iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VI **Month of publication:** June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72222

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

Investigation of Flexible Pavement with Non-Biodegradable Waste Plastic

Andimenu Anil Kumar[1], B. Ramesh [2]
[1]M-Tech Scholar department of Civil Engineering, Pydah College of Engineering Kakinada -Yanam Road, Patavala, East Godavari District, Andhrapradesh, 533461
[2]Assistant professor department of Civil Engineering, Pydah College of Engineering Kakinada -Yanam Road, Patavala, East Godavari District, Andhrapradesh, 533461

Abstract: Waste plastic, which includes the wrappers of junk foods, chocolates, chips, hand-carry bags, plastic bottles, and any other kind of plastic, is mostly to blame for the significant environmental and severe economic problems that are now being experienced in the modern world. When plastics are manufactured, a substantial amount of energy and other natural resources are used. This leads to the depletion of the environment in a number of different ways, which is a consequence of the production process. The longevity of the road as well as its structural integrity are both enhanced by the incorporation of polymer into the asphalt that is used to create the pavement. Polymer, particularly in the form of low-density polymers, is added to asphalt, which results in an improvement in the properties of the asphalt. In the context of transportation, the term "plastic road" refers to roads that are constructed from plastic that has been abandoned. It is well acknowledged that these roads provide improved durability and performance in contrast to conventional roads. Additionally, it has been shown that these highways did not have as many structural problems as their counterparts, which were normal pavements. Certainly, this was a noteworthy discovery. According to the research findings, using a larger quantity of waste plastic ultimately reduces the need for bitumen by ten percent. As a consequence of this, the quality of the pavement as well as the material strength of the pavement are both enhanced. In addition, the incorporation of polymer into asphalt has the potential to enhance the structural strength and durability of flexible pavement. There is a possibility that plastic waste might replace between 10 and 15 per cent of the bitumen that is used in the production of flexible pavement. Furthermore, it has the potential to save around Rs 1,00,724.76 for every additional km of road patch.
Keywords: Structural Integrity, Asphalt, Polymer, Low-density polymers, Plastic Road

I. INTRODUCTIONS

Rapid industrial growth, which was accompanied by expanding population expansion, resulted in the production of an excessive number of waste materials. This excessive amount of waste materials was created. Consequently, this resulted in a discernible rise in the quantity of waste products that were generated. The issue of disposing of such a significant number of rubbishes, particularly waste materials that are not biodegradable, has become a major cause of worry in many countries, including those that are industrialised as well as those that are still in the process of developing. One of the most effective therapies for this issue is the recycling of waste materials into useable commodities, which is also regarded to be one of the most sustainable solutions for this problem. [1] As a consequence of this, there is a significant amount of funding for programs that have the objective of developing unique and imaginative uses for waste materials. A great number of research projects have been carried out in order to uncover the ways in which certain waste products may be used in the production of construction materials. For the purpose of this research, the performance of the waste materials, their availability, the environmental repercussions they have, and feasibility studies have all been taken into account. The goal of these research enquiries is to figure out how to make efficient use of waste resources that are not only safe but also cost-effective, as well as how to mix these waste resources with construction materials that are efficient. The use of waste materials in the construction of highways and flexible roads is not only a concept that is considered to be cost-effective, but it is also considered to be the most advantageous solution in terms of its capacity to fulfil its intended purpose. It is not [1].

Using certain polymers, it has been shown that it is feasible to enhance the overall performance of concrete pavements that are flexible. Specifically, this is due to the fact that these polymers provide a much-improved resistance to rutting and cracking, both of which are brought on by thermal expansion. Furthermore, it has been shown to have a high degree of resistance to fatigue damage, stripping, and high heat sensitivity. Polyethylene, a kind of plastic material that is widespread in its use, has been demonstrated to be one of the most effective polymer additives via several studies. It is not [2, 3].

A significant portion of the packaging sector makes use of low-density polyethylene (LDPE), which is a kind of plastic that is used in the production of thin plastic bags. Due to the fact that they are not biodegradable in their natural condition, the disposal of such a vast number, on the other hand, is a cause for worry for the environment. The use of plastic and waste plastic bags in the construction materials has been the subject of a variety of research methodologies, which have been carried out to explore the matter. In the course of the production process, they may be used either as a binder modifier or as an aggregate coat, depending on the chemical composition and physical state of the material. The outcomes of the modified asphalt mixture were favourable, and they exhibited an improvement in terms of both the performance and the durability of the modified asphalt mixture. both [1] and [4].

