Experimental Investigation of Plastic Coated Aggregate

Yogita Bhiva Alave
Civil Engineering Department
Vidyavardhini's college of Engineering and Technology
Vasai(W), Maharashtra, India

Sanika Shekhar Mahimkar
Civil Engineering Department
Vidyavardhini's college of Engineering and Technology
Vasai(W), Maharashtra, India

Ketki Sanjay Patil
Civil Engineering Department
Vidyavardhini's college of Engineering and Technology
Vasai(W), Maharashtra, India

Jayprakash Jiyalal Gupta
Civil Engineering Department
Vidyavardhini's college of Engineering and Technology
Vasai(W), Maharashtra, India

Arbaz Kazi
Civil Engineering Department
Vidyavardhini's college of Engineering and Technology
Vasai(W), Maharashtra, India

***Abstract*—The increasing traffic load requires the pavements to be more efficient with longer life spans. To improve the present situation of the road networks, proper maintenance and use for modern construction technologies is important. Plastic waste poses a major problem for their disposal and thus have a great impact on the environment. Researches have showed that plastic can be used for the construction of bituminous roads as well, in fact plastic imparts more strength to the aggregates in comparison to the natural aggregates. In this project, we have carried out certain tests like crushing test, impact test, abrasion test, stripping value test and test for specific gravity on conventional as well as plastic coated aggregates and the results are compared. The tests were performed on 0%, 5%, 5.5%, 6% and 8% of plastic, coated on the aggregates. The Marshall method of mix design is used for the determination of optimum bitumen content which is further used for the design of flexible bituminous pavement using VG-30 grade of bitumen. Certain tests performed on the bitumen are ductility test, penetration test, softening point test and viscosity test. Through this project we aim to impart strength and increase the life span of the flexible pavements designed using plastic coated aggregates.**

Keywords*—Plastic waste, Bituminous roads, Plastic-coated aggregates, Marshall mix design method, VG-30.

I. INTRODUCTION

A. *Introduction:*

Due to urbanization and the growing population, the day to day requirements are also increasing which has led to the development of various industries which in turn has increased the generation of plastic waste on a large scale. All the sectors of the economy are revolutionized due to the use of plastic. Plastic waste poses a major problem for their disposal and thus have a great impact on the environment.

Various techniques are being researched about for the effective disposal of the plastic waste. Researches have showed that plastic can be used for the construction of bituminous roads as well, in fact plastic imparts more strength to the aggregates in comparison to the natural aggregates. In this project, aggregates will be coated with various proportions of plastic and certain tests will be performed on the plastic-coated aggregates. Finally, the results will be compared and analysed based on the conventional properties of aggregates. The Marshall method of mix design will be used for the determination of optimum bitumen content using VG-30 grade of bitumen which will be further used for the design of flexible bituminous pavement.

The various experiments have been carried out whether the waste plastic can be reused productively. The various literature indicated that the waste plastic when added to hot aggregates will form a fine coat of plastic over the aggregate and such aggregates when mixed with binder is found to have higher strength, higher resistance and better performance over a period of time. Along with bitumen, use waste plastic increases its life and smoothness.[1]

B. *Obective of Work:*

- To evaluate hardness, toughness, crushing and abrasive resistance of plastic coated aggregate.
- To design dense bituminous mix of plastic coated aggregate as per IRC111:2009.
- To evaluate the optimum bitumen content.
- To perform economic analysis for the entire project.

C. *Scope of Work:*

- The plastic to be used for coating should not have high strength melting point
- The study is based on plastic coated with normal aggregate
- The study is only applicable for dense bitumen mix design

II. REVIEW OF LITERATURE

A. *General*

Pavements are the key elements of infrastructure of the country, whose functions are to promote transport activities, economic activities and to improve the standard of living. Flexible pavements are those, which on the whole have low or negligible flexural strength and are rather flexible in their structural action under the loads. The layers of flexible pavement reflect the deformation of the lower layers onto the surface of the layer. The flexible pavement layers transmit the

vertical or compressive stress to the lower layer by grain to grain transfers through the point of contact into each granular structure. A well compacted granular structure consisting of strong graded aggregate can transfer the compressive stress through a wider area and thus forms a good flexible pavement layer. Due to unexpected economic developments in the given region, the traffic loads on the arterial roads may increase at a rapid rate; the pavements also undergo higher distress due to the increased wheel loads and load repetitions. Under such circumstances no amount of routine and periodic maintenance can prevent rapid structural deterioration. Therefore, the existing pavement is to be strengthened by providing additional pavement layer or overlaying one or more layers above the existing flexible pavement. The maintenance engineering should therefore carry out structural evaluation studies periodically and take the decision in time to provide the required overlay before structural damages take place.[2] The Use of plastic waste in flexible pavements would open up a solution for the disposal issues regarding plastic wastes. Many research works have been done in the area of use of plastic waste in bituminous road construction.[3]

