A Study on Influence Of LDPE on Properties of Bitumen Pavement Under Submergence Condition

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***Abstract*— Now a days, the bituminous pavements are expected perform better since there is steady increment in high traffic intensity and there is significant change in daily and seasonal temperature. In addition, the performance of bituminous pavements is found to be very poor in moisture induced situations. Over the years, the presence of moisture has been major cause for pavement failure. Moisture damage leads to stripping which is the disintegration of binder from the aggregates. Research has indicated that the addition of polymers to asphalt binders helps to increase in the bond between the aggregate and the binder which can enhance many properties of the asphalt pavements to help meet the above mentioned demands. Plastics are used extensively in day to day life and there are tonnes of wastes are generated. The safe disposal of these plastic wastes poses a major problem to society by considering the surrounding environment. It is because plastic is a non-biodegradable product and hence using this as an additive is considered to be beneficial. In the present study, an attempt has been made to study the influence of partial replacement of Low density polyethylene (LDPE) wastes in bituminous pavement when submerged in water between 1 to 4 days. Various percentage of LDPE i.e. 2%, 3%, 4%, 5%, 6% were mixed with bitumen and subjected to Marshall test. And various engineering properties were studied and compared between with and without LDPE content. Mainly this study focused on the effect of LDPE waste on the Marshall stability and loss in stability by using retained Marshall Stability theory. The results revealed that 5% addition of LDPE gave the best results on all soaking days. Hence LDPE is therefore can be recommended as a good hydro-carbon additive for the reduction in loss of stability.**

Keywords*— Marshall Stability test; Bitumen; Plastic (Low density polyethyelene); OBC (Optimum Binder Contetnt);

INTRODUCTION

Transportation contributes to the economic, urbanization, social and cultural development of any country. Three basic modes of transportation are by land, water, air. Road network of any country is the backbone of its economy. All hard surfaced pavement types can be categorized into two groups, flexible and rigid. Construction of highway involves a huge outlay of investment. An accurate engineering design can save considerable amount of money which is to be invested as well as reliable performance of the highway can be attained. The bituminous mix design aims to determine the optimum proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical.

The failures of roads and highways can be attributed to geological, geotechnical design, construction and usage. There are many other factors which cause pavement failure. One such factor is water, when rainfall occurs part of the water flows on the surface and part of it percolate through the soil mass until it reaches the ground water. In India, there are several regions where heavy rainfall occurs which results in persistent flooding over constructed roads under flat terrain. This flood condition leads to the failure of road pavement due to many reasons such as increase in moisture content, decrease in strength, stripping of bitumen etc. The most serious consequence of flooding is the loss of adhesion between the aggregate and bitumen. This leads to deterioration of the surface layer which has major impact on the durability of the pavement. Under heavy rainfall, swelling is more predominant in asphalt or flexible pavement. It is an upward movement in a pavement due to swelling of the sub-grade on which it lies. It is caused due to several reasons such as swelling of expansive soils in the sub-grade, or frost heave due to ice under the pavement. It is essential to drain surface water from the carriage way and shoulder by not allowing it to percolate to the underlying sub grade layer.

Due to increase in population, urbanization, the industrial revolution and lifestyle resulted in an increase in usage of plastic waste. Safe disposal of this huge amount of waste plastic generated is a serious threat. Since these are non-bio-degradable products which are hazardous to environmental and human health. Some studies show that 10 million tonnes of plastic are produced in India and among which only 2 million tonnes of plastic waste is recycled. In the present life scenario, complete ban of plastic is not possible, hence Indian government has taken an initiative to implement 4R policy in the form of "Swachh Bharat Abhiyan".

Modification of BC with the synthetic polymer binder can be considered as a solution to overcome the above mentioned problems. On the basis of several studies, the bitumen roads can be modified by using LDPE as a hydrocarbon additive to the mixture so as to reduce its swell and loss of stability in the asphalt pavement. It was discovered that durability of the pavement, fatigue life was increased. And some studies showed that rutting and low temperature cracks of the pavement are reduced.