A. *Objectives of the Work*

One of the primary goals of this endeavour is to investigate the incorporation of polyethylene into bituminous mix and its ability to enhance the mechanical properties of the mix. Additionally, the Marshall Stability and Flow Test and the resistance of the wearing course against structural failures will be evaluated as part of this endeavour. An additional aspect that is included in the scope of the investigation is the economic separation that is achieved through the use of this technology, as well as the impact that it has on the organisation of waste.

- To determine the Optimum Binder Content (OBC) and Optimum Plastic Content (OPC) that can be added in bitumen yielding effective results.
- Comparison of experimental results of conventional HMA with Polymer added HMA.
- To conduct economic calculations.

II. RESEARCH METHODOLOGY &MATERIALS

Literature review of past books, scientific journals and reports on polymer additions in Hot Mix Asphalt.
Field studies of the recycled polymer processing plants to get more information and collect samples.
Detailed study of HMA design. Finding Optimum Binder Content (OBC) using Marshall Mix design method. Five percentages of bitumen have been examined to determine the best percentage of bitumen for the aggregates used, which include 3.5,4, 4.5, 5 and 6% by weight of the mix. Finding the results and effects of LDPE polymer addition in HMA and comparing it with conventional HMA in terms of bulk density, Marshall stability, flow and air voids. Intended percentages are from (6-18%) by weight of OBC.
End Results and Discussions.
Conclusions & Recommendations.
This work's major objective is to evaluate the characteristics of HMA that have been changed with waste plastic bags. We will provide clarity on the process and approach we will use to complete the assessment. Materials characterisation is carried out during the initial step of the process to ascertain the aggregates', bitumen's, and waste plastics' distinctive physical characteristics. Within the second phase, there is a comprehensive development of experimental test work in order to achieve the objectives of the research studies.

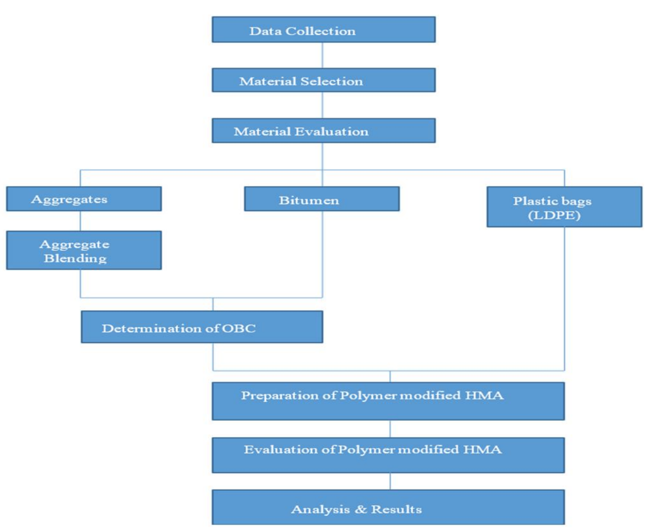


Figure 1: Flow chart of laboratory testing procedure

A. Materials Selection

Hot mix asphalt and waste plastic bags are required for the study

Table 1: Sources of materials used

Materials	Sources
Aggregates	Crushed rocks (Kakinada)
Bitumen	Ultra Chemicals, DHA, Kakinada
Waste Plastic Bags	Local Thin Plastic Bags

Plastic waste collected from nearby disposal site | Source of aggregate (Kakinada Crush)

Figure 2: Source of Material Used

Bitumen: For this investigation, the asphalt binder that had a ratio of 60/70 was used. To evaluate the characteristics of asphalt, a variety of tests were carried out in the laboratory. We conducted a variety of tests, including penetration, ductility, softening point, specific gravity, flash point, and softening point.