B. Overview of Literature:

S. Rajasekaran and all studied the Waste plastics both by domestic and industrial sectors can be used in the production of asphalt mix. Waste plastics, mainly used for packing are made up of Polyethylene Polypropylene polystyrene. Their softening varies between 110ºC – 140ºC and they do not produce any toxic gases during heating but the softened plastics have tendency to form a film like structure over the aggregate, when it is sprayed over the hot aggregate at 160ºC. The Plastics Coated Aggregates (PCA) is a better raw material for the construction of flexible pavement. PCA was then mixed with hot bitumen of different types and the mixes were used for road construction. PCA - Bitumen mix showed improved binding property and less wetting property. The sample showed higher Marshall Stability value in the range of 18-20KN and the load bearing capacity of the road is increased by 100%. The roads laid since 2002 using PCA-Bitumen mixes are performing well. A detailed study on the performances of these roads shows that the constructed with PCA –Bitumen mix are performing well. This process is eco-friendly and economical too (S. Rajasekaran, 2013)[4]

Apurva J Chavan had found that Plastic coating on aggregates is used for the better performance of roads. This helps to have a better binding of bitumen with plastic wasted coated aggregate due to increased bonding and increased area of contact between polymers and bitumen. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reducing rutting, ravelling and there is no pothole formation. The roads can withstand heavy traffic and show better durability (Chavan, APRIL 2013)[5]

Pratiksha Singh Rajput and all developed that The Marshall specimen were prepared without adding plastic waste and adding plastic waste 6%to 14% by weight of bitumen in the mix. The Marshall parameters obtained summarized the variation of stability, flow value, bulk density, air voids and voids fill bitumen (VFB%). (Pratiksha Singh Rajput, April 2016)[3]

S. Elango, 2018 investigated that using 10% of plastic coated aggregate and bitumen with addition of eggshell up to 15% is more favourable for the flexible pavement construction. And thereby use of plastic and eggshell proved effective for construction for flexible pavement and acts as a boon to the society. (S. Elango, 2018) [6]

Imran Ali, Rupesh Kumar, et al, (2018) investigated by adding plastic waste to road construction. It increases the marshal stability test value. It normally saves the 10% bitumen in comparison to the ordinary road. (Imran Ali, 2018)[7]

Prince Ghalayan and Er. Sumit Rana (2017) shows that with increase of waste plastic in bitumen increases the properties of aggregate and bitumen. The optimum use of plastic can be 12 % of bitumen based on Marshal Stability test. The modified bitumen shows good result when compared to standard results. For all modified binders prepared, the penetration values decrease as waste plastic ratio increases whilst, softening point values increase as waste plastic ratio increases. The coating of aggregates with waste plastic reduces the absorption of moisture. By using waste commodity plastics in binder modification carries the advantage of a cheap, technologically effective means of enhancing conventional binder performance and offers an alternative way to manage plastic waste. This has added more value in minimizing the disposal of plastic waste is the eco-friendly technique. (Prince Ghalayan, 2017)[8]

K. L. A.V. Harnadh et.al. (2015) by using the waste plastic as a coated material to the aggregates, properties of aggregates were improved with different Waste plastics. It is showed better values than conventional aggregates. By this the poor quality of aggregates will be improved by using plastic as a modifier and can be used in construction. The water absorption property has decreased and by this there will be less porosity and provide better resistance to water and water stagnation. Plastic coated aggregate exhibit good nature in abrasive charge and in impact tests. The use of the innovative technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source of income. (K. L. A.V. Harnadh, May-2015)[9]

Mr.K. Selvakumar,et.al. (2018) Study was conducted to improve the Stability of Flexible Pavement Construction. Thus waste Plastic is coated on Aggregate and addition of Stone dust waste on Bitumen had been done for the better Performance of said pavements. From the experimental analysis, one can understand that both Plastic Coated Aggregate and Stone dust waste were acted as have a better binding with Bitumen. More importantly Plastic Coated Aggregate can reduce the Voids. Hence the roads can withstand heavy traffic and shows better durability. The obtained test results show that, that the addition of plastic waste like Low density polyethylene, Polypropylene, Polyethylene Terephthalate and filler material like stone dust improves the stability value of the bituminous mixes. It shows the good resistances to properties of the aggregates like specific gravity, Crushing, Impact and Water Absorption. It improves the overall performance of the mix (Mr.K. Selvakumar, 2018)[10]