Use of the waste plastic in the construction of bitumen roads will help in the disposal of vast quantities of plastic. Dr. Rajagopalan Vasudevan is an Indian scientist, professor at Thiagarajar College of Engineering who developed an innovative method to reuse plastic waste to construct better, more durable and very cost effective roads. He is known as "Plastic man of India". He was awarded Padma Shri in 2018. Studies have revealed that in bituminous construction addition of waste plastics in small doses about 5% to 10%, by weight of bitumen helps in substantial increase in the Marshall stability, strength and other desirable properties of the bituminous mix. This results in improved longevity and pavement performance. The use of waste plastic thus contributes to the construction of green roads.

1.1. Literature Review

Igwe, Kemejika and ***Amadi-Oparaeli (2015)***, carried out a study on asphalt pavement in order to ascertain the properties of swell and loss in stability that will occur under submergence of water between 1 to 5 days. It was found that the addition of polystyrene to bituminous concrete mix up to 2.5% reduced the amount loss of stability due to submergence of concrete. Similarly, the amount of swell in the bituminous concrete was reduced considerably due to submergence.

Nur Ali (2013), carried out a study on the effect of flood puddle to the durability of asphalt concrete mixture on road pavement. In this technique immersion test was carried out on 1, 3, 5 and 7 days to the two types of asphalt mixture, one with Retona as additive and other without it and those results were compared. The research revealed that asphalt mixture not containing Retona experienced a rapid decrease of RSI value to follow an increase in duration of immersion. Further, the FDI and SDI values of the mixtures also showed that the deterioration of durability of the asphalt mixture containing Retona was smaller than the mixture without Retona. Overall, the Laboratory experiments showed that the asphalt concrete mixtures retained until seven days of submergence, where the mixture containing Retona was more durable than the mixture without it.

Ottos and ***Amadi- Oparaeli (2018),*** focused on the effect of polythene on the index of retained stability. The result revealed that addition of polythene to asphalt concrete at 3% provided better resistance against the effect of moisture in term of the Index of Retained Stability. Hence the performances of the modified asphalt concrete when soaked in water under various days were better than the conventional asphalt concrete in terms of its Index of retained stability. It was also observed that 3% of polythene bags gave better results in all the days of soaking.

1.2. Objectives

The main aim of the project is to reduce the loss of strength in roads under flood condition which arises during heavy rainfall by using LDPE wastes as the partial replacement of bitumen.

The objectives of the study are:

- To reduce the loss of stability due to submergence in bitumen pavement.
- To provide road which has relatively longer service life.
- To reduce the cost of construction of bituminous pavement by using LDPE as the partial replacement of bitumen.
- To provide an eco-friendly roadway.

I. MATERIAL

2.1 Bitumen

Bitumen is black viscous mixture which is obtained from the fractional distillation of crude oil. It acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures.VG30 bitumen was used in the present study to prepare the samples. Table 1 shows the test results of basic properties of bitumen.

Table 1: Basic Properties of Bitumen

Properties	Results
Specific gravity	1.02
Penetration	36 mm
Softening point	37°C
Flash point	330°C
Fire point	350°C
Ductility	79 mm
Viscosity	60/70

2.2. Fine Aggregate

Aggregates of size below 4.75 mm as per MORTH Specifications (5th revision) [Anonymous, 2013] were used as fine aggregate. Fine aggregates were collected from college premises with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. It fills the voids in the coarse aggregate and stiffens the binder. Table 2 shows the test results of basic properties of fine aggregates.

Table 2: Basic Properties of Fine Aggregates

Properties	Results
Specific gravity	2.64
Water absorption	1.45%

2.3. Coarse Aggregate

In present study, coarse aggregates of 20mm down size were used as coarse aggregates as per MORTH Specifications (5th revision) [Anonymous, 2013]. Table 3 shows the test results of basic properties.

Table 3: Basic Properties of Coarse Aggregates

Properties	Results
Specific gravity	2.67
Impact value	18.75%
Water absorption	0.39%

2.4. LDPE Films

Stabilizing additives are used in the mixture to provide better binding property. In this present study LDPE films were used as stabilizing additive to improve performance characteristics of pavement. These were collected from milk parlour. LDPE has good tensile strength, stiffness and creep. It exhibits excellent toughness at low temperature. Low density plastic waste shredded into pieces of uniform size was used in the study.