Table 1: Summary of bitumen properties

Test	Specifications	Results	MORTH Specifications Limits
Penetration (0.01mm)	IS: 1203-1978	63	60-70
Ductility (cm)	IS 1208: Part 1 : 2023	128	Min. 100 cm
Softening point (°C)	IS 1205:2022	49	46-56
Flash point (°C)	IS 1209: 2021	240	Min. 232°C
Fire point (°C)	IS 1209: 2021	252	
Specific gravity (g/cm^3)	IS 1202:2021	1.03	1.01-1.06

Table II: Waste Plastic Properties

Properties	**Details**
Plastic type	Waste plastic bags
Plastic material	Low density polyethylene
Size (mm)	2.00-4.50
Density (g/cm^3)	0.93
Melting point (°C)	112

Table 2: Results of Aggregate Testing

Test	Coarse Aggregates	Fine Aggregates	Filler	Standard Designation	Specifications
Bulk Specific Gravity (G_{sb})	2.63	2.62	2.64	IS 1202:2021	2.5 – 3.00
Apparent Specific Gravity (G_{sa})	2.69	2.72	2.64		
Effective Specific Gravity (G_{se})	2.66	2.61	2.64		
Water Absorption	2.35	2.15	2.01	IS 13826-6, part 6	<5%
Crushing Value	11.02%			IS: 2386 (Part IV)	<15%
Impact Value	12.24%			IS: 2386 (Part IV)	10-30%
Los Angeles Abrasion Value	23.12%			IS: 2386 (Part IV)	<40%

III. RESULTS AND DISCUSSIONS

Experimental work and results are divided in two groups in this chapter. Firstly, Marshall Test is performed with varying bitumen percentages i.e. 3.5, 4.0, 4.5, 5.0 and 5.5% and the optimum bitumen content (OBC) is calculated from these experiments.

After OBC has been determined, next step involves adding different polymer percentages i.e. 6, 8, 10, 12,14,16 & 18% in hot asphalt mix according to the mass of OBC.

Marshall test results for modified samples are studied and finally the optimum plastic content is obtained.

A. Marshall Test

15 samples having weight 1275 gm each were prepared using five different bitumen percentages 3.5, 4, 4.5, 5 and 5.5% to find the optimum bitumen content (OBC). Table 4-3 and Figures 4-2 to Figure 4-7 show summary of Marshall Test results

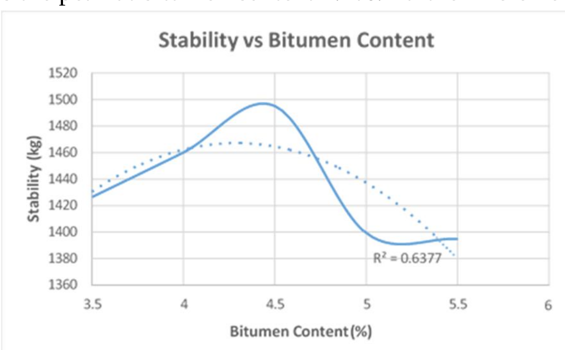
Table 5: Summary of Marshall Test results

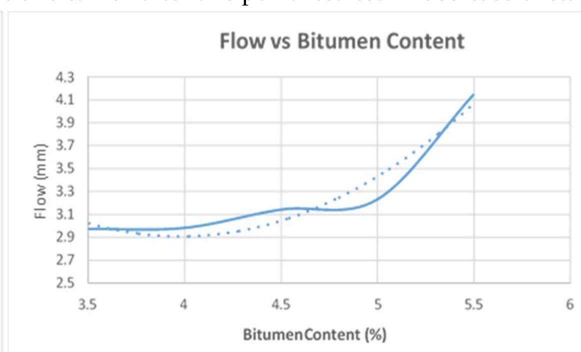
Bitumen Content (%)	Sample	Stability (kg)	Flow (mm)	Gmb (g/cm^3)	V_a (%)	V_b (%)	VMA (%)	VFA (%)
3.50	1	1514	3.35	2.3	7.45	9.01	16.46	54.74
	2	1405	3.1	2.29	8.65	8.90	17.55	50.71
	3	1360	2.46	2.31	7.31	9.03	16.34	55.26
	Average	1426.33	2.97	2.3	7.80	8.98	16.78	53.51
4	1	1550	3.55	2.33	5.50	9.14	14.64	62.43
	2	1370	2.86	2.31	6.40	9.06	15.46	58.60
	3	1460	2.52	2.34	5.82	9.10	14.92	60.99
	Average	1460	2.98	2.33	5.91	9.10	15.01	60.64
4.50	1	1445	2.98	2.34	4.40	9.15	13.55	67.53
	2	1512	3.32	2.35	4.76	9.19	13.95	65.88
	3	1528	3.12	2.37	4.39	9.18	13.57	67.65
	Average	1495	3.14	2.353	4.52	9.17	13.69	67.01

