



Use of electronic waste plastic in asphalt mix with marble dust as filler

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E-waste is becoming burgeoning global issue, which showcases the impacts of the same on environment and on humans. Marble cutting industries is another industry producing huge amount of marble dust as a waste which is degrading the environment. E-waste and waste marble dust can be utilized in construction industry in different forms thus helps in reducing its impact on environment. In this analysis, electronic waste plastic materials including recycled PCB's and other PVC components of e-waste has been used as a partial replacement for coarse aggregates and marble dust is used as complete replacement for filler in asphalt mix for pavement. A significant increase of Marshall Stability and Flow Value has been observed as percentage of e-waste plastic increases. The plastic content of mix varies 0 %, 4 %, 8 % and 12 % by weight of aggregate. Plots of various Marshall Parameters such as Marshall Stability, Flow value, voids filled with bitumen, voids in mineral aggregates and unit weight against the bitumen content shows an improving trend of parameters with increasing the plastic replacement. Comparison with earlier published result shows that increasing the plastic replacement beyond 12% will have a negative influence on stability value. The recycling of e-waste plastic and marble dust in asphalt mix design for pavements provide us a better way of resource utilization in a cost-effective manner.

Keywords: Asphalt mix, Bitumen, E-waste, Flow values, Marble dust, Marshall properties, Stability value

1 Introduction

Electronic waste is one of the fastest growing wastes in today's world. Discarded electrical or electronic equipment leads to generation of E-waste. Technology obsolescence is one of the major factors that contribute to E-waste in developing countries. It is generated by all sectors whether it's small or big. India being a developing nation must be aware of modern waste growth and should take initiatives for proper disposal with increased rate of reuse and recycle¹. As per the joint reports by ASSOCHAM² and KPMG, India is the fifth largest generator of e-waste in the world where roughly 18.5 lakh metric tonnes of E-waste are discarded each year. Telecom sector is a major source of this waste. ASSOCHAM² report shows most Indians prefer switching to a new handset every two years, thereby validating the above-stated contribution by the telecom sector².

Electronic waste can be utilized in construction industry as stated by Patel *et al.*³ His study pointed out that the waste collected in a city should be sorted, segregated and electronic waste should be crushed and use for plinth filling purpose. He concluded that 1 Kg of bitumen with 10 % of electronic fibre saved 100g of bitumen. Bitumen of 80/100 penetration

grade was used as binder in the study. Tests were conducted on 5%, 10% and 15% replacements of bitumen and the results were compared with the standard results obtained using plain bitumen. Electronic waste was added to bituminous pavement which showed a considerable cost reduction of Rs. 2.254 /kg and Rs. 2254 /MT.

Composition of E-waste is influenced by various factors such as economic conditions, waste segregation programs, recycling industry methodology and regulation enforcement. On gondo FO *et al.*⁴ found that in general E-Waste is composed of 60% metals, 2% printed circuit boards (PCB), 15% plastics, 5% metal-plastic mixture, 12% CRT & LCD monitors and other minor components.

Raja shree T *et al.*⁵ made an attempt to study the use of electronic waste Printed circuit board (PCB) as an alternative to conventional material like aggregate in a DBM layer of flexible pavement. They carried out a Number of laboratory tests replacing aggregates partially by shredded E- waste. A number of specimens were prepared as per standard Marshall Stability Test for different percent of bitumen content. It was 4.5%, 5%, 5.5% and 6% by weight of the aggregates and aggregates were partially replaced by E-waste in shredded form with 7.5%, 10%, 12.5% and 15% by volume of mould. It was observed that partial

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replacement of e-waste is technically feasible and at 5.5 % bitumen content with a 7.5 % aggregate replaced by e-waste showed increased stability keeping all the other parameters within limits. But as the e-waste percentage was increased beyond 7.5%, decrease in stability was observed.

Another industry causing a great environmental degradation is Marble-processing industry. This industry produces a huge amount of Marble dust as a waste during Marble cutting operations. This waste is not degradable and causes various impacts to environment. 70% of them are wasted in the industry and only 30% is treated as a sale-able product. This 30% recovery causes 70% of burden on our environment. Marble industries usually dispose their waste in open fields or pits which results in water logging problems, porosity reduction of soils etc. Marble waste increases the alkalinity of soil and results in soil fertility problems. These industries aim to get large slabs of marble for selling purpose but larger sizes cause more wastage of marble. Ullah *S et al.*⁶ studied the possible solution to deal with problem of marble waste with its re-use in civil works especially roads because other works do not use such huge amount of waste.

