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Experimental Study on Use of Waste Polyethylene in Bituminous Paving Mixes

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Abstract: Robust boost in highway infrastructure development in India gave a kick start to industrial activities and passenger journeys, which has resulted in continuous growth of vehicles day-by-day. Also the continuous change in climate brought a challenge in front of highway engineers to design and construct such pavements which can withstand with the increased wheel load and typical climatic conditions. Flexible pavements are more preferred in developing countries like India. In these flexible pavements, Bitumen, a by-product of crude oil is used as a binding agent. It is used because of its low cost and good binding property. Research activities are continuously carrying out in order to enhance the properties of bitumen to make advanced flexible pavements to meet the present challenges. Alternative for bitumen is also being in search to make the roads cheaper and provide better serviceability.

Recent studies suggested that the common environmental waste Polyethylene (LDPE) commonly known as polythene is an effective substitute of bitumen up to some extent. The abundance of plastic waste dumped in the environment and its harmful effects call for an urgent action. Over the past decade we have produced and consumed more plastic than the entire century. India alone produces 40,000 Tonnes of plastic everyday of which only 60% gets recycled. Approximately 6 million Tonnes of plastic waste goes un-recycled every year in India. In the present study, the attempt has been made to investigate the effect of polythene in the asphalt concrete properties. Polythene added in shredded state as binder modifier. It is introduced to the mixture by coating the heated aggregates mixed with hot bitumen used in preparing the asphalt concrete mix. Marshall Mix design method is used, first to determine the optimum bitumen binder content with 3 three trial mixes carrying bitumen percentages of 5, 5.5 and 6 percent and then further to test the modified mixture properties at varying percentage 3, 5, 7, 9 11 and 13 percent has been taken into consideration.

I. INTRODUCTION

Progress follows the line of transportation. Transportation contributes to the economic, industrial, social and cultural development of any country.

Transportation by road system is the only mode which could give maximum flexibility of service from origin to destination, to one and all. Proudly, India is having second largest road network in the world, spanning over a total of 5.9 million km with 1.70 km of roads per square kilometer of land, and road network size consisting all types of roads including Expressways length 1581 km. This road network transports 64.5 per cent of all goods in the country and 90 per cent of India's total passenger traffic uses road network to commute. Road transportation has gradually increased over the years with the improvement in connectivity between cities, towns and villages in the country.

According to Economic Survey 2017-18, Indian road network is consists of 1581 km -Expressways, 1,15,530 km -National Highways, 1,76,166 km -State Highways and 5,326,166 km Other major district and rural roads. These amazing networks of roads also have Elevated Expressways, Cloverleaf Interchange, river Road Bridge and flyover, which are longest and largest in India as well as in Asia.

There are two types of pavements based on design considerations i.e. flexible pavement and rigid pavement. Difference between flexible and rigid pavements is based on the manner in which the loads are distributed to the subgrade.

1) *Flexible Pavements:* Flexible pavement is constructed from mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade. Bitumen has been widely used in the construction of flexible pavements for a long time. This is the most convenient and simple type of construction. The cost of construction of single lane bituminous pavement varies from 20 to 30 lakhs per km in plain areas.

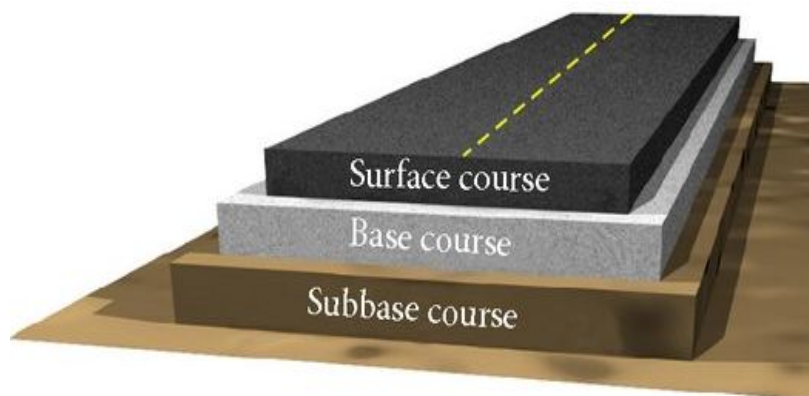


Fig. 1 Flexible pavement cross-section

- 2) *Rigid Pavements:* A rigid pavement is constructed from cement concrete or reinforced concrete slabs. The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resist the loads from traffic. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil.