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

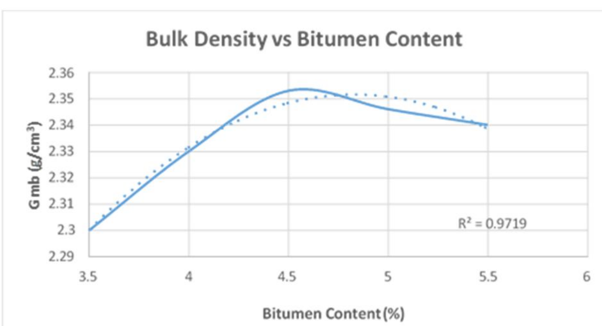
Bitumen Content (%)	Sample	Stability (kg)	Flow (mm)	Gmb (g/cm^3)	V_a (%)	V_b (%)	VMA (%)	VFA (%)
5	1	1601	3.5	2.34	4.01	9.15	13.16	69.53
	2	1348	3.38	2.36	3.56	9.19	12.75	
	3	1248	2.81	2.34	4.56	9.13	13.69	
	Average	1399	3.23	2.346	4.04	9.16	13.20	69.37
5.50	1	1558	4.25	2.34	3.87	9.11	12.98	70.18
	2	1356	4.07	2.35	3.74	9.13	12.87	
	3	1270	4.12	2.33	3.98	9.08	13.06	69.53
	Average	1394.67	4.15	2.34	3.86	9.11	12.97	70.21

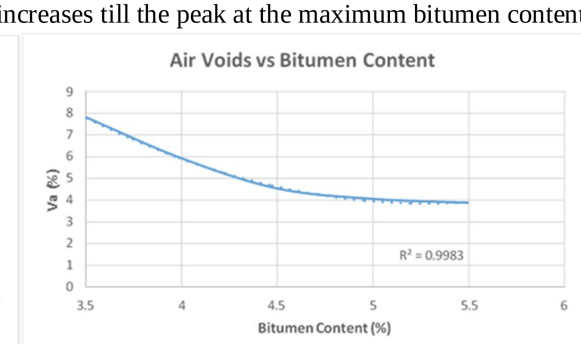
Stability vs B.C: Stability refers to the maximum load sustained by the specimen till failure when loading is applied at a constant rate of 50 mm/min [16]. stability against different for different bitumen contents is shown. Stability increases as the B.C increases till it reaches the peak at bitumen content 4.4%. Further increment of bitumen after this point resulted in decrease of stability.





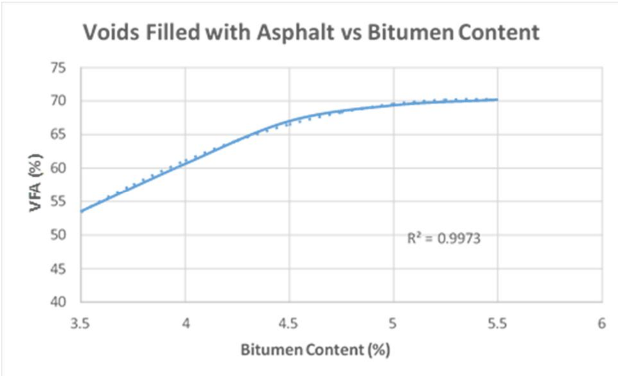
Flow is defined as the maximum vertical deformation caused in a specimen at maximum load [16]., flow values against varying bitumen contents are shown. Flow increases as the binder content increases till the peak at the maximum bitumen content of 5.5%.

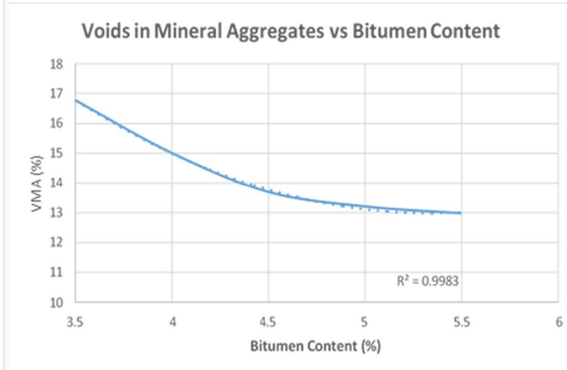




Bulk density is the actual density of the compacted mix. In, bulk density values against different bitumen contents are mentioned. Bulk density increases as the bitumen content increases till the peak at bitumen content 4.8%. Gradual decrease in bulk density is observed after peak value when bitumen content is increased further