II. EXPERIMENTAL METHODS

3.1. Gradation of Aggregates

For preparation of Bituminous mix (Dense bituminous macadam), aggregates as per MORTH grading as given in Table 1 were selected. After selecting the aggregates and their gradation, proportioning of aggregates was done. Common methods of proportioning of aggregates are trial and error procedure, graphical method, analytical method. In this study graphical method was adopted for gradation purpose. In graphical method Rothfuch's method was used. The results from Rothfutch's method are shown in table 5.

Table 4: Results obtained from Rothfutch's graph

IS Sieves	% used	Wt. of Materials (g)
20 mm	25	300
12.5 mm	30	360
6 mm	25	300
S Dust	17	204
Filler	3	36
Bitumen	-	-
Total	100	1200

3.2. Marshall Stability Test

The Marshall stability of compacted specimen of bituminous mix indicates its resistance to deformation under applied incremental load. This flow value indicates the extent of deformation it undergoes due to loading or its flexibility. This test is conducted on compacted cylindrical specimens of bituminous mix of diameter 101.6mm and thickness 63.5mm. The Marshall test conducted in the present study was carried out mainly in two different stages:

- Preparation of Marshall samples
- Tests on samples

3.3 Preparation of Marshall samples

This technique involves preparation of a series of specimens for bitumen contents from 3% to 7% with increments of 0.5% such that test data curves revealed well-defined values. In order to provide accurate data, two test specimens were prepared for each percentage of asphalt. In this study, two classes of asphalt concrete were prepared namely unmodified bituminous concrete and modified bituminous concrete. Where unmodified samples are those samples without plastic replacement and modified bitumen samples are those in which bitumen is replaced by plastic (by weight of bitumen).

3.4. Mixing and sample preparation

The mixing of ingredients was done as per the following procedure:

- The aggregates and filler were mixed together in designed proportion to fulfill the design requirements and specified gradation. Approximately 1200gms of the sieved aggregates and filler material were taken and heated to a temperature of 175 °C to 190 °C on a controlled condition.
- The Bitumen binder was heated to a temperature of 120 °C to 165 °C. The weighed quantity of bitumen (say 3.5 percent by weight of aggregates) was added to the heated aggregate.
- Then it was thoroughly mixed at the recommended temperature of 160 °C for VG30 (60/70 penetration grade) grade bitumen. Then the mix was transferred into a casting mould and was compacted by rammer with 75 numbers of blows on either side of the sample at temperature of 149 °C of VG 30 grade bitumen.
- The compacted specimens were cooled to room temperature in the mould and then removed using a specimen extractor.
- The weight of specimen in air and in water was determined.
- The specimens were kept immersed in water in thermostatically controlled water bath at 60 °C ± 10 °C for 30 to 40 minutes.

3.5. Marshall test on samples

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate of 50 mm/min. In the present study the Marshall properties such as stability, flow value, unit weight and air voids were studied. The results obtained were used to determine the optimum binder content using well- defined graph. After obtaining the optimum asphalt content; fresh asphalt mixes were prepared using the optimum value. Then these samples were immersed in moisture at varying duration i.e. 1 to 4 days. in the Marshall method of mix design, each compacted test specimen is subjected to the following tests and analysis.

a. Bulk specific gravity (Gb)
b. Stability and Flow test
c. Density and Void analysis

a. Bulk specific gravity (Gb):

Bulk specific gravities of saturated surface dry specimens were determined.

b. Stability and flow tests:

After determining the bulk specific gravity of the test specimens, the stability and flow tests were performed. When the testing apparatus is ready, the specimens were taken out from controlled water bath after 30-40 minutes. the specimen was placed at Marshall test head. The flow meter was initially set to zero. The load was applied at a constant rate of deformation of 51 mm per minute. The Marshall Stability Value which is the maximum load before failure and the corresponding flow value which is the deformation of specimen up to maximum load was recorded. The entire testing process starting with the extraction of specimen from bath up to measurement of flow and stability shall not take more 30 seconds. While the stability test is in progress, hold the flow meter firmly over the guide road and record.

The above procedure was carried out on specimens over a series of specimens for bitumen contents from 3% to 7% with increments of 0.5%. In this study the Marshall properties such as stability, flow value, unit weight and air voids were studied to obtain the optimum binder content.