The aim of this study is to re-use marble waste as filler material in wearing course along with partial replacement of recycled electronic waste plastic to get economical asphalt mix and analyze its effects on the Marshall properties of asphalt mix. Prof. Lakshmi Murugan⁷ in her study used plastic from Printed Circuit Board (PCB) as partial replacement for aggregates and stone dust as filler. In current study we utilize electronic waste plastic including PCB and other plastic and PVC components obtained from E-waste as partial replacement of aggregates and used marble dust as filler.

2 Material used

VG 30 grade bitumen is obtained from civil construction wing All India Radio Delhi Fig. 1(a), Recycled E waste plastic was acquired from E- waste Recycle Hub, Delhi, (this plastic was shredded) and marble dust was brought from Jaharvir Polymers Pvt. Ltd. , New Delhi. Coarse aggregates Fig. 1(b) and Fine aggregates was provided by Enkay Test House, Delhi (ISO 9001, ISO 14000, SA 8000 certified laboratory).

3 Methodology

3.1 Tests Performed on Plain Bitumen

Tests were conducted on plain bitumen like ductility test, Penetration test to measure the hardness



Fig. 1 — Raw materials for tests (a) VG 30 grade bitumen and (b) Marble dust.

or softness of bitumen, specific gravity, softening point test etc. at Delhi Technological University laboratory and at Enkay Test house, Delhi. Results obtained is provided in Table 1.

Tests were performed according to the specifications provided in respective Indian Standard code⁸ and the results obtained were compared with specifications provided in Indian Road Congress (IRC-73, 2013)⁹.

3.2 Tests performed on aggregate

3.2.1 Tests on mineral aggregate

Coarse aggregates consisted of angular stone chips divided into 2 categories of 10mm and 6mm size. Tests for strength, specific gravity, water absorption test and particle shape test was conducted on aggregates. Filler consisting of marble dust with fractions passing 4.75mm sieve and retained on 75 micron IS sieve was tested for above parameters. Its specific gravity was calculated as 3.06. Tests were conducted as per standards given in IS:2386 (PART IV)¹⁰ to determine their physical properties as summarized in Table 2.

Table 1 — Physical properties of bitumen.

Test Parameters	Units of Measurements	Results Obtained	Minimum Requirements as per IS: 73-2013 [13]	Method Reference
Absolute Viscosity at 60°C	Poise	2460	2400	IS:1206(P-2)-1978
Kinematic viscosity at 135°C	cst	378	350	IS:1206(P-3)-1978
Flash Point, COC	°C	302	220 .	IS:1209-1978
Penetration at 25°C 100g 5Sec.	0.1mm	66	50-70	IS:1203-1978
Softening Point, (R&B)	°C	54	47	IS:1205-1978
Ductility at 25°C on residue	cm	58	40	IS: 1208-1978
Specific Gravity at 27°C	No unit	1.01	0.97-1.02	IS 1202-1978

Table 2 — Physical properties of aggregates.

Property	Name of the test	Actual value	Permissible value as per MORT&H ¹⁴
For strength	Crushing strength	18.8%	30 % Maximum
	Los Angeles abrasion value	16.9%	30 % Maximum
	Impact value	16.25%	24 % Maximum
Average specific gravity	Coarse aggregate 10mm	2.762	2-3
	Coarse aggregate 6mm	2.677	
	Marble Dust	3.06	-
Water absorption	Water absorption	1.33%	2 % Maximum
Particle shape	Flakiness	17 %	30 % Maximum
	Elongation	15 %	30 % Maximum

Table 3 — Physical properties of E-waste plastic.

Properties	E-waste particle
Specific gravity	1.01
Absorption	< 0.25 %
Colour	white and green
Shape	Angular and smooth
Crushing value	< 2 %
Impact value	< 2 %

3.2.2 Tests on E-waste plastic aggregate

Recycled E-Waste is used in crushed form for partial replacement of coarse aggregate of 6mm size. Specific gravity, water absorption, Shape, Crushing value and Impact value test were conducted on crushed plastic. Results are provided in Table 3.

3.2.3 Gradation of individual aggregates

A sieve analysis, or gradation test determines the distribution of aggregate particles by size within a given sample. This information can then be used to determine compliance with design and production requirements. Data can also be used to better understand the relationship between aggregates or blends and to predict trends during production.

The test is performed according to Indian Standard Method of Test for Aggregates for Concrete (IS : 2386-1963): Part 1 Particle Size and Shape¹⁰.

Result of sieve analysis Fig. 2 is given in Table 4.



Fig. 2 — Sieve analysis being performed on coarse aggregate.