Amit Kumar Sahu, (2016) studies on the performance of plastic tar road conclusively proves that it is good for heavy traffic due to better binding, increased strength and better surface condition for a prolonged period of exposure to variation in climatic changes Above all, the process helps to dispose waste plastics usefully and easily. Develop a technology, which is eco-friendly. Generate jobs for rag pickers. Avoid disposal of plastics waste by incineration and land filling. Use higher percentage of plastics waste. Reduce the need of bitumen by around 10%. The problems like bleeding are reduce in hot temperature region. Avoid the use of anti-stripping agents. It shows that with the increase of waste plastic in bitumen increases the properties of aggregate and bitumen. (Amit Kumar Sahu, 17th & 18th March 2016)[11]

Based on the study and experimental data Brajesh Mishra, (2018) for waste plastic modified bituminous concrete mix compared with conventional bituminous concrete mix. The results showed that waste plastic can be conveniently used as a modifier for bituminous concrete mix as it gets coated over the aggregates of the mixture and reduces porosity, absorption of moisture and improves binding property of the mix. The Optimum Bitumen Content (OBC) was found to be 5.17% by weight of aggregates and the Optimum Plastic Content (OPC) to be added as a modifier of bituminous concrete mix was found to be 9 % weight of Optimum Bitumen Content (OBC) of bituminous concrete mix. Bituminous concrete mix modified with waste plastic coated aggregates showed higher (approximately 31%) Marshall Stability and higher flow value as compared to conventional bituminous concrete mix. Marshall Stability value increases with plastic content up to 11% and thereafter decreases. Thus the use of higher percentage of waste plastic/ polythene is not preferable. (Brajesh Mishra, 2018)[12]

Gandhiraj.J, (2018) investigated the use of waste plastic in construction of roads brings out a better performance. Since there is better binding of bitumen with plastic.so that the frequency of voids is also reduced due to increased bonding and area of contact between polymers and bitumen. The roads can withstand heavy traffic, thereby making them more durable. The use of the innovative technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment. Using of waste plastic in flexible pavements shows good result when compared with conventional flexible pavements. In this project the partial replacement of plastic waste in bitumen such as 1%, 2% and 2.75% by the weight of metals. Based on Marshall stability and flow test, the stability can be increased than the conventional mix in the replacement of 1% of PET wastes and then the flow value remains same for conventional and partial mix. Increasing the percentage of replacement of PET waste of 2% the stability and flow can be decreased. (Gandhiraj.J, April 2018)[13]

By using plastic as a coating over aggregates, M. Chandu, (2016) investigated that the properties of aggregates are improved. This shows that weak aggregates can be used in construction by using plastic as a binder material. By adding plastic coat to the weak aggregates, the rheological properties have been improved. The bandings between the aggregates are reducing the road failure i.e. pot holes. The percentage of plastic 2.5%, 5%, 7.5% is added to aggregate samples respectively PP type of plastic, for LDPE type of plastic for both, plastic coated aggregates are increased the binding properties. Based on engineering properties the plastic coated aggregate samples are more stable, strengthen than normal aggregates and can be used in plastic roads. The low density polythene type of plastic shows better performance values than polypropylene. The weak aggregates with plastic coated are used in base and base of the pavement layers. The engineering properties are increased to plastic coated aggregates while comparing with normal aggregates. (M. Chandu, December 2016)[14]

R. Manju, et.al. (2017) investigated that the plastic mixed with bitumen and aggregates is used for the better performance of the roads. The polymer coated on aggregates reduces the voids and moisture absorption. This results in the reduction of ruts and there is no pothole formation. The plastic pavement can withstand heavy traffic and are durable than flexible pavement. The use of plastic mix will reduce the bitumen content by 10% and increases the strength and performance of the road. This new technology is eco-friendly. (R. Manju, 2017)[1]

C. Conclusion from Literature:

After reading and understanding the mentioned research papers, it can be concluded that the effective reduction of plastic waste is possible by coating the aggregates with different plastic and incorporating it with bitumen proportions which can be used in flexible pavement without compromising strength and life of pavement. There is need of recycling plastic waste to the fullest for protecting the environment and using it for pavement construction have been proven successful by many of researchers.