3.6. Preparation of modified bitumen samples

In this study LDPE (Low density polyethylene) was used as a partial replacement of bitumen in DBM. The LDPE films were shredded into small pieces. After obtaining the optimum binder content values the LDPE films were added. The LDPE was added at varying amounts i.e. 2%, 3%, 4%, 5%, 6% by weight of the optimum binder content to the samples. There are two important processes for manufacturing bitumen mix using a waste plastic namely dry and wet process. Wet process was adopted for partial replacement of bitumen with plastic in the present experimental study. In the wet process waste plastic were shredded and then mixed with bitumen in a particular ratio. By mixing plastic with bitumen the ability of bitumen to withstand high temperature is increased. This mixture is then added to heated aggregates as mentioned above in preparation of Marshall samples.

3.7. Submergence

The unmodified samples and modified bitumen samples were immersed in water at varying duration of 1 to 4 days. The samples were subjected to loading and the stability value was obtained after each day of curing and the values were recorded.

3.8. Retained strength index (RSI)

Retained Stability is the measure of moisture induced striping in the mix and subsequent loss of stability due to weakened bond between aggregates and binder. The test was conducted of the Marshall machine with the unmodified and modified Marshall samples. The stability for each samples was determined before and after immersion.

$$RSI = \frac{S_i}{S_0}$$

Where,

S_i = stability after immersion at time ti or stability of conditioned specimen.

S_o= stability before immersion or stability of unconditioned specimen.

III. RESULTS

4.1. Marshal test for obtaining optimum binder content

Table 5: Marshall Stability and flow values for control mix

Bitumen%	Stability in kg	Flow value in mm
3.0	2300.0	3.60
3.5	2650.0	3.65
4.0	2725.0	3.75
4.5	2825.0	3.80
5.0	2112.5	4.30
5.5	2100.0	4.80
6.0	2087.5	5.00

Table 6: Density and void analysis for control mix

Bitumen%	G_b	V_v	VMA	VFB
3.0	2.272	9.168	15.917	42.523
3.5	2.300	6.9120	14.925	53.688
4.0	2.249	7.9272	15.853	49.994
4.5	2.302	7.420	15.389	51.841
5.0	2.021	7.2905	16.347	55.402
5.5	2.327	10.3793	19.134	45.755
6.0	2.090	8.835	17.741	50.579

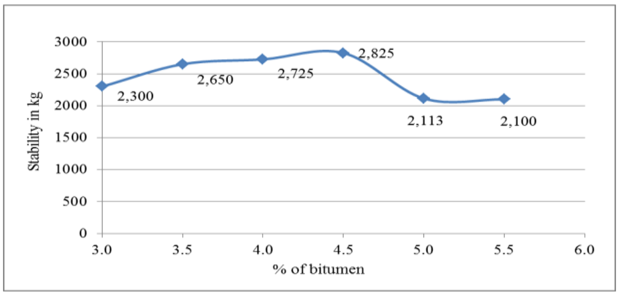

Fig. 1: Marshall Stability for Regular DBM

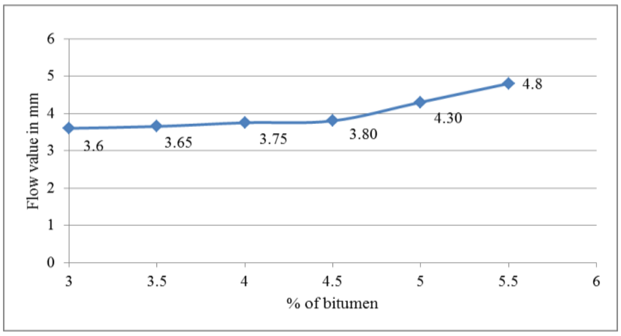

Fig. 2: Flow Value for Regular DBM

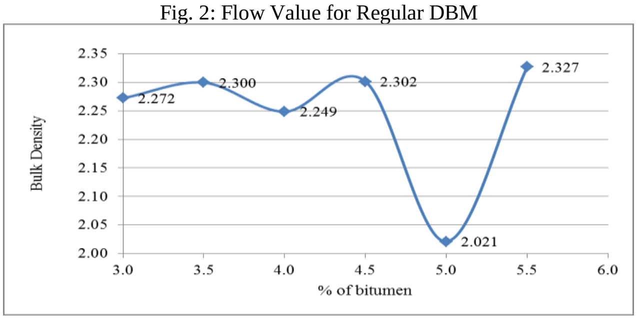

Fig. 3: Bulk Density for Regular DBM

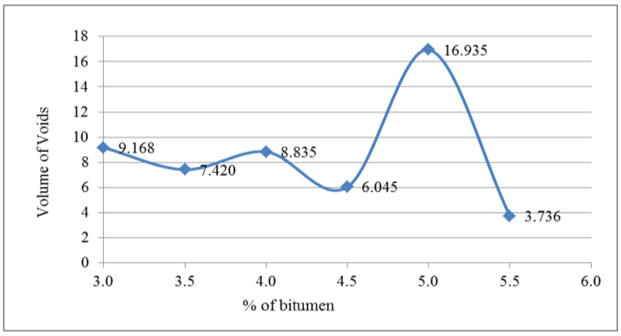

Fig. 4: Volume of Voids in Regular DBM

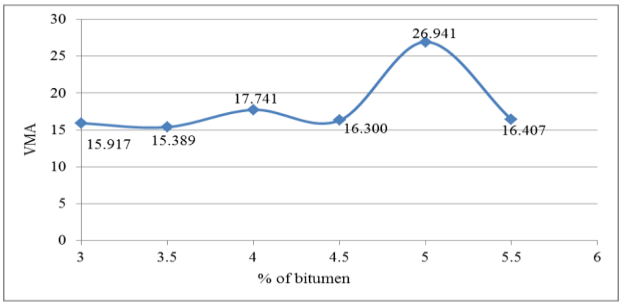

Fig. 5: VMA in Regular DBM

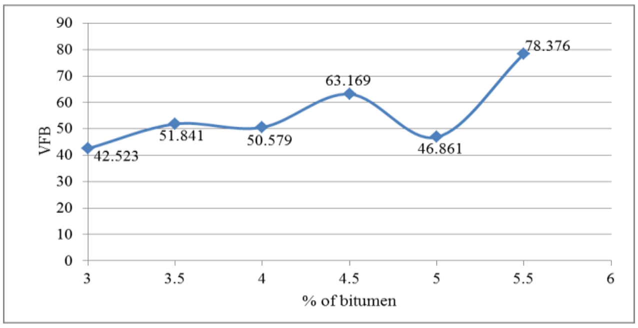

Fig. 6: VFB in Regular DBM

4.2. Marshall test on submerged samples

Marshall test for each percentage of LDPE, 2 samples have been tested. So the average of 2 was taken. The mean values are shown in Table 5.4.

Table 7- Marshall Stability results of bituminous concrete soaked between 1-4 days for varying percentage of LDPE replacement.

LDPE Content (%)	Marshall Stability Values (N) (average values)				
	Day-0	Day-1	Day-2	Day-3	Day-4
0	2800	1975	2287.5	1825	1050
2	2850	2400	2225	1900	1350
3	3175	2900	2450	2075	1625
4	3602.5	3325	3037	2690	2300
5	3000	3025	2625	2425	1950
6	2400	2012.5	1720	1595	1450

Table 8- Retained Marshall stability of bituminous concrete soaked between 1-4 days for varying percentage of LDPE replacement.

LDPE Content (%)	IRS (average values)			
	Day-1	Day-2	Day-3	Day-4
0	70.54	81.69	65.18	37.5
2	84.21	78.07	66.67	47.37
3	91.34	77.17	65.35	51.18
4	92.3	84.3	74.67	63.84
5	100.83	87.5	80.83	65
6	83.85	71.67	66.46	60.42