4 Marshall stability and flow test

Marshall method commonly designs bituminous concrete mix. This test is widely used in routine test of pavement construction. The stability of the mix is the maximum load carried by a compacted specimen and the test is carried out at the standard test temperature of 60°C. The flow is measured in units of 0.25 mm during the stability test where deformation is calculated using dial gauge between the no load initial condition and the condition when maximum load is carried by the specimen (the flow value may also be measured by deformation units of 0.1 mm). Aim of

Table 4 — Result of sieve analysis on aggregates, filler and plastic.

Sieve Size, mm	% of Aggregates Passing			
	10mm	6 mm	Plastic Aggregate	Marble Dust
20	84.3	100.0	100.0	100
10	24.5	96.1	100	100
4.75	10.2	14.5	48.2	100
2.36	0.5	0.4	30.9	100
1.18	0.1	0.3	18.9	100
0.6	0.1	0.3	9.7	100
0.3	0.1	0.3	0.1	99
0.15	0.1	0.2	0.1	89
0.075	0.1	0.1	0.1	62

Table 5 — Sample mix specification.

MIX	A:B:C:D
0% Plastic	10:70:0:20
4% Plastic	10:66:4:20
8% Plastic	10:62:8:20
12% Plastic	10:58:12:20

the test is to obtain the optimum bitumen content for the asphalt mix.

The test was conducted at Enkay Test House, Mangolpuri Industrial area, Phase1, New Delhi under the expert supervision. The test was conducted according to the specifications of ASTM D-1559¹¹.

4.1 Sample mix specification

Sample is prepared according to specifications provided by 'Specification for Road and Bridge work MORT&H'¹². Mix is prepared by taking 1200g of raw materials for no plastic sample and 4%, 8% and 12% replacement of coarse aggregate (6mm) by E-Waste plastic. Mix specifications is given in Table 5.

A-10mm coarse aggregate, **B**- 6 mm Coarse aggregate, **C**-Crushed Plastic, **D**- Marble Dust.

4.2 Test procedure

In the process the stability test, the specimens are heated at a temperature of $60 \pm 10^\circ \text{C}$ in an oven for a minimum of 2 hours or a water bath for 30-40 minutes. Specimens are removed from oven and are kept in the lower segment of the breaking head. Then the upper segment of the breaking head was placed on the specimen and the complete assembly was placed in position of the Marshall testing machine. The flow meter (dial gauge) was then positioned over one of the post and the reading adjusted to zero. Application of load is done at a rate of 50 mm per minute until the maximum load reading is obtained. The maximum load was recorded in Newton and at the same time flow was recorded by flow meter in millimeter¹³.

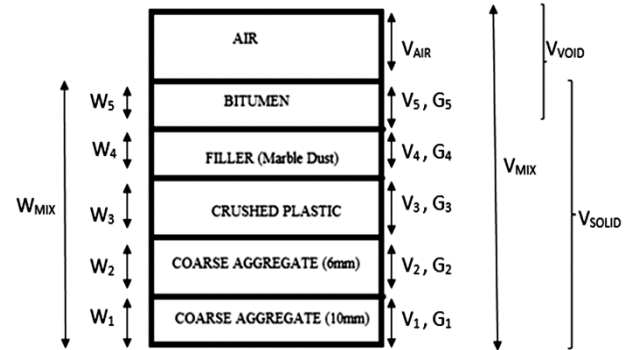


Fig. 3 — Diagrammatic representation of constituents of asphalt mixes.

5 Parameters used

Based on volume considered for different constituents in an asphalt mix as given in Fig. 3, the definitions and other formulae used in calculations hereafter are as follows:

- i. Theoretical Specific Gravity (G_t)

$$G_t = \frac{(W_1 + W_2 + W_3 + W_4 + W_5)}{\left(\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_4}{G_4} + \frac{W_5}{G_5}\right)} \quad \dots(1)$$

Refer Fig. 3 for the meaning of the terms.

- ii. Bulk Specific Gravity (G_m)

$$G_m = \frac{W_{mix}}{V_{mix} \times \gamma_w} \quad \dots(2)$$

- iii. Percentage Air Voids (V_v)

$$V_v = \left(1 - \frac{G_m}{G_t}\right) \times 100 \quad \dots(3)$$

- iv. Percentage Volume of Bitumen (V_B)

$$V_B = \frac{W_4}{W_1 + W_2 + W_3 + W_4 + W_5} \times \frac{G_m}{G_4} \times 100 \quad \dots(4)$$

Refer Fig. 3 for the meaning of the terms.

v. Voids in Mineral Aggregate (V_{MA})

$$V_{MA} = V_V + V_B \quad \dots(5)$$

vi. Voids Fill With Bitumen (V_{FB})

$$V_{FB} = \frac{V_b}{V_{ma}} \times 100 \quad \dots(6)$$

6 Results and Discussion

6.1 Tests on aggregates

Softening point, penetration, viscosity, Ductility and specific gravity tests were conducted for pure bitumen. Table 1 shows the result of the test which are in accordance with the specified limits provided in IRC 73, 2013⁹.