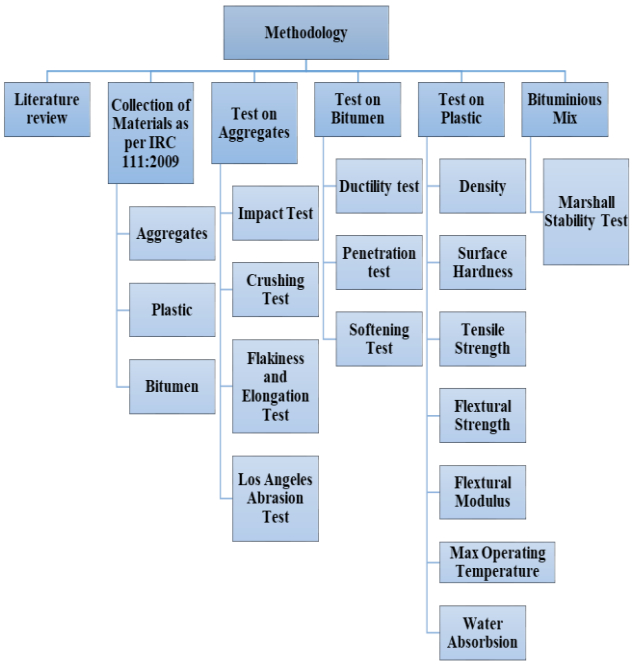
III. MATERIALS AND METHODOLOGY

A. Materials Used:

1. Aggregate of size 10mm and 20mm
2. Bitumen of VG30 category
3. Plastic Clinkers
4. Fillers

B. Methodology:

The methodology is the general research strategy that outlines the way in which research is to be undertaken and, among other things, identifies the methods to be used in it. Methodology does not define specific methods, even though much attention is given to the nature and kinds of processes to be followed in a procedure or to attain an objective. Without a proper well- organized research plan, it is impossible to complete the project with the deadlines and to reach to a conclusion. Experimental investigation of aggregate includes various types of testing like compaction, impact, etc. also it includes a comparison of aggregate for different sources, finding out the result, analyzing the data, etc. Experimental investigation of aggregate and coating partially it with polypropylene waste plastic and then using it for dense bituminous paved road is the process involved in our methodology. The proposed methodology chart of the project is shown below:



C. Tests on Aggregate:

1. **Impact test:** The impact test on the normal aggregate and the plastic coated aggregate will be carried out the basis of procedure mentioned in IS:2386, part IV- 1963., the detail procedure of which is attached in the appendix. The details of observation obtained in impact test for both normal and coated aggregates are given below:

Flakiness Index			Elongation Index	
Sr.No	**Observation**	**0%**	**Observation**	**0%**
1	Initial weight of aggregates (W_1) in gm	680	Initial weight of aggregates (W_1) in gm	610
2	Weight of aggregates passing (W_2) in gm	47	Weight of aggregates retained (W_2) in gm	100
3	Flakiness Index = (W_2/W_1)*100	6.90 %	Elongation Index = (W_2/W_1)*100	16.39 %

Table No.: 1 Summary of Impact Test on Aggregate

2. **Crushing Test:** The crushing test on the normal aggregate and the plastic coated aggregate will be carried out the basis of procedure mentioned in IS:2386, part IV- 1963., the detail procedure of which is attached in the appendix. The details of observation obtained in crushing test for both normal and coated aggregates are given below:

Table No.: 2 Summary of Crushing Test on Aggregate

Sr. No.	Observation	0%	5%	5.50%	6%	8%
1	Total weight of dry sample (W_1) in gm	2700	2700	2660	2540	2400
2	Weight of fines passing 2.36mm sieve (W_2) in gm	520	168.18	320	360	220
3	Aggregate crushing value = (W_2/W_1)*100	19.26%	6.20%	12.03%	14.17%	9.16%

3. **Flakiness and Elongation Test:** The crushing test on the normal aggregate and the plastic coated aggregate will be carried out the basis of procedure mentioned in IS:2386, part I- 1963., the detail procedure of which is attached in the appendix. The details of observation obtained in crushing test for both normal and coated aggregates are given below:

Sr.No	Observation	0%	5%	5.50 %	6%	8%
1	Total weight of aggregate sample filling the cylindrical measure (W_1) in gm	340	290	340	300	160
2	Weight of aggregate passing through 1.4mm IS sieve (W_2) in gm	51	21.34	35	40	14
3	Aggregate impact value = (W_2/W_1)*100	15%	7.35 %	10.29 %	13.33 %	8.75 %

Table No.: 3 Summary of Shape Test Conducted on Aggregate

4. **Los Angeles Abrasion Test:** The crushing test on the normal aggregate and the plastic coated aggregate will be carried out the basis of procedure mentioned in IS:2386, part IV- 1963., the detail procedure of which is attached in the appendix. The details of observation obtained in crushing test for both normal and coated aggregates are given below:

Table No.: 4 Summary of Abrasions Test Conducted on Aggregate

Sr. No.	Observation	0%	5%	5.50%	6%	8%
1	Original weight of aggregate (W_1) in gm	5000	5000	5000	5000	5000
2	Weight of aggregate retained on 1.70mm IS sieve (W_2) in gm	4060	4560	4540	4470	4620
3	Loss in weight	940	440	460	530	380

	due to wear (W_1-W_2) in gm					
4	Loss Angeles Abrasion value = (W_2-W_1)/W_1*100	18.80 %	8.80%	9.20%	10.60 %	7.60 %

The figure below shows the shows the summary of value obtained from various tests performed on aggregates:

