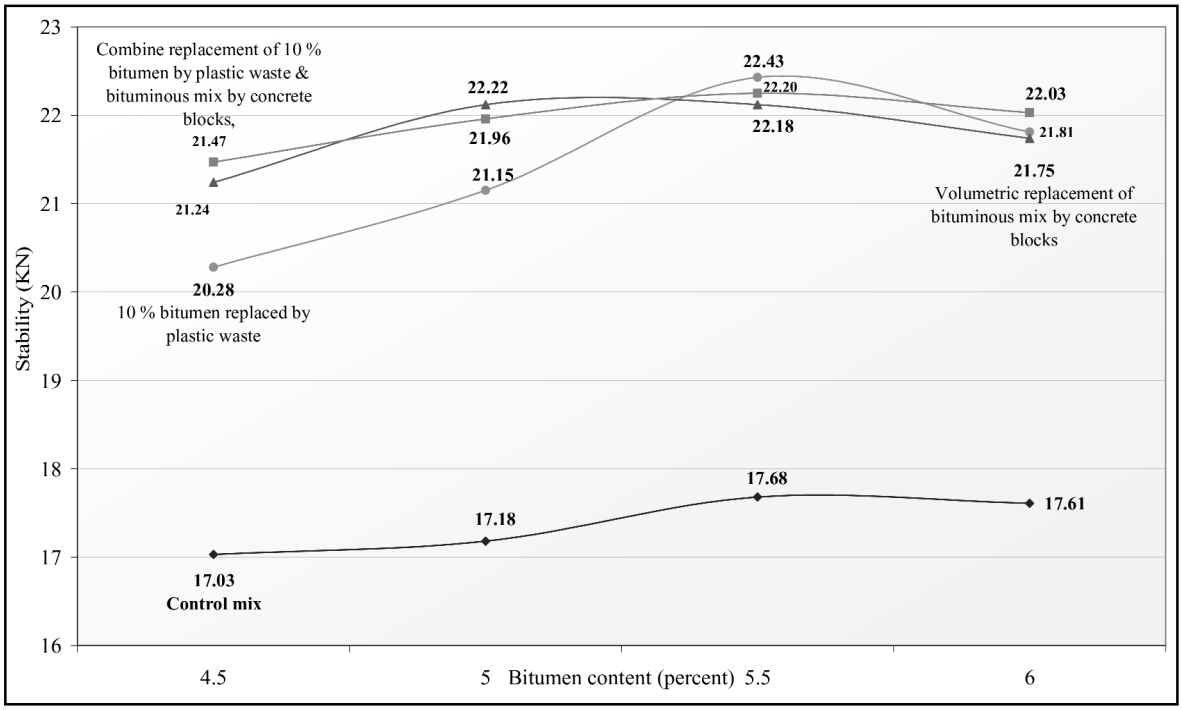

Fig. 5: Stability (KN) Vs Bitumen Content (Percentage) for all cases

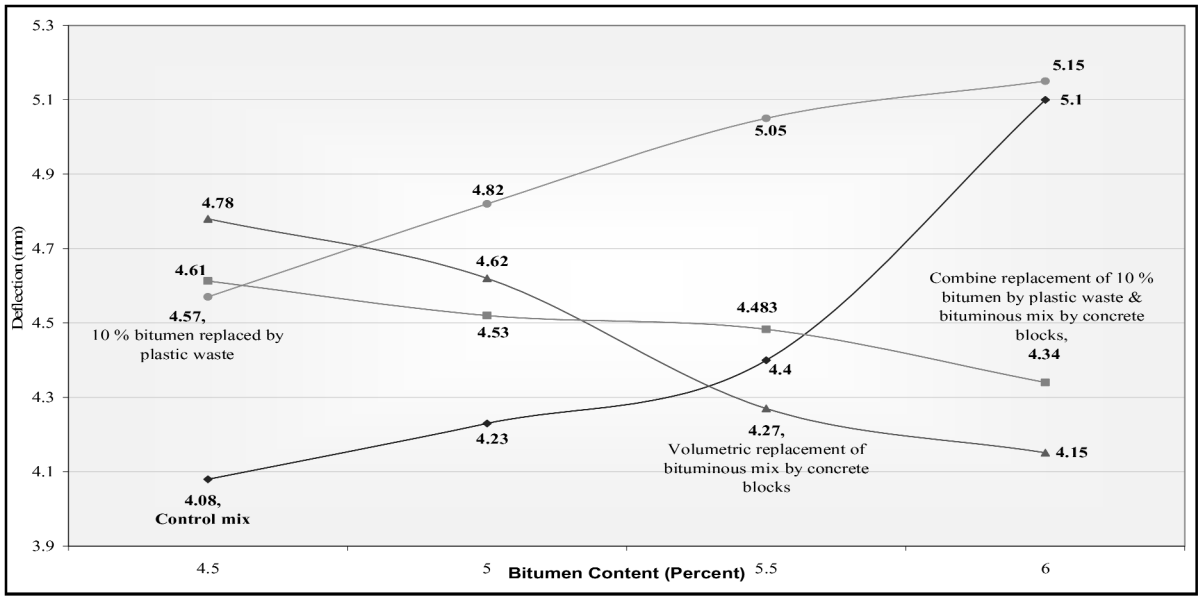

Fig. 6 : Flow (mm) Vs Bitumen Content (Percentage) for all cases

waste and 9.20 percent of bituminous mix volumetrically replaced by concrete blocks shows 25.57 percent increased stability keeping all the other parameters within limits.

- The sudden increase in stability is because of natural aggregates are coated with plastic waste before mixing with bitumen which do not allow water to enter inside and increases its stripping value also due to replacement of bituminous mix by concrete blocks as reinforcement ultimately increases its strength.
- From the experimental work it is clear that the properties of laboratorial designed bituminous mix for bituminous concrete are much more superior to those of the control mixes entirely composed of mineral aggregates and can be effectively used in practical applications.

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