Bitumen penetration grade of 60/70, which is harder than 80/100 and withstands a greater traffic load, is used. The characteristics of this grade correspond to those of S 65 grade of IS-73-2013 and IS-1208-1978. The penetration value for this bitumen is within the specified limit. Softening point is little higher than the minimum required value which indicates that bituminous binder can withstand higher temperature. Ductility is higher than the minimum required value, this shows a better adhesive property of bitumen and its ability to stretch and form a thin ductile film around aggregates so that physical interlocking of the aggregates is improved. Specific gravity is within specification. Absolute and Kinematic viscosity is higher than minimum required value, this shows that liquid bitumen will provide greater flow resistance.

6.2 Tests on mineral aggregate

Strength test, Water absorption test, specific gravity and shape test were conducted on mineral aggregates. Results obtained are presented in Table 2. The actual values obtained are in accordance with the MORT&H specifications¹².

Conventional Marshall Stability test uses stone dust as filler having specific gravity about 2.87 while in

this study Marble dust is used as filler and its specific gravity was found as 3.06. This indicates marble dust being heavier than conventional stone dust.

Properties of crushed Electronic Waste plastic are presented in Table 3.

Pellets prepared from recycled electronic waste plastics (PCB + Plastic Components) were used in bituminous mixes as partial aggregate replacement. Plastic particles are naturally having a lower specific gravity, crushing value and impact value than mineral aggregates thus increasing the plastic replacement may reduce the strength. These particles are angular in shape with smooth surface. The angularity helps in better interlocking.

6.3 Aggregate gradation and selection

Sieve analysis has been carried out for the aggregate to be tested for their physical properties and Grading of aggregate is to be determining for Mix design for 10 mm nominal size of aggregate. In present study, using the aggregates blending was done for the Bituminous Asphalt mix. The gradations are shown in Table 4.

7 Marshall test result

Marshall Stability test and flow test were conducted on asphalt mix sample with no plastic replacement and 4%, 8% and 12% plastic replacement of coarse aggregate (6mm). Results are presented in Table 6.

The relationship between marshall stability value (KN) versus percentage bitumen content is shown in Fig. 4(a) At optimum binder content of 5.5 %, we obtained the maximum stability value for both no plastic asphalt mixes and modified asphalt mix. As the plastic content of mix varies from 0 %, 4 %, 8 % and 12 %, an increase in the marshall stability value is observed with increase in the plastic replacement.

Table 6(a) — Marshall test result for no plastic replacement mix.

Blended Civil Proportion Ratio	Nominal Size of Aggregate, Crushed Plastic and Dust Taken By Weights				Bitumen VG 30 Mix by Weights (gm)	Marshall Stability Value at 60°C , kN	Flow, mm	Gt
	A Coarse Aggregate 10mm (gm)	B Coarse Aggregate 6mm (gm)	C Crushed Plastic (gm)	D Marble Dust (gm)				
A : B : C : D 10 : 70 : 0 : 20	120	840	0	240	4.5%- 54	7.7	2.22	2.593
	120	840	0	240	5%- 60	8.3	2.58	2.578
	120	840	0	240	5.5%- 66	9.4	2.77	2.562
	120	840	0	240	6%- 72	9.2	2.31	2.547

Table 6(b) — Marshall test result for 4% plastic replacement mix.

Blended Civil Proportion Ratio	Nominal Size of Aggregate, Crushed Plastic and Dust Taken By Weights				Bitumen VG 30 Mix by Weights (gm)	Marshal Stability Value at 60°C, kN	Flow, mm	Gt
	A	B	C	D				
	Coarse Aggregate 10mm (gm)	Coarse Aggregate 6mm (gm)	Crushed Plastic (gm)	Marble Dust (gm)				
A : B : C : D 10 : 66 : 4 : 20	120	792	48	240	4.5%- 54	8.6	2.32	2.444
	120	792	48	240	5%- 60	9.2	2.5	2.43
	120	792	48	240	5.5%- 66	9.8	2.68	2.417
	120	792	48	240	6%- 72	9.4	2.91	2.404

Table 6(c) — Marshall test result for 8% plastic replacement mix.