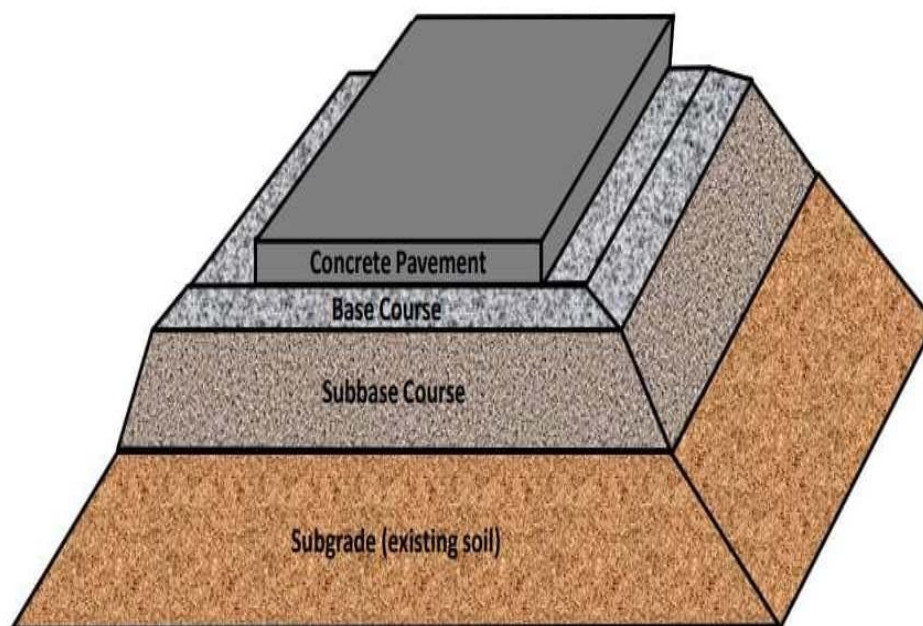


Fig. 2 Rigid pavement cross-Section

II. PROBLEM STATEMENT

In India, flexible pavements with bituminous surfaces are widely used. Due to increased traffic intensity of roads, overloading of commercial vehicles and temperature variation of pavements due to climatic changes leads to formation of various distresses like rutting, shoving, bleeding, cracking and potholing of bituminous surfacing. Due to high temperature, bitumen becomes very soft in summer and brittle in winter. Also, in a developing country like India, roadway construction is taking place at a very high pace which require large demand of construction material that too eco-friendly and economical. Several Studies have revealed that properties of bitumen and bituminous mixes can be improved/ modified with addition of certain additives and the bitumen premixed with these additives/modifiers is known as “modified bitumen”. The present study aims for use of modified bitumen by using waste plastic for road construction. This study includes details of literature and methodology of using modifiers in bitumen and aims to provide highway construction in an eco-friendly and economical way. The modified bitumen mix shows better binding property, stability, density and more resistant to water.

A. Polymer Modification of Bituminous Concrete: A Solution

Bituminous concrete used in the construction of flexible pavements can be modified by addition of waste polyethylene which is an environmental waste.



Fig. 1 An open drain clogged due to plastic waste

III. OBJECTIVES OF THE STUDY

The objectives of the study are as follows:

- 1) To enhance the properties of bituminous mixes with increased strength.
- 2) To conduct a series of laboratory tests conventional and modified bitumen binders and to study the suitability of the same for use in flexible pavement.
- 3) To improve the quality of flexible pavement construction by combining the bituminous binder with identified waste plastic material.
- 4) To propose an effective method of disposal of waste plastic (LDPE) by using them in flexible pavements.

IV. METHODOLOGY

To achieve the study goals, working procedure is as follows:

Selection of research area in the field of flexible pavement construction.

Review of previous studies, which include revision of books, scientific papers and reports in the field of recycled polymer modifiers of asphalt mix.

Title finalization.

Problem identification.

Material selection as per the need of study and material evaluation.

Identifying Optimum Bitumen Content (OBC) using Marshal Mix design procedure. Three percentages of bitumen have been examined to determine the best percentage of bitumen for the aggregates, which include 5%, 5.5% & 6% by weight of the mix (as per the MORTH specifications).

Identifying the effects of adding different percentages of Waste plastic (LDPE) as modifier on the asphalt mix properties comparing it with conventional mix in terms of bulk density, Marshal stability, flow value and air voids. Intended percentages are from 3% to 13 % by weight of OBC.

V. ANALYSIS OF DATA AND DISCUSSION

Testing is done on prepared Marshall Samples and the calculation work carried out to find out the desired parameters:

ρ_A Bulk Density

Va% Air voids content

Vb% Percent volume of bitumen

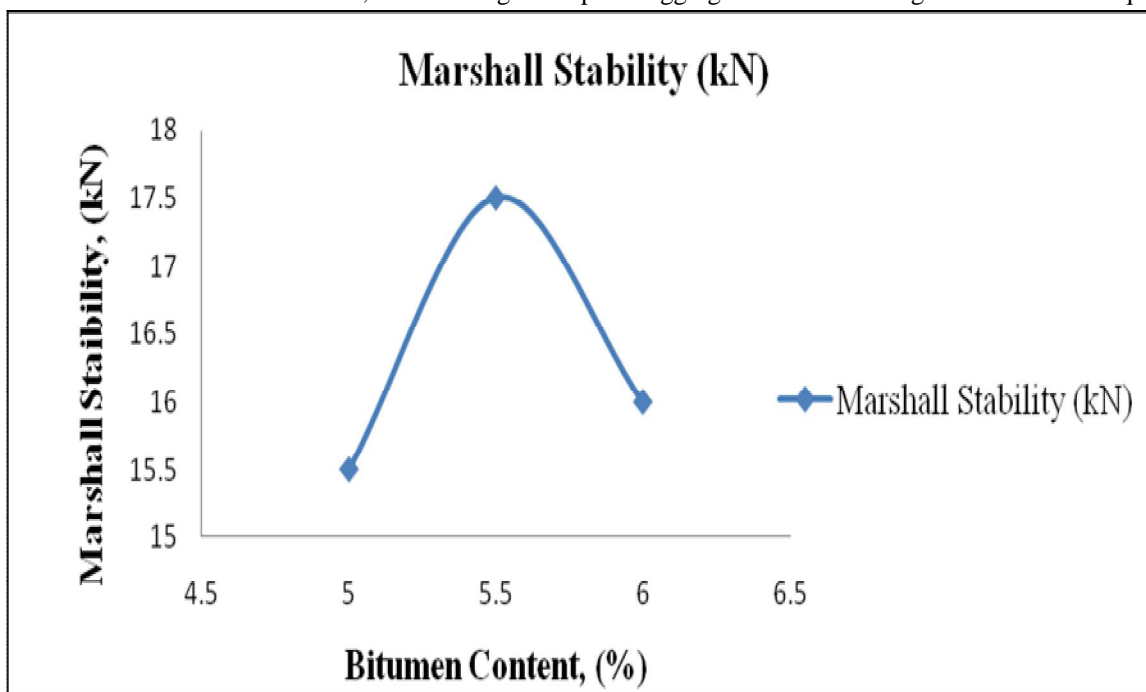
VMA% Percent voids in Mineral Aggregates

VFB% Percent Voids Filled with Bitumen

Marshall Stability results of ordinary BC with different % of bitumen content

Sample	Bitumen content (%)	Marshall Stability, (kN)
A	5.00	15.50
B	5.50	17.50
C	6.00	16.00

Above table results shows that OBC is 5.50%, so for 1200gm sample of aggregates 5.50% i.e. 66gm of bitumen is required.



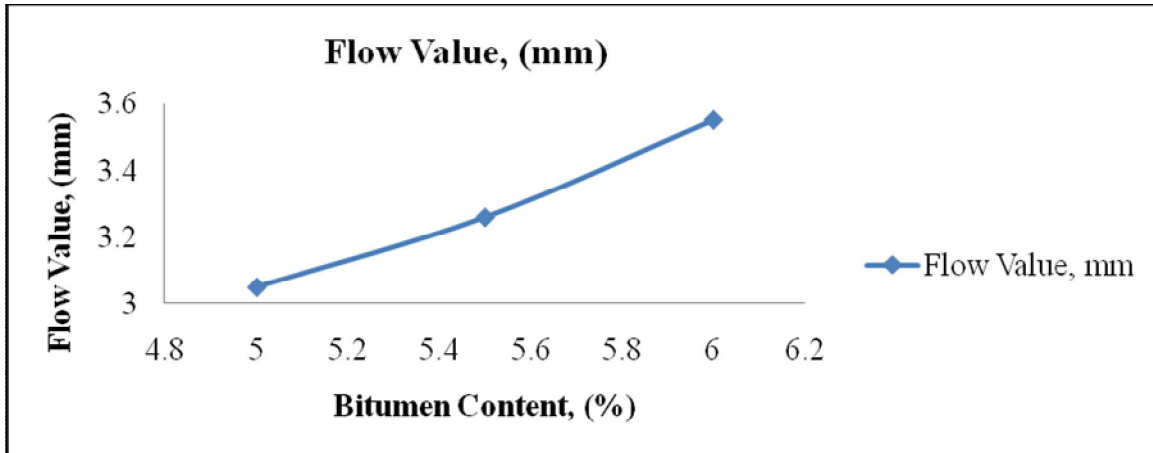
Marshall Stability graph of ordinary BC with different % of bitumen content

Stability is the maximum load required to produce failure of the specimen when load is applied at constant rate 50 mm/min. Stability of asphalt mix increases as the bitumen content increase till it reaches the peak at bitumen content 5.5% then it started to decline gradually at higher bitumen content.

Marshall Flow Value Results of ordinary BC with different % of Bitumen content

Sample	Bitumen content (%)	Marshall Flow, (mm)
A	5.00	3.05
B	5.50	3.26
C	6.00	3.55

Above table test results shows that Flow Value results of Marshall Samples are within the specified range i.e. 2mm to 4mm. Mean Flow Value is 3.28mm.



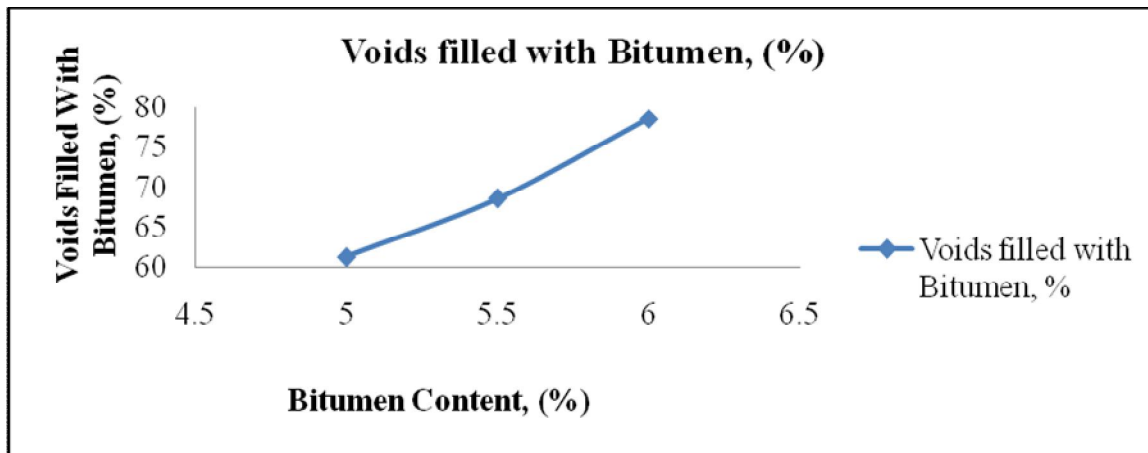
Marshall Flow Value graph of ordinary BC with different % of bitumen content

Flow is the total amount of deformation which occurs at maximum load. In Figure (4.3) Flow results for different bitumen contents are represented. Flow of asphalt mix increases as the bitumen content increase till it reaches the peak at the max bitumen content 6 %.

Percentage of Voids filled Results of ordinary BC with different % of bitumen content

Sample	Bitumen Content, (%)	Voids filled with Bitumen, (%)
A	5.00	61.27
B	5.50	68.53
C	6.00	78.52

Above table test results shows that Voids filled with Bitumen in Marshall Samples are within the specified range i.e. 65% to 75%.



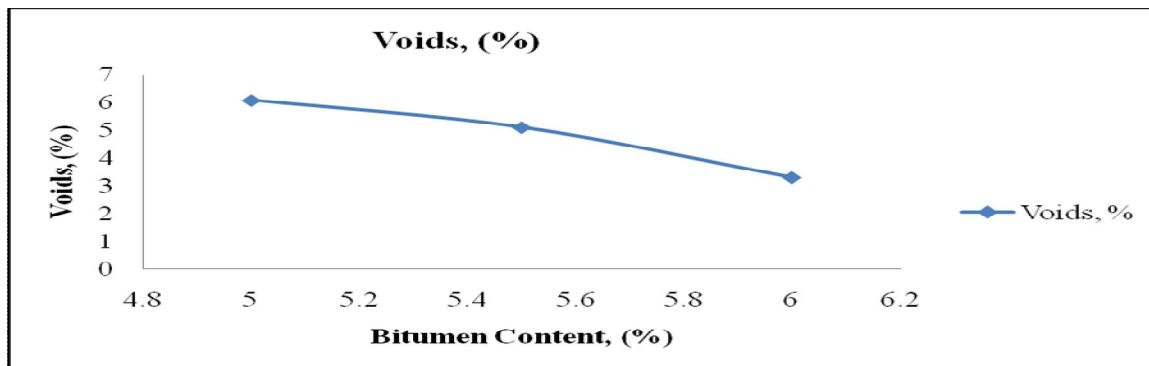
Voids filled graph of ordinary BC with different % of bitumen content

Voids Filled with Bitumen (VFB) is the percentage of voids in mineral aggregates filled with bitumen. In Figure (4.4) VFB% results for different bitumen contents are represented. Minimum VFB content value is at the lowest bitumen percentage (5%), VFB% increase gradually as bitumen content increase due to the increase of voids percentage filled with bitumen in the asphalt mix.

Air Voids Result of ordinary BC with different % of Bitumen Content

Sample	Bitumen Content, (%)	Air Voids, (%)
A	5.00	6.08
B	5.50	5.1
C	6.00	3.29

Above table test results shows that Flow Value results of Marshall Samples are within the specified range i.e. 2mm to 4mm. Mean Flow Value is 3.28mm



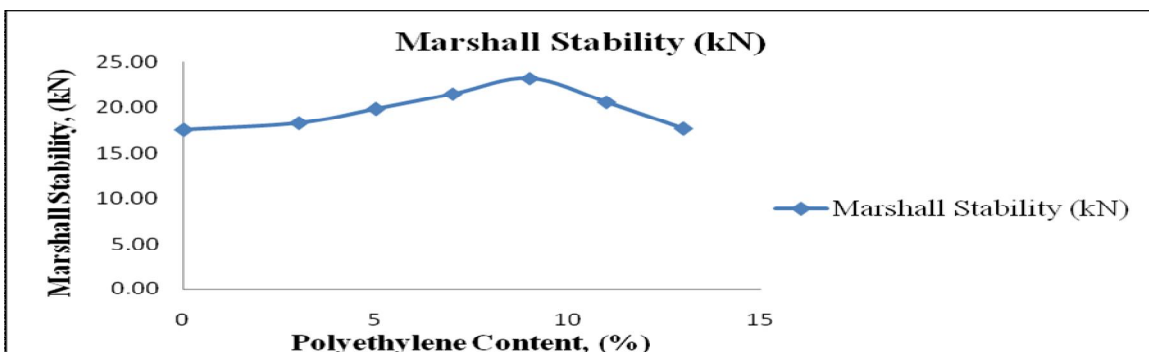
Air Voids graph of ordinary BC with different % of bitumen content

Va % is the percentage of air voids by volume in specimen or compacted asphalt mix. In Figure (4.5) Va% results for different bitumen contents are represented. Maximum air voids content value is at the lowest bitumen percentage (5%), Va% decrease gradually as bitumen content increase due to the increase of voids percentage filled with bitumen in the asphalt mix.

Marshall Stability Results of samples with varying polyethylene content

Sample No.	Polyethylene Content (%)	Avg. Marshall Stability (kN)
B	0	17.57
D	3	18.30
E	5	19.83
F	7	21.47
G	9	23.23
H	11	20.57
I	13	17.70

Above table results shows that OPC is 9%, so for partially replacing OBC (5.5% i.e. 66 gm) 5.94gm out of 66gm bitumen can be replaced by plastic for increased Marshall Stability.

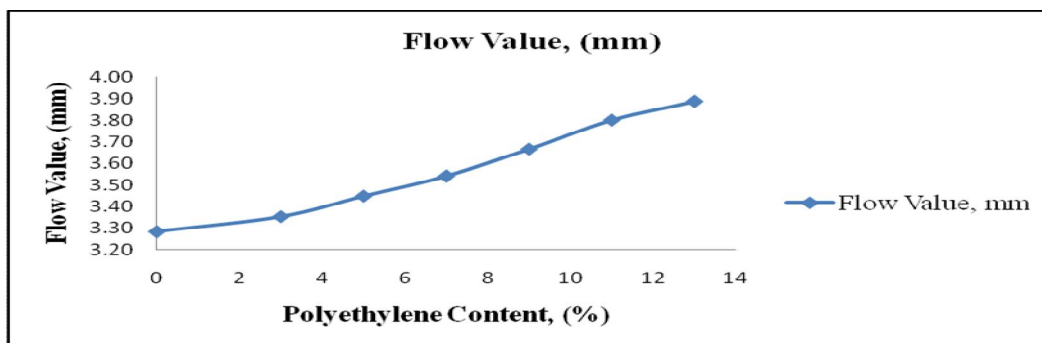


Marshall Stability graph of modified BC with different % of polyethylene content

Marshall Flow Value Results of samples with varying polyethylene content

Sample No.	Polyethylene Content, (%)	Flow Value (mm)
B	0	3.28
D	3	3.35
E	5	3.45
F	7	3.54
G	9	3.66
H	11	3.80
I	13	3.89

Back page table results shows that at OPC 9%, the Flow Value is 3.66mm which is in the specified range.

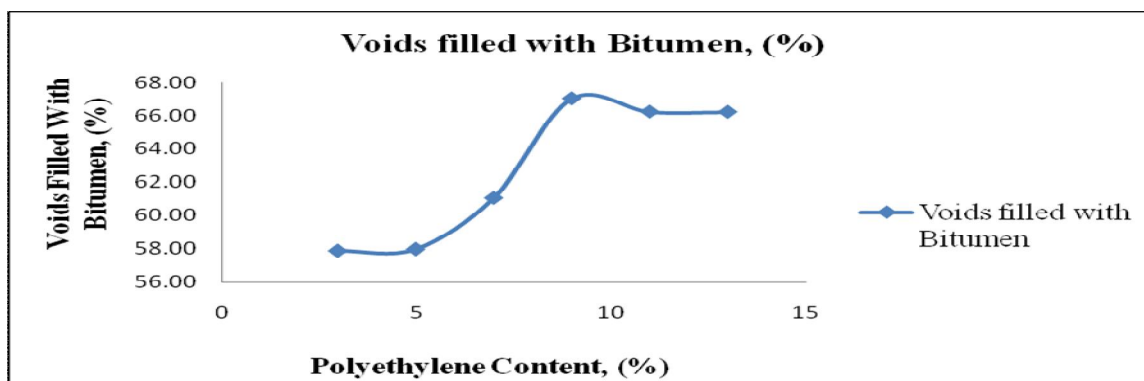


Marshall Flow Value graph of modified BC with different % of polyethylene content

Voids filled with bitumen, Results of samples with varying polyethylene Content

Sample No.	Polyethylene Content, %	Voids Filled with Bitumen, (%)
B	0	68.53
D	3	57.87
E	5	57.97
F	7	61.06
G	9	67.01
H	11	66.21
I	13	66.19

Above table results shows that at OPC 9%, the percentage of voids filled with bitumen is 67.01, which is in the specified range.

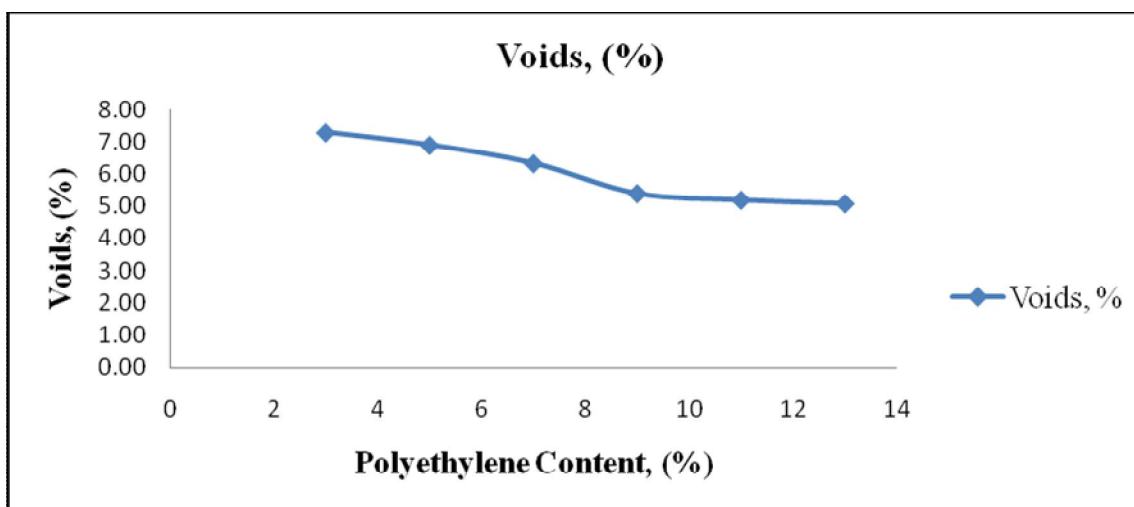


Voids filled graph of modified BC with different % of polyethylene content

Voids %, Results of samples with varying polyethylene content

Sample No.	Polyethylene Content, (%)	Voids, (%)
B	0	5.51
D	3	7.29
E	5	6.89
F	7	6.32
G	9	5.38
H	11	5.18
I	13	5.07

Above table results shows that at OPC 9%, the percentage of Air Voids in total mix, $V_v\%$ is 5.38%, which is in the specified range.



Air Voids graph of modified BC with different % of polyethylene content

VI. CONCLUSIONS

A detailed study has been done to analyze the effect of polymer modification in BC layer of flexible pavements and results of Marshall Properties supported the study.

The following conclusions are drawn from the study:

It is observed that Marshall Stability value increases with polyethylene content up to 9% and thereafter decreases.

It is also observed that the Marshall Flow value shows minor changes upon addition of polythene. While, the mean value of the results found satisfactory.

Percentage of Voids in Mineral Aggregate (VMA), Percentage of Air Voids in Bituminous Mix (V_A) and Percentage of Voids Filled with Bitumen (VFB) are within the design requirements of bituminous mixes for pavement layers.

Effect of admixtures: Fly Ash & Lime helped in gaining the strength and resistance to deformation.

Considering these factors we can assure that we can obtain a more stable, durable and economical mix for the pavements by polymer modifications.

A regular road requires 10 tonnes of bitumen for each kilometer. A plastic road however, requires only nine tonnes of bitumen and one tonne of waste plastic for coating. So, for every km, the plastic roads save as much as one tonne of bitumen. And this will also help in job creation in scrap industry and allied activities.

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