V_a (%) is air voids percentage by volume in specimen [16]. In Va (%) values for different bitumen contents are mentioned. Maximum air voids content value is at the lowest bitumen percentage (3.5%). As bitumen content increases, air voids tend to decrease





The Voids Filled with Asphalt (VFA) % is the fraction of voids in mineral aggregates that are filled with asphalt. This percentage is referred to as the VFA percentage. Figure 4-6 provides a visual representation of the VFA values in relation to the different bitumen contents by way of example. When the percentage of bitumen is at its lowest, the minimum concentration of volatile fatty acids is 3.5%. As more bitumen is added to the mixture, the percentage of volatile fatty acids (VFA) gradually goes up because there are more empty spaces filled with bitumen. In mineral aggregates, "Voids in Mineral Aggregates" (VMA) means the amount of empty space in the aggregates measured by volume before adding bitumen. Figure 4-7 presents a comparison between the measurements of the VMA% and the various bitumen concentrations. The bitumen percentage levels that are the lowest (3.5%) are the ones that exhibit the highest number of voids in mineral aggregates, and the VMA% gradually decreases as the bitumen content increases.

B. Polymer Addition in Hot Mix Asphalt

In order to determine the impact that the addition of LDPE has on HMA, fourteen samples were made at OBC. Seven different proportions of LDPE were taken into consideration, namely 6, 8, 10, 12, 14, 16, and 18% by the weight of OBC. The mechanical parameters of asphalt mix are shown in Table 4-5, which is organised according to the weight of OBC and uses varying percentages of LDPE.

Table 6: Mechanical properties of asphalt mix with LDPE bags addition

Plastic Percentage (%)	Sample	OBC (%)	Stability (kg)	Flow (mm)	Gmb (%)	Va (%)	Vb (%)	VMA (%)	VFA (%)
6	1	4.7	1758	2.95	2.34	4.31	11.71	16.02	73.10
	2	4.7	1760	2.97	2.36	4.33	11.73	16.06	73.04
	Average	4.7	1759	2.96	2.35	4.32	11.72	16.04	73.07
8	1	4.7	1766	3.09	2.33	4.38	11.68	16.06	72.73
	2	4.7	1768	3.11	2.35	4.4	11.66	16.06	72.60
	Average	4.7	1767	3.1	2.34	4.39	11.67	16.06	72.67
10	1	4.7	1971	3.22	2.34	4.33	11.69	16.02	72.97
	2	4.7	1973	3.24	2.36	4.35	11.71	16.06	72.91
	Average	4.7	1972	3.23	2.35	4.34	11.7	16.04	72.94
12	1	4.7	1985	3.4	2.33	4.53	11.66	16.19	72.02
	2	4.7	1987	3.6	2.35	4.55	11.68	16.23	71.97
	Average	4.7	1986	3.5	2.34	4.54	11.67	16.21	71.99
14	1	4.7	2034	3.4	2.331	4.76	11.64	16.4	70.98
	2	4.7	2036	3.42	2.353	4.78	11.66	16.44	70.92
	Average	4.7	2035	3.41	2.342	4.77	11.65	16.42	70.95

Plastic Percentage (%)	Sample	OBC (%)	Stability (kg)	Flow (mm)	Gmb (%)	Va (%)	Vb (%)	VMA (%)	VFA (%)
16	1	4.7	1932	3.88	2.31	4.7	11.55	16.25	71.08
	2	4.7	1934	3.9	2.33	4.72	11.57	16.29	71.03
	Average	4.7	1933	3.89	2.32	4.71	11.56	16.27	71.05
18	1	4.7	1719	4.01	2.3	4.85	11.53	16.38	70.39
	2	4.7	1721	4.03	2.32	4.87	11.55	16.42	70.34
	Average	4.7	1720	4.02	2.31	4.86	11.54	16.4	70.37