Blended Civil Proportion Ratio	Nominal Size of Aggregate, Crushed Plastic and Dust Taken By Weights				Bitumen VG 30 Mix by Weights (gm)	Marshal Stability Value at 60°C, kN	Flow, mm	Gt
	A	B	C	D				
	Coarse Aggregate 10mm (gm)	Coarse Aggregate 6mm (gm)	Crushed Plastic (gm)	Marble Dust (gm)				
A : B : C : D 10 : 62 : 8 : 20	120	744	96	240	4.5%- 54	9.6	3.29	2.311
	120	744	96	240	5%- 60	10.2	3.75	2.299
	120	744	96	240	5.5%- 66	11.6	4.01	2.288
	120	744	96	240	6%- 72	11.3	4.58	2.277

Table 6(d) — Marshall test result for 12% plastic replacement mix.

Blended Civil Proportion Ratio	Nominal Size of Aggregate, Crushed Plastic and Dust Taken By Weights				Bitumen VG 30 Mix by Weights (gm)	Marshal Stability Value at 60°C, kN	Flow, mm	Gt
	A	B	C	D				
	Coarse Aggregate 10mm (gm)	Coarse Aggregate 6mm(gm)	Crushed Plastic (gm)	Marble Dust (gm)				
A : B : C : D 10 : 58 : 12 : 20	120	696	144	240	4.5%- 54	10.7	3.48	2.1914
	120	696	144	240	5%- 60	11.3	4.23	2.1816
	120	696	144	240	5.5%- 66	11.9	5.03	2.172
	120	696	144	240	6%- 72	11.5	5.27	2.162

The variation of flow values with different plastic content in the modified asphalt mix can be seen in Fig. 4(b). As the plastic percentage increase in the asphalt mix, flow value increases. From the Fig. 4(b), it can be observed that at optimum binder content of 5.5%, a significant increase in the value of flow is observed with increasing plastic content of the asphalt mix.

7.1 Marshall properties

The variation of bulk specific gravity with percentage bitumen content is given in Fig. 5(a). The graph shows that by increasing the light weight plastic variation, bulk specific gravity of the mix decreases. For a particular plastic content, there is a very little variation with different bitumen content.

Percentage air voids (V_v) for different percentage of bitumen is shown in Fig. 5(b). The trends clearly shows that for increasing the percentage of plastic replacement of 6mm aggregate, air voids reduces in the asphalt mix. For no plastic asphalt mix, air void is almost same for different percentage of binder in the mix, but with increase in plastic replacement, the variations increases.

The graph for Voids in mineral aggregate (VMA) given in Fig. 5(c) shows a similar trend to the graph of V_v versus % Bitumen. With increase in bitumen content, the VMA value increase for no plastic mix but the increase for plastic mix asphalt is very small.

In Fig. 6, flow values observed for plastic asphalt mixes show that the maximum flow occurs at 12% plastic replacement and a maximum flow value of