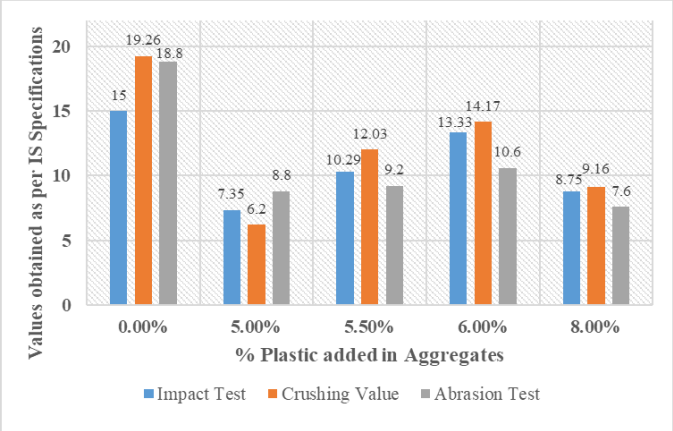


Fig. No.: 1 Aggregate Result Summary

D. Tests on Bitumen:

1. **Ductility Test:** The ductility test on the bitumen sample was carried out in accordance with IS 208-1978, the procedure of which is attached in the appendix.
2. **Softening Test:** The softening test on the bitumen sample was carried out in accordance with IS 1205 -1978, the procedure of which is attached in the appendix.
3. **Penetration Test:** The penetration test on the bitumen sample was carried out in accordance with IS 1203 - 1978, the procedure of which is attached in the appendix

The summary of results obtained of the various test mentioned above is shown in the table below:

Table No.: 5 Summary of Test Results Conducted on Bitumen

Test on VG30 Bitumen	Test Results on VG30 Bitumen	VG30 Standard Results
Penetration at 25°C	50-70	60
Softening point °C, min	47	56
Ductility at 25°C, cm, min	40	68

E. Tests on Plastic Clinkers:

Plastic used in the project was in the form of clinkers having diameter less than 5 mm. The test conducted at the source and properties noted are presented in table below:

Table No.: 6 Properties of Waste Plastic Clinkers

Sr. No.	Property	Value
1	Density	0.92 gm/cc
2	Surface Hardness	SD48
3	Tensile Strength	10 MPa
4	Flexural Modulus	0.25 GPa
5	Max. Operating Temperature	50º
6	Water Absorption	0.01%
7	Melting Temperature	220ºC - 260ºC

F. Marshall Stability Test:

As per IRC 111: 2009, the detailed procedure of finding Stability and Flow of the bitumen using marshal stability test is presented below:

Requirements:

- Cylinder: Dia. =101.6mm, Height = 63.5mm
- Hammer
- MST load application machine
- Weighing machine
- Specimen Extractor

Preparation:

1. Specimen preparation:

Approximately 1200gm of aggregates and filler are heated to a temperature of 175-190°C. Bitumen is heated to a temperature of 121-125°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 154-160°C. The mix is placed in a preheated mould and compacted by a rammer with 75 blows on either side at 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.

2. Mould preparation:

Oil is applied to inner part of the mould and a filter paper is placed at the bottom.

Procedure:

1. Mix prepared in above steps is filled in the mould with a collar extension and then filter paper is placed on the top. Mix is then compacted at a compacting temperature of 149°C which is used for VG30 grade.
2. Compaction is done by a hammer and 75 blows are given on the either top side of the mould. Specimen is then allowed to cool at a room temperature for 24 hours. Specimen is then removed using specimen extractor.
3. Sample is then placed in water birth at temperature of 60 °C for 30 to 40 minutes. Specimen is then removed from water bath and placed on the lower plate of Marshall stability test apparatus and then it is claimed by upper plate. This is the Assembly of Marshall stability test.
4. Place this assembly on Marshall stability test apparatus and plays ball over it and then proving ring gauge is attached along with strain dial gauge.
5. Load is then applied at the rate of 50.8 mm per minute until failure. Failure is indicated by movement of proving ring in opposite direction. At this instant, proving ring

division is noted down. This gives us stability value which is expressed in kg.
6. Reading of strain dial gauge is also noted down which gives us flow value which is expressed in unit of deformation.
7. 0.25mm = 1unit
8. Correction is applied for height of specimen greater than or less than 63.5 mm after compaction before putting it in Marshall stability head. Then,
9. Marshall stability value = Initial Marshall stability value * correction factor

Table for correction factor is given below:

Table No.: 7 Correction Factor for Marshall Stability Test

Average Thickness of Specimen, mm	Correction Factor
57.2	1.19
58.7	1.14
60.3	1.09
61.9	1.04
63.5	1.00
65.1	0.96
66.7	0.93
68.3	0.89
69.8	0.86

G. Conclusion for Aggregate Tests:

The various test on the aggregates show that, 6% plastic waste when coated with aggregates shows favourable results. Apart the bitumen obtained from the source is VG30 which is being confirmed by comparing results with IS standards. The plastic that is to be used for aggregate coating is Low Density Polyethylene which can be interpreted from the results.

IV. RESULTS AND DISCUSSION

A. General:

Tests are performed on normal aggregates as well as on plastic coated aggregates (PCA) and results were compared with IRC/MORTH specifications as given below. As we can see from the table that aggregates were good to be used for pavement construction but other aggregates of poor quality can also be used and by coating it with optimal plastic content 6%, its strength can be increased as given in table below. This aggregates are to be used for surface courses hence aggregates are compared with the specifications for surface courses.

Sr. No.	Name of Test	Results obtained		IRC/MORTH Specifications for surface course (max %)
		Normal aggregate	Plastic coated aggregates	
1.	Crushing test	19.26%	14.17%	30%
2.	Impact test	15.00%	13.33%	30%
3.	Abrasion test	18.80%	10.60%	30%

Table No.: 8 Comparison Between Results Obtained and Standard Specification as per IRC/MORTH

From the above table it can be concluded that the plastic coated aggregate with selected optimal percentage is 5.09% less effective in terms of crushing strength, 1.67% less effective in terms of impact strength, and 8.27% less effective in terms of abrasion value when compared with normal aggregates.

B. Results of Optimum Bitumen Content

After evaluating results of plastic coated aggregates, the next step was to find optimal bitumen content which will be required for making dense bituminous mix. Marshall Stability test results were used for the same. Three bitumen contents were used starting from 8.00%, then 8.50% and last 9.00% for finding the optimum bitumen content (OBC). The parameters obtained for 8% bituminous mix are shown below, similar steps were done finding parameters of other said contents.

Weight of sample in air (W_a) = 1066gm
Weight of sample in water (W_w) = 556gm
Weight of coarse aggregate (W_1) = 356gm
Weight of fine aggregate (W_2) = 478gm
Weight of filler (W_3) = 480gm
Weight of bitumen (W_b) = 96gm
Specific gravity of coarse aggregate (G_1) = 2.6
Specific gravity of fine aggregate (G_2) = 2.0
Specific gravity of filler (G_3) = 1.8
Specific gravity of bitumen (G_B) = 1.1
Specific gravity of plastic = 0.96

1. Bulk Specific Gravity of the mix (G_{mb}) is defined as

$$G_{mb} = \frac{\text{Weight of mix}}{(\text{Vol. of mix})}$$

$$G_{mb} = \frac{1066}{524} = 2.034$$

2. Theoretical specific gravity of air voids (G_t):

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{(\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b})}$$

$$G_t = \frac{356 + 478 + 480 + 96}{(\frac{356}{2.6} + \frac{478}{2.0} + \frac{480}{1.8} + \frac{96}{1.1})} = 2.652$$

3. % Air Voids (V_v) :

$$V_v = \frac{(G_t - G_{mb})}{G_t} * 100$$

$$V_v = \frac{(2.652 - 2.034)}{2.652} * 100 = 23.30\%$$

4. % Vol. of Bitumen (V_b):

$$V_b = \frac{W_b * G_{mb}}{W_a * G_b} * 100$$

$$V_b = \frac{96 * 2.034}{1066 * 1.1} * 100 = 16.65\%$$

5. Voids in Mineral Aggregate (VMA):

$$VMA = V_v + V_b$$

$$VMA = 23.30 + 16.65 = 39.95\%$$

6. Voids filled with bitumen (VFB):

$$VFB = \frac{V_b * 100}{VMA} = \frac{16.65 * 100}{39.95} = 41.68\%$$

The detailed summary of results of all trials are presented below in the table

Table No.: 9 Results of Marshall Stability Test

Bitumen content	Height of specimen (mm)	Weight of Specimen in (gm)			Bulk volume in cc	Bulk sp.gr. of mix (Gmb)	Max specific gravity (Gmm)	Marshall stability in kg
		Air	Water	SSD				
8.00%	59	1066	556	1080	524	2.034	2.652	768*3.36= 2580
8.50%	65	1286	673	1200	526	2.445		782*3.36= 2627
9.00%	67	1340	774	1300	529	2.533		717*3.36= 2410

Following table shows the parameters for obtaining the optimum bitumen content

Table No.: 10 Parameters for Obtaining Optimum Bitumen Content

Bitumen content	Air void (Vv) %	Stability value in Kg	Density in g/cc	Flow value in mm	VMA %	VFB %
8.00%	23.30	2580	2.034	1.83	39.95	41.68
8.50%	6.86	2627	2.445	3.73	23.46	72.25
9.00%	3.505	2410	2.435	4.87	20.00	76.35

C. Results on Marshall Stability Test:

Following graphs shows the variation in test with the variation in bitumen content.

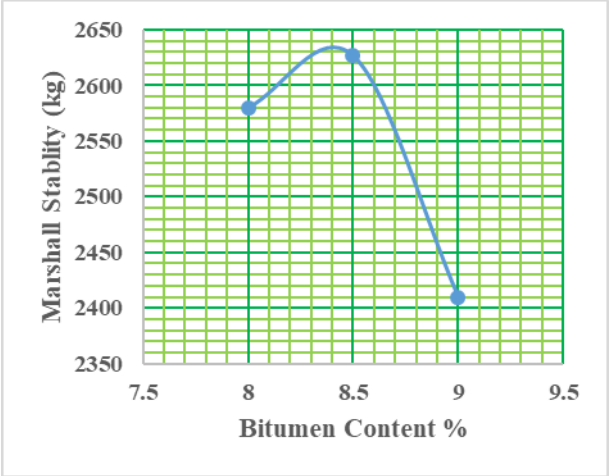


Fig. No.: 2 Bitumen content vs Marshall Stability

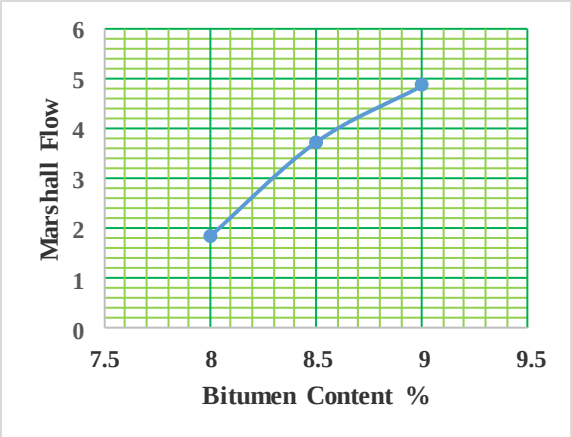


Fig. No.: 3 Bitumen content vs Marshall Flow

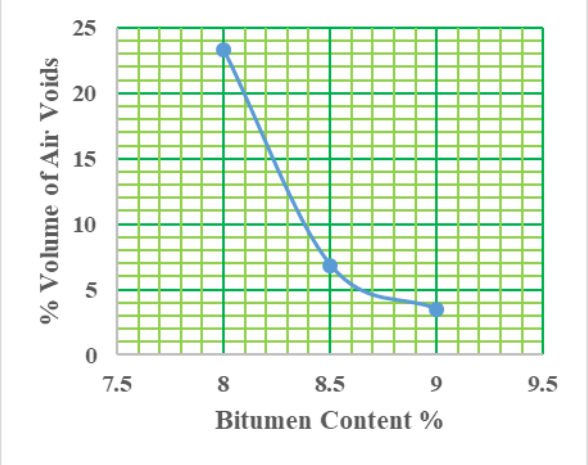


Fig No.: 4 Bitumen content vs % Volume of Air Voids

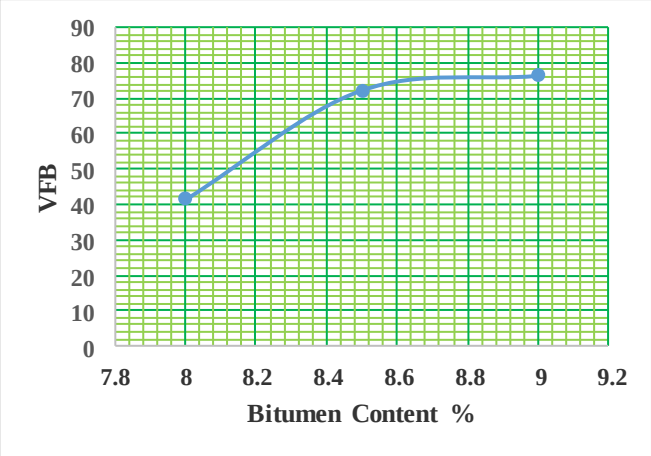


Fig. No.: 5 Bitumen content vs VFB

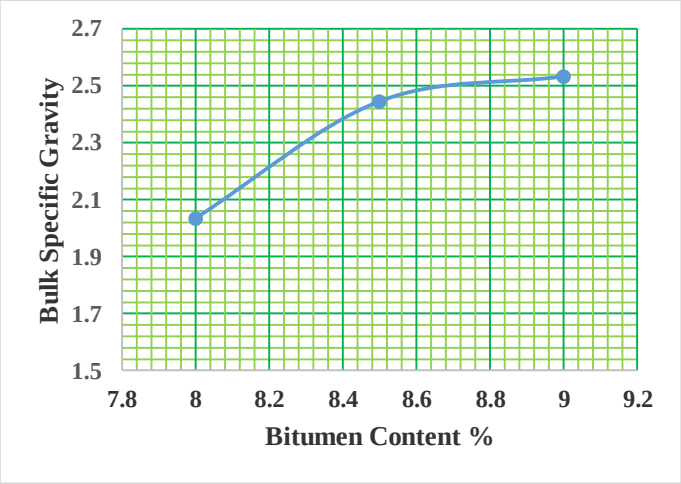


Fig. No.: 6 Bitumen content vs Bulk Specific Gravity

Determination of Optimum Bitumen Content:

To determine the optimum binder content for the mix design one must take average value of the following three bitumen contents found form the graphs obtained in the previous step.

- Binder content corresponding to maximum stability
- Binder content corresponding to maximum bulk specific gravity (G_{mb})
- Binder content corresponding to the median of designed limits of percent air voids (V_v) in the total mix (i.e. 4%)

Optimum Bitumen Content =

$$(8.5 + 8.5 + 8.8)/3 = 8.6\%$$

After finding optimum binder content, the next step is to check Marshall test results as per specifications mentioned in IRC 94-1966, which is presented in the table below:

Table No.: 11 IRC 94-1966 Specifications

Test Property	Specified Value	Obtained Value
Marshall Stability (kg) - minimum	340	2410
Flow Value	8-17	1.83-4.87
% Air voids in the mix	3-5	3.5-23.30
% Voids filled in bitumen (VFB)	75-85	41.68-73.65

D. Econamic Analysis:

Economic Analysis was done with a view of constructing new road (i.e. flexible pavement) considering same specification i.e. 6% plastic coated aggregates and 8.6% bitumen content for the mix. The detail analysis is presented below:

- Cost of waste plastics: ₹8/- per Kg.
- Cost of processing: ₹6/- per Kg.
- Total cost of waste plastics: ₹14/- per Kg.
- Optimum percentage of plastic in the blend as per the test results is around 6% (% wt. of aggregate)
- Generally, roads in India are constructed in basic width of 3.0 m, 3.75 m and 4.0 m.
- Consider 1 Km length road of width 3.75 m. it uses bitumen approx. 21300 Kg. (For new work) and 11925 Kg. (For Up gradation).
- For 3.75m width and 1km length road, amount of aggregates used in road construction (1 Km length x 3.75 m width): 3750 sq.m. x 12.5 Kg per sq.m. (avg.) = 46875 Kg.
- Amount of waste plastic used in road (6% by wt.): 2812.5 Kg.
- Total cost of waste plastic used in road using dry process: ₹40,000/-
- Cost of Bitumen(VG30) per drum (200 Kg): - 6800/-
- Cost of Bitumen Per Kg.: - ₹34/-
- Cost of Road (New)/Km including BBM, Carpet and Seal Coat: ₹18,95,000/-.
- Bitumen required for work (approx.): 21,300 Kg. per Km
- Cost of bitumen in new work per Km.: ₹7,25,000/- -
- Cost of Bitumen saved (2812.5Kg. equivalent to plastic used): ₹95625/-

Total savings per Km.: 95625 - 14*2812.5 = ₹56,250/-

E. Conclusion Based on Resuls and Disscussion:

The aggregates coated with optimum plastic content 6% which was then used for preparation of dense bituminous macadam mix, the results so obtained didn't satisfy the conditions laid down by the IRC. Economic point of view it is seen incorporating plastic can reduce the cost of new pavement.

V. CONCLUSION AND FUTURE SCOPE

A. Conclusion:

1. The experimental process of coating of plastic with aggregate was successfully carried out.
2. The coating of aggregate with plastic initially showed feasible results with increase in physical property of aggregate but after a point reduction was observed
3. Due to the plastic coating on the surface of the aggregates the permeability is reduced which means that the mixture becomes more intact thus providing a solution up to some extent for stagnant water on the roads.

4. The coated aggregate was used for preparation of dense bituminous macadam mix.
5. The aggregates coated with optimum plastic content which was then used for preparation of dense bituminous macadam mix, didn't satisfy the conditions laid down by the IRC
6. The increasing plastic waste can be reduced efficiently by using it in the construction of flexible bituminous pavements, but experimental study should be properly carried out before coming to a concrete conclusion.

B. Future Scope:

1. In this project, VG30 grade of bitumen was used. Therefore, other grades of bitumen can also be used for the same bitumen mix design to obtain better results than VG30 grade of Bitumen.
2. Above analysis are based on the dense bituminous macadam (DBM), hence one can change the pavement type and can see what maybe the results.
3. Number of test that have been used to prove the suitability of PCA can be increased and additional test like water absorption, stripping value, etc. can also be used to obtain better results and reliability.
4. As in this project, 6% plastic coating was proven to be optimum but percentage near to 6% can also be tested to get more accuracy and same goes with determination of optimum bitumen content.
5. During coating of aggregates with plastic, eggshell powder can also be mixed to impart certain drainage and other properties to the aggregates which will be helpful for road maintenance.
6. Various software can also be used for determining the deflection characteristics of road pavement made with plastic coated aggregates.

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