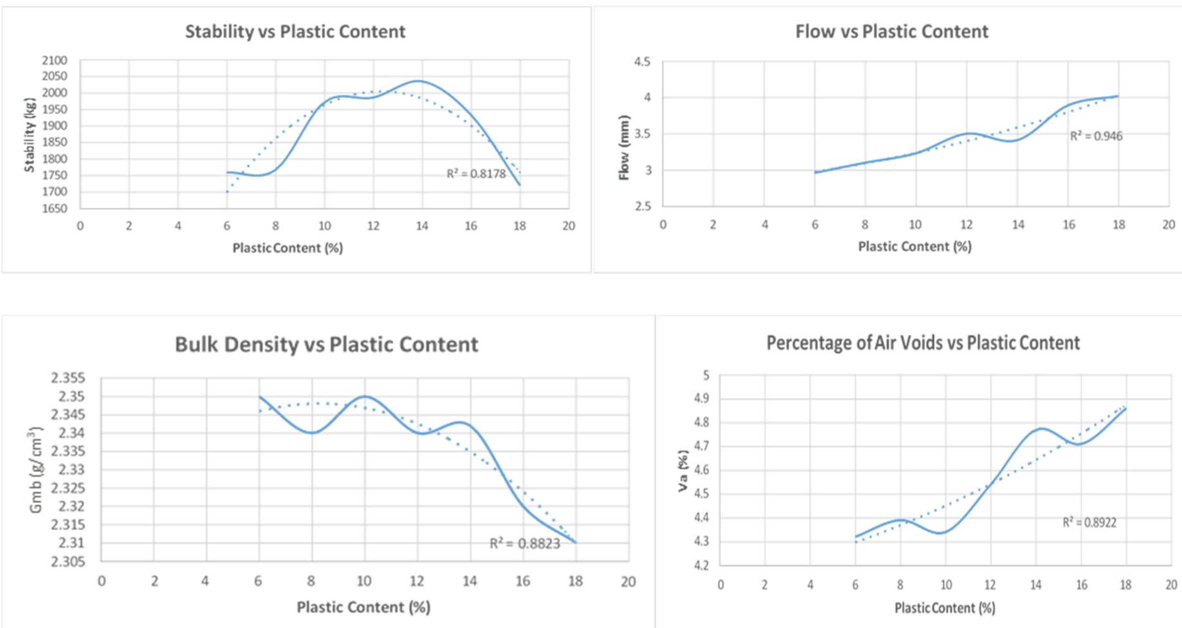


Figure 4: Mechanical properties of asphalt mix with LDPE bags addition

In most cases, the stability of modified mixes is greater than that of standard bitumen mixes. Every single one of the stability values for the various percentages of modifiers is greater than the stability of the standard mix at all. The greatest stability value, with an LDPE content of approximately 14%, is nearly 2035 kilogrammes. Figure 4-8 shows that the stability of the modified asphalt mix gets better as the phosphorus content (P.C.) increases, peaking at 14% P.C., and then it drops sharply as the P.C. goes higher.

The flow rate of modified mix is often much higher than that of normal mix in the majority of instances. As can be seen in Figure 4-9, the flow is proven to rise in a consistent manner as the proportion of PC material increases. It is observed that the flow value increases from 3 mm to 4 mm when the pressure concentration is 18%.

The graph demonstrates that the modified mix has a lower bulk density in comparison to the conventional asphalt mixes. This is something that can be seen. As can be observed in the general pattern that was shown before, the bulk density has a tendency to drop as the proportion of PC increases. When the percentage is 6.5 per cent, the bulk density is at its maximum (2.35 g/cm³), whereas when it is 18 per cent, it is at its lowest (2.31 g/cm³). The bulk density is at its highest when it is at its lowest. This decrease in bulk density may have occurred as a result of the low density of the plastic material that was added (plastic material), which is one of the probable explanations for this phenomenon. According to Figure 4-10, there is a correlation between the bulk density of the mixture and the amount of plastic it contains.

Generally, air voids of modified mixes are higher than conventional mixes. Air voids of modified mixes increase gradually as the plastic content increases till it reaches the highest Va value at 18% P.C. represents asphalt mix air voids against plastic content relationship.

C. Cost Analysis

An average 1 km of road requires about 16.92 tons of bitumen (bitumen content 4.7 %), using the polyethylene content of 10% by weight of bitumen. These calculations are based on the estimated costs of processed plastics.