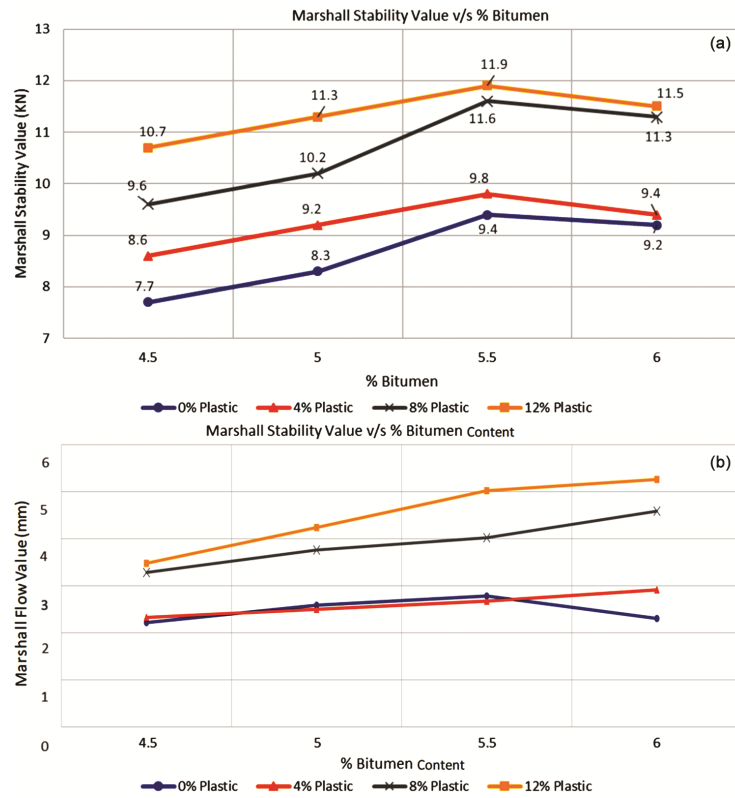
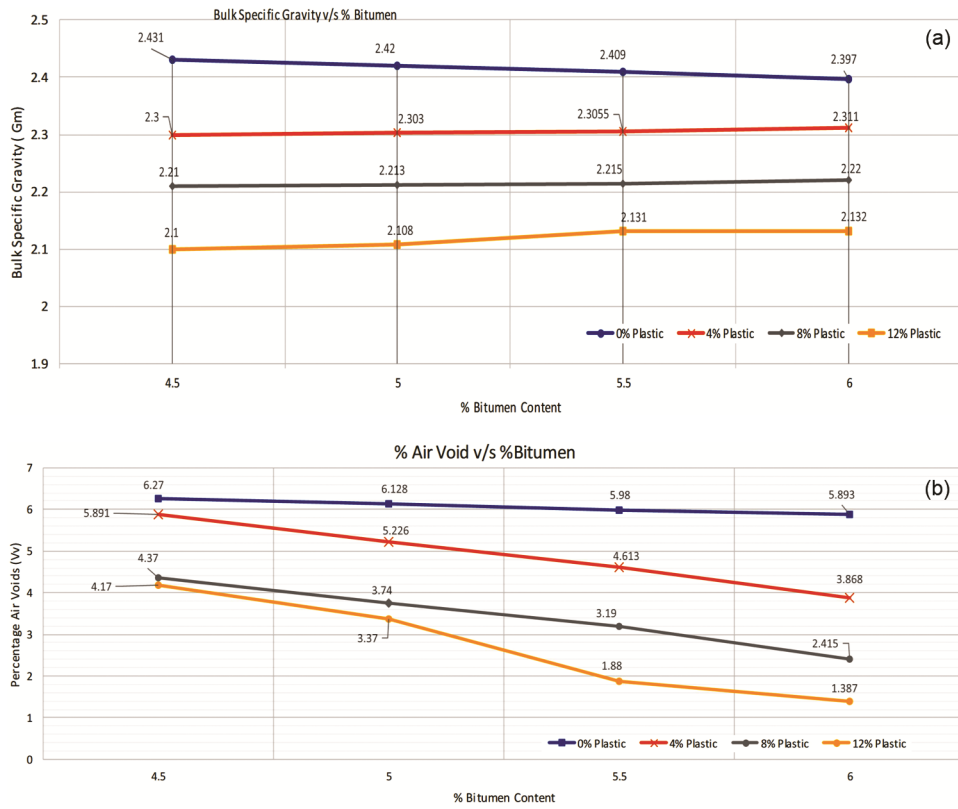


Fig. 4 — Variation of marshall results (a) Stability (kN) and (b) Flow (mm) for different % of plastic replacement.



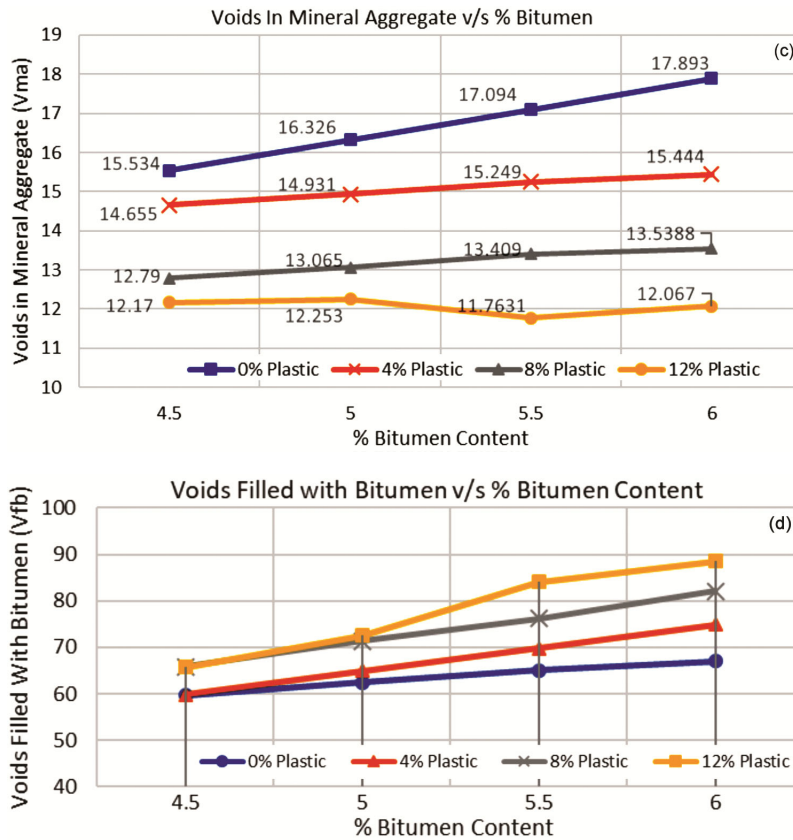


Fig. 5 — Variation of marshall results (a) Bulk specific gravity, (b) VV, (c) VMA and (d) VFB for different % of plastic replacement at varying bitumen content.