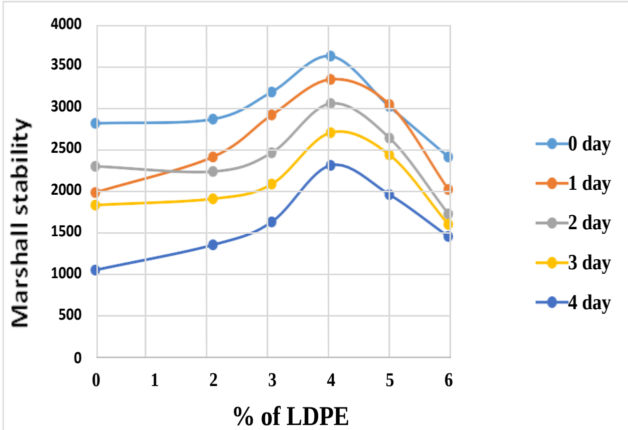

Fig. 7: Marshall stability vs. LDPE

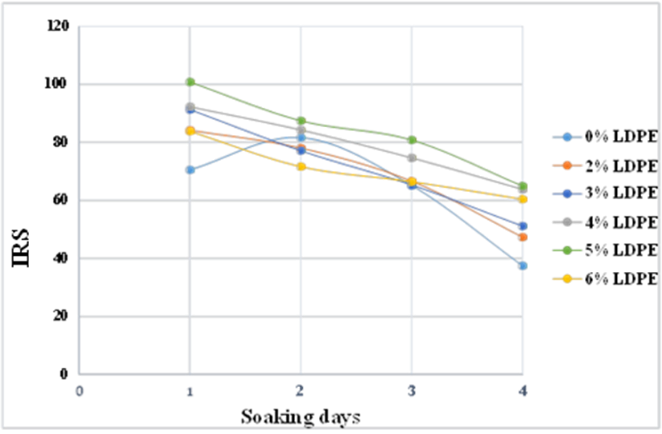

Fig. 8: IRS vs. Soaking days

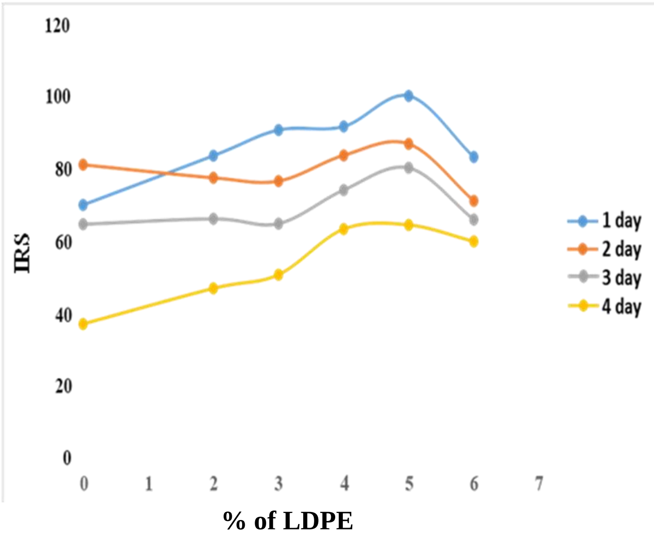

Fig. 9: IRS vs. LDPE content

IV. DISCUSSIONS

It was observed from Fig 1 to 6 that with increase in bitumen concentration the Marshall stability value increases up to certain bitumen content and there after it decreases. That particular bitumen content is called as optimum binder content (OBC). In present study, OBC for conventional DBM mix was found as 4.5%.

The reduction in loss of stability of bituminous pavement could be achieved by replacing some amount of bitumen by LDPE. From the graph 5.9 it was observed that the Marshall stability value gradually increased from 0% to 4% and thereafter its value start decreasing. Using the theory of retained Marshall Stability it was observed that addition of LDPE showed reduction in loss in stability by increasing IRS value between 0% to 5% LDPE content after which IRS value start to decline.

The index of retain stability is one of the most important property when dealing with issues related to submergence of bituminous concrete. The maximum IRS value obtained for the unmodified bituminous concrete was 84.80 % which was at 2nd day of soaking. From graph 5.09 and 5.10 it was observed that the modified bituminous concrete possess much higher and higher values than that of conventional bituminous concrete. The maximum IRS obtained for 2% to 6% LDPE content were 84.21%, 94.34%, 92.3%, 100.83% and 83.85%. From graph 5.10 the addition of LDPE at 5% gives the highest value of 100.83%.

V. CONCLUSION

- The performance of modified bituminous pavement was better in terms of its IRS values than conventional bituminous pavement i.e. unmodified one. It is important to note that 5% addition of LDPE gives the best results on all soaking days.
- Hence LDPE is therefore can be recommended as a good hydro-carbon additive for the reduction in loss of stability.
- The resulting road pavement can withstand heavy traffic and hence it provides better service life.
- By partial replacement of LDPE, the amount of bitumen used is decreased which thereby results in reduction in the cost of construction of bituminous pavement.
- This study will have a positive impact on the environment as it will reduce the plastic wastes which are considered a threat.

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