- Specific Gravity of HMA = 2.4
- Road Lane Width = 3.75 m
- Thickness of the wearing cross = 40 mm = 0.04 m
- Length of road = 1 km = 1000 m
- Total volume of Asphalt Mix Wearing Course = 3.75 × 1000 × 0.04 =150 m^3
- Total weight of asphalt mix = 150 × 2400 = 360000 kg
- Weight of bitumen = 4.7 % × 360000 = 16920 kg
- Amount of bitumen used in conventional HMA = 16.92 tons

Table II-3: Economic Analysis

Size of the road	Bitumen needed	Plastics needed	Bitumen saved	Cost saved
1kmx3.75mx0.04m	16.2 tons	1.692 tons	1.692 tons	Rs 1,00,724.76/-

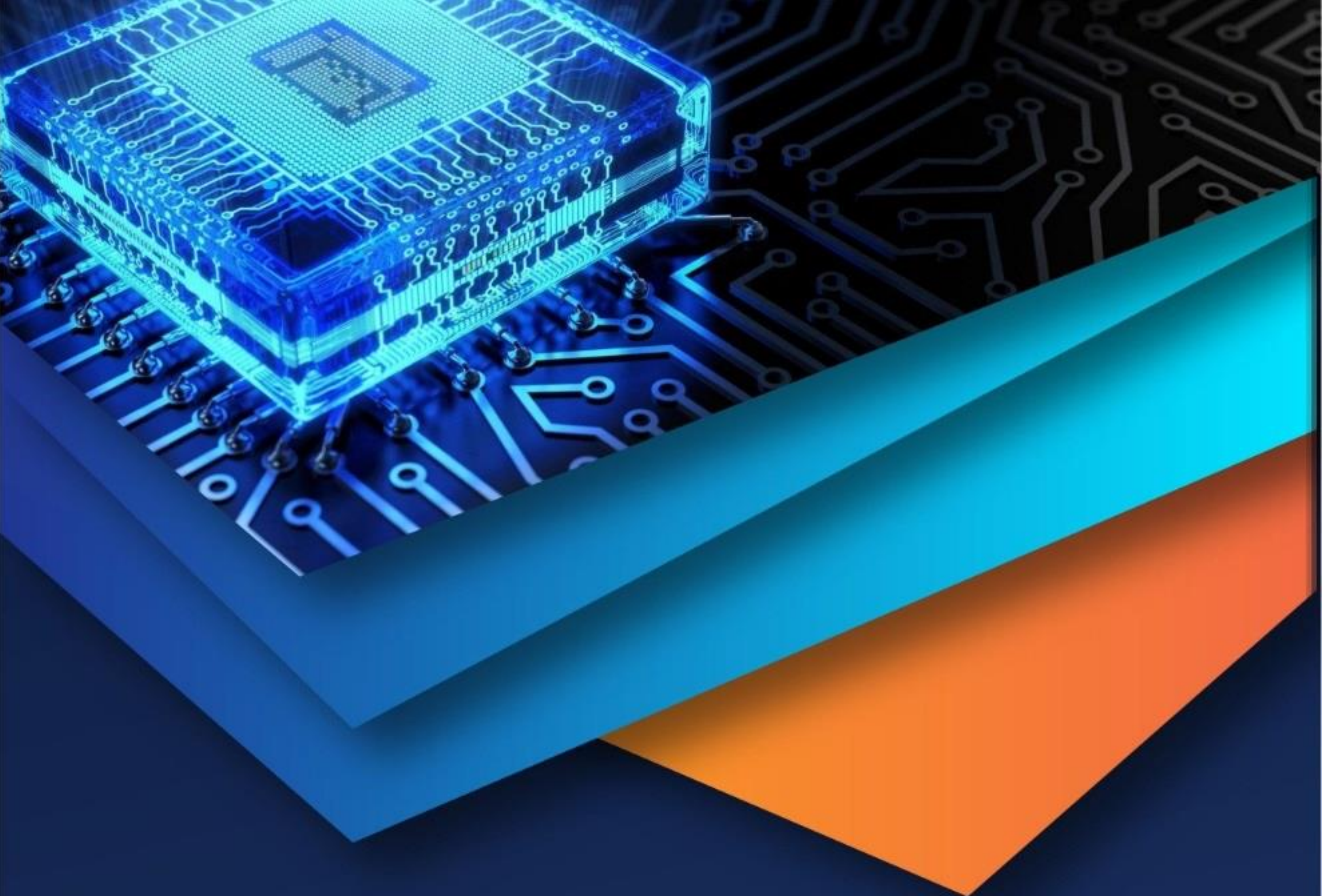
It is obvious from calculations that modified HMA having 10% OPC has higher stability value as compared to the conventional HMA. Other mechanical properties of modified mix are still within the allowed specifications range. There is a slight increase in flow and air voids values in modified HMA while VMA and bulk density are approximately the same for both the hot mixes. 10% bitumen can be saved if LDPE is being used in its place in pavement construction and this method also proves to be economical as it can save around 1 lac approximately on a patch of 1 km long flexible pavement.