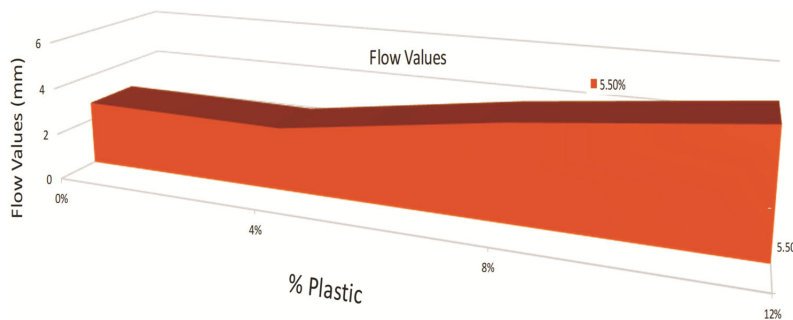


Fig. 6 — Variation of flow value (mm) for different % of plastic replacement at OBC (5.5%).

5.3 mm occurs. Because of such high flow values, the mixes are flexible and sturdy. Desolation of plastic particles at higher percentage replacement is identified to be the major factor influencing the flow of asphalt mix. Conversely, at no plastic mix, flow observed is minimum.

Similarly from the Fig. 7. it can be observed that for optimum bitumen content of 5.5%, Marshall Quotient values are higher for plastic substituted Asphalt mix as compared to normal asphalt mix. As

per Fig. 6 and Fig. 7, higher values of flow values and Marshall Quotient of modified asphalt mix signify that the modified mixes were elastic and stronger as compared to no plastic asphalt mix. Higher marshall quotient values ensure the resistance of bituminous pavement against failure due to shear, permanent warping, and failure of pothole.

The effect of plastic replacement of coarse aggregate on unit weight of the modified asphalt mix is plotted in Fig. 8 for the desired optimum binder

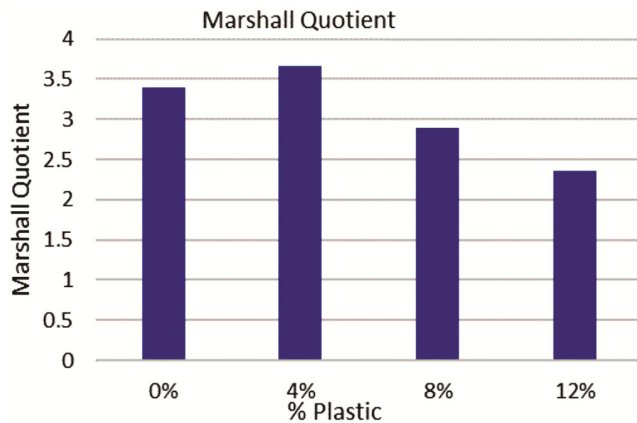


Fig. 7 — Variation of marshall quotient for different % of plastic replacement at OBC (5.5%).

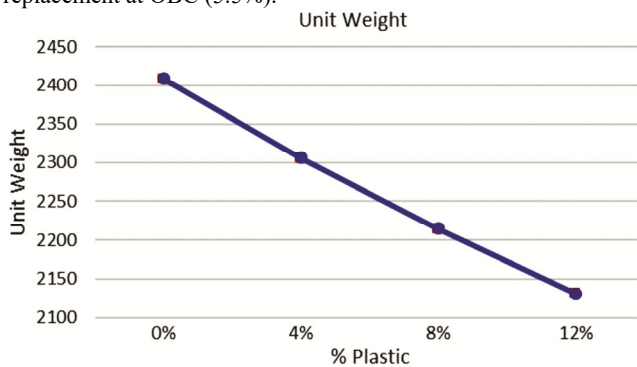


Fig. 8 — Variation of unit weight for different % of plastic replacement at OBC (5.5%).

content (OBC) of 5.5 %. The graph shows that with increase in plastic replacement, the unit weight of the mix decrease. This can be attributed to the fact that heavy weight aggregate is being replaced by a light weight plastic.

8 Determination of Optimum Bitumen Content

Optimum binder content or optimum bitumen content is calculated by taking average value of following three binder content observed in above graphs.

- i. Bitumen content correspond to maximum unit weight
- ii. Bitumen content corresponding to the median of designed limits of percentage air voids in total mix
- iii. Bitumen content correspond to maximum stability

OBC of asphalt mix with different conditions are given in Table 7.

Hence for the bituminous asphalt mix, OBC is found as 5.5%

Table 7 — Determination of optimum bitumen content.

Conditions	Range of % Bitumen
For Maximum Stability	5.25 – 5.75
For Maximum Unit Weight	5 – 5.6
For % Air Void	5.2 – 5.6

9 Conclusions

Result of tests conducted in this research are in accordance to specified limit provided for the particular test by MORT&H¹². Based on the results observed, it was concluded that an increase in plastic replacement of coarse aggregate (6mm) increases the Marshall Stability and Marshall Flow value. According to Prof. Lakshmi Murugan⁷, plastic particles at higher replacement percentages was found to have a negative influence on the modified mix properties, therefore, we kept our plastic content of mix as 0 %, 4 %, 8 % and 12 % and the optimum plastic content was observed to be 12%. Optimum bitumen content (OBC) for various percentage of plastic replacement was observed to be in the range 5.3% to 5.6%. In this research, marble dust was used as filler instead of conventional stone dust, thus the stability value obtained was lower than what would have obtained if stone dust was used, but still all the Marshall properties was within the specified limit according to MORT&H¹².

Voids in mineral aggregate (VMA) is an important parameter, as it provides a measure of the ability of the mix to hold an adequate amount of bitumen whereas Voids filled with Bitumen (VFB) indicates effective bitumen film thickness between aggregates. From the Fig. 5(c), it is observed that with increase in plastic content of asphalt mix V_{FB} is increasing. The increase of V_{FB} indicates that the thickness of film of bitumen present in the voids between the aggregates increases, due to which cracking at low-temperature reduces and the durability of asphalt mix increases. This occurs due to bitumen performing the filling and healing to improve the flexibility of mixture.

Replacement of coarse aggregate of 6mm size with plastic improves many properties of asphalt mix. Flow value at OBC increases from 2.77mm for no plastic mix to 5.03mm for 12% replacement shown in Fig. 6. This signifies that the modified mixes were more elastic and stronger as compared to no plastic asphalt mix. Replacement of heavy weight aggregate with light weight plastic also reduces the unit weight. The plastic used was angular in shape and due this interlocking between the particles increased in the

mix and ultimately the strength increased. In a similar analysis conducted by Prof. Lakshmi Murugan⁷, the author used recycled printed circuit board (PCB) as coarse aggregate replacement with stone dust as filler and concluded that upto 12% replacement, the stability values increases. In current work, Plastic e-waste was used along with PCB as partial replacement for coarse aggregate and marble dust as complete replacement for filler.

The use of E-waste plastic particles and Marble Dust as a filler in the modified asphalt mix seems to be feasible and can be one of the alternatives to make our earth greener, cleaner and pavements more tenacious, which ultimately fulfils the objective of recycling and reusing the waste products in bituminous pavements. It leads to natural resource conservation, waste reduction in environment and last but not the least makes our design more cost effective and economical. Further investigation on effect of partial replacement of Stone Dust with Marble Dust in varying percentage or can vary the grade of bitumen to observe the effects on Marshall stability value and flow value of the modified asphalt mix so as to help make pavements more durable.

References

- 1 Mmereki D, Li B, Baldwin A & Hong L, *From Pollut. Resour*, (2016) 65.
- 2 ASSOCHAM-KPMG joint study, *The Associated Chambers of Commerce & Industry of India*, India (2016).
- 3 Patel V J, Kumavat H R & Tapkire G V, *Int J Innov Res Sci Eng Technol*, 6 (2017) 57.
- 4 Ongondo FO, Williams I D & Cherrette TJ, *Waste Manage*, 31(2011) 714.
- 5 Rajashree T, Digvijay K & Anand T, *J. Environ. Res. Develop*, 9 (2015) 1010.
- 6 Ullah S, Alam M & Khan R, *Int J Eng Res Appl*, 7 (2017) 58.
- 7 Murugan L, *GRADEVINAR*, 70 (2018) 607.
- 8 *Methods for Testing Tar and Bituminous Materials*, Bureau of Indian Standards IS 1201-1220, India (1978).
- 9 *Paving Bitumen- Specifications*, Bureau of Indian Standards IS 73 India (2013).
- 10 *Specification for Roads and Bridge Works*, Indian Road Congress Ministry of Road Transport and Highways , New Delhi, India, IV (2013).
- 11 Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus, ASTM D-1559, vol 04.03 Road and Paving Materials.
- 12 *Indian Standard Methods of Test for Aggregates for Concrete*, Bureau of Indian Standards IS 2386 Part 1, India (1963).
- 13 Ranadive M S & Shinde M K, *Int J Civ Strut Environ Infrastruct Eng Res Dev*, 2 (2012) 1.