IV. CONCLUSIONS

1) Waste plastic sheets can be easily used as a modifier for asphalt mixes for sustainable management of plastic waste as well as for improved performance of asphalt mix.
2) Optimum Plastic Content (OPC) that can be effectively used as a modifier in bitumen mixes is found to be 10% by weight of OBC through experimental work conducted.
3) Modified bitumen mix with 10% OPC has approximately 30% more stability value as compared to the conventional mixes.
4) Bulk density tends to decrease with addition of LDPE. This is because of the low density of plastic material that tends to decrease the overall bulk density of mix.
5) Flow value has direct relationship with polymer addition as it increases with the increase in polymer in mixes but it also increases the stiffness of mix as well
6) Cost analysis conducted on 1-kilometre patch of pavement shows that approximately Rs. 1,00,724.76/- can be saved if 10% OPC is used by weight of OBC.
7) Polymer modified HMA demonstrates best outlining properties in terms of designover conventional bitumen mixes and also it has a higher softening temperature that tends to reduce rutting phenomena.
8) Lesser stripping is observed in courses with modified bitumen mixes.
9) Poor quality aggregates can be made stronger by coating them with plastics as it decreases the aggregate impact value.
10) Water absorption capacity of aggregates becomes lesser when aggregates are coated with plastics. It is due the water-resistant nature of plastics increasing the binding force among particles.
11) There is no evolution of dangerous gases during their production, thus, making it environmental friendly project.
12) Waste materials generated by heavy industries find their useful application in polymer modified pavements.
13) Methods which were previously used for waste disposals were the main reasons of environmental pollution. This effective and environmental friendly technique helps us to overcome the hazardous effects caused by landfilling and incineration techniques.
14) There is improved solid waste management at urban levels if plastic waste generated is properly and effectively utilized in such projects.
15) Better environmental hygiene is created.
16) Life of pavements increase due to the decrease in wear and tear of structures.
17) Polymer modified HMA exhibit better physical and chemical properties as compared to conventional HMA.

REFERENCES

[1] C. Justo and A. Veeraragavan, "Utilization of waste plastic bags in bituminous mix for improved performance of roads," Centre for Transportation Engineering, Bangalore University, Bangalore, India, pp. 43-44, 2002.
[2] M. T. Awwad and L. Shbeeb, "The use of polyethylene in hot asphalt mixtures," a American Journal of Applied Sciences, vol. 4, pp. 390-396, 2007.
[3] Z. Kalantar, A. Mahrez, and M. R. Karim, "Properties of bituminous binder modified with waste polyethylene terephthalate (PET)," 2009.
[4] Ç. Giriftinoğlu, "The Use of Plastic Waste Materials in Asphalt Pavement," 2007.
[5] A. F. Abdalqader, "Landfills needs assessment in Gaza strip and sites selection using GIS," Unpublished Master Thesis). The Islamic University of Gaza, Gaza, Palestine, 2011.
[6] V. Swami, A. Jirge, K. Patil, S. Patil, S. Patil, and K. Salokhe, "Use of waste plastic in construction of bituminous road," International Journal of Engineering Science and Technology, vol. 4, 2012.
[7] M. H. Sadd, Q. Dai, V. Parameswaran, and A. Shukla, "Microstructural simulation of asphalt materials: modeling and experimental studies," Journal of materials in civil engineering, vol. 16, pp. 107-115, 2004.
[8] S. A. Taih, "The effect of additives in hot asphalt mixtures," Journal of Engineering and Sustainable Development, vol. 15, pp. 132-151, 2011.
[9] T. Yi-qiu and A. Al-Hadidy, "The Effect of Plastomers Polymer Type and Concentration on Asphalt and Moisture Damage of SMA Mixtures," AL Rafdain Engineering Journal, vol. 19, pp. 1-11, 2011.
[10] P. Jain, S. Kumar, and J. Sengupta, "Mitigation of rutting in bituminous roads by use of waste polymeric packaging materials," 2011.
[11] T. Officials and L. Advanced Asphalt Technologies, A Manual for Design of Hot Mix Asphalt with Commentary vol. 673: Transportation Research Board, 2011.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY