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Partial Replacment of LDPE in Bituminous Pavement

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***Abstract:** Bituminous concrete mix is a composite material which is widely used for the construction of flexible pavements, surfacing of roads and airports, various parking lots etc. It generally consists of bitumen which works as a binder material, coarse aggregates, fine aggregates and filler materials which are generally mixed together in right proportion and laid down in layers followed by the compaction. In this present age of modernization and urbanization, construction is non stoppable and the construction by demolishing of old building has arisen a serious problem of treatment of demolished waste. Similarly, the use of plastic in our day-to-day life and its improper disposal is also creating serious environment pollution. So, there is big challenge in managing the demolished waste as well as the waste plastics. In this project i.e. partial replacement of LDPE in Bituminous concrete mix we have tried to replace LDPE (2%, 4%, 6% and 8% respectively) in bitumen content for the improvement of the pavement characteristics satisfying both the strength criteria and the economic aspects giving emphasize to less environment degradation and sustainability.*

***Key Words:** Bituminous concrete, Pavement, LDPE, Subgrade, Sub-base course, Base course, Binder course, Prime coat, Tack coat, Seal coat, Softening point, Ductility, Penetration value, Bulk Density.*

I. INTRODUCTION

This project has been developed for the reuse of the Low density polyethylene. The main aim of this project is to replace the certain amount of a bitumen by the LDPE for the improvement of the Bituminous pavement characteristics satisfying both the strength criteria and the economic aspects giving emphasize to less environment degradation. In this project we have used LDPE in the partial replacement of Bitumen and checked whether it met the specifications and standard. LDPE used in this project has been obtained by converting the plastic (polythene bags, milk pouches, lotion bottles, eye drop bottles into smaller pieces of size less than (2.36mm).

II. LITERATURE REVIEW

Currently all over the world concrete is the composite materials used for the construction of any Civil Engineering. In this project there was also partial replacement in the bitumen (4.5, 5, 5.5, 6 and 6.5) % by LDPE by weight respectively [6] [7] [8] [9].

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By the partial replacement of the LDPE a bituminous mix was prepared and then checked for the Marshall stability and the flow value.

A. Objectives

The main objective of this project was to study the variation in the characteristics of the mix when Bitumen binder was replaced by various percentages of LDPE. The objectives of this project are listed below:

a) Strength to resist shear deformation under traffic at higher tempe

b) To study the properties of the bitumen binder with replacement by LDPE.

c) To find out the optimum binder content.

d) To find out the optimum quantity of LDPE when replaced in binder will enhance the overall properties of the mix.

B. Research Papers

1. [1] Investigate the effectiveness of polymerized pellets mix additive on improving asphalt mix properties. In this paper stiffness, rutting, fatigue, and thermal cracking resistance properties of asphalt mix modified with polymerized pellets are compared to the mixes containing unmodified and polymer-modified binders.

2. [2] Studied the evaluation of modified bituminous concrete mix developed using rubber and plastic waste materials. Present study attempts to utilize these waste materials as partial replacement of bitumen to develop a modified binder, for making bituminous concrete mix. To simulate with the field conditions, 'Marshall Stability Analysis' was performed on the samples prepared by partially replacing 'Optimum Bitumen Content' with waste plastic (4%, 6%, 8% and 10%) and crumb rubber (5%, 10% and 15%). Experimental results demonstrate that partial substitution of bitumen with waste plastic results up to 16% increment in strength whereas with rubber material, about 50% increment in strength was observed as compared to the conventional mix (CM).

3. [3] Investigate the engineering properties of the asphalt mixtures containing waste plastic at different percentages i.e. 4%, 6%, 8%, and 10% by weight of bitumen The experimental tests performed in the study were stability, tensile strength, resilient modulus and dynamic creep test. Results showed that the mixture with 4% plastic has the highest stability (184kN). However, the stability slightly decreases with the increase of plastic additive. On the other hand, the highest tensile strength among the modified asphaltic concrete is 1049kPa (8% plastic added). The modified asphalt mixture with 8% plastic has the highest resilient modulus, which is 3422 MPa (25°C) and 494Mpa (40°C). Where the highest creep modulus recorded is 73.30Mpa at 8% plastic added.

4. [4] [10] Firstly studied the properties of bitumen with the plastic replacement and the properties of aggregates with plastic. Then after conducting Marshall 26 stability test and flow test with varying percentage of plastic replacement it came to a conclusion that use of 15% plastic content on bitumen by its weight increased the marshal stability value and the flow value decreased (resistance to permanent deformation on load increased).

5. [5] The waste plastic and rubber can be used to partially replace the conventional material which is bitumen to improve desired mechanical characteristics for particular road mix. In the present study, a comparison is carried out between use of waste plastic like PET bottles and crumb rubber (3%, 4.5%,6%,7.5%,9%by weight of bitumen) in bitumen concrete mixes to analyze which has better ability to modify bitumen so as to use it for road construction. 6% plastic by the wt. of bitumen was found out as an optimum bitumen content with all the test within limits.

III. RESEARCH METHODOLOGY AND EXPERIMENTATION

The main objectives of bituminous mix design (sometimes also called asphalt mix design) is to determine the proportion of the bitumen content, filler, fine aggregates and coarse aggregates to produce a mix which is workable, strong, durable and economical. There are two ways for designing of mix design i.e. Dry mix design and wet mix design. In Bitumen mix design we will decide:

1. Proportion of bitumen
2. Proportion of coarse aggregate
3. Proportion of fine aggregate
4. Proportion of filler material

A. Constituent of Bituminous Mix

The main constituents of a bitumen mix for pavement construction are:

1. Binder: - Binder is any material which is used to bind separate particles together to give appropriate consistency, or facilitate adhesion to a surface and offers impermeability. In bituminous mix design bitumen, asphalt and tar are known as binder.

2. Coarse Aggregates: - These are the aggregates which offers compressive and shear strength to the mix and also facilitates good interlocking properties between aggregates.

3. Fine Aggregates: - Aggregates which fill the voids in the mix created by the coarse aggregates and provide stiffness to the binder are known as fine aggregates.

4. Filler: -Fillers are finely divided substances usually have a particle size of less than 75 microns which are insoluble in bitumen. The functions of filler material are to fill voids, to stiffen the binder and to offer impermeability.

For the research, the partial replacement of bitumen is done with plastic powder

B. Experiment/Test Performed

Following tests and experiments were performed in this research.

a. Test on Bitumen

3.2.1.1 Penetration Test

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25°C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred. The Figure 0.1 shows a schematic Penetration Test setup.

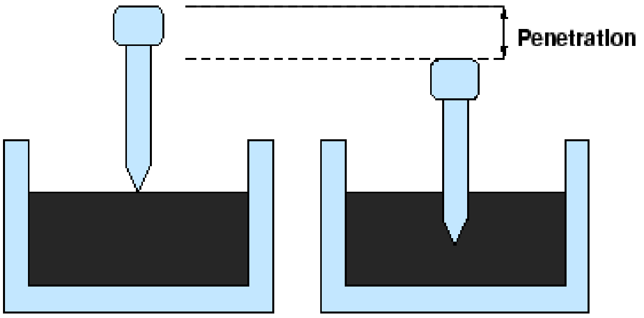

Fig:1- Penetration Test Setup

b. Softening Test

Bituminous does not suddenly change from solid to liquid but as the temperature increases, it gradually becomes software until it flows readily. All semi-solid state bitumen grades need sufficient fluidity before they are used for the application with the aggregate mix. Common procedure however is it to liquefy the bitumen by heating. The softening point is the temperature at which the substance attains particular degree of softening under specified condition of test. It is usually determined by ring and ball test. A brass ring containing the test sample of bitumen and liquid medium is then heated at a specified rate. The temperature at which the softened bitumen touches the metal plate placed at the specified distance below the ring is recorded as softening point of a particular bitumen. The apparatus the procedure is standardized by BIS.

c. Ductility Test

Ductility is defined as the distance in cm, to which a standard sample of the material will be elongated without breaking of the thread. In flexible, pavement the bitumen binder should form thin ductile films around the aggregates to improve the physical interlocking of the aggregate. If the binder material doesn't pass the desired ductility value, then cracks will form and lead to previous pavement. A minimum ductility value of 75 cm has been specified by the BIS. The test is conducted at a temperature at 27±0.5 the rate of pull of the pulling device of the ductility machine is of 50±2.5mm.

d. Specific Gravity of Bitumen (IS: 1202 – 1978

Pycnometer Method*:* This method covers the determination of specific gravity for semi-solid bitumen road tars and creosote and anthracene oil. Method (b): Balance method ′ This balance method of test is intended for the determination of the specific gravity of all bituminous materials sufficiently solid to be handled in fragments.

e. Test on Aggregate

f. Aggregate Impact Value

The aggregate Impact value indicates a relative measure of the resistance of aggregate to a sudden shock or an Impact, which in some aggregates differs from its resistance to a slope compressive load in crushing test. A modified Impact test is also often carried out in the case of soft aggregates to find the wet Impact value after soaking the test sample. Various agencies have specified the maximum permissible aggregate Impact values for the different types of pavements. IRC has specified the following values. The maximum allowable aggregate Impact value for water bound Macadam; Sub-Base coarse 50% whereas cement concrete used in base course is 45%. WBM base course with Bitumen surface in should be 40%. Bituminous Macadam base course should have A.I.V of 35%. All the surface courses should possess an A.I.V below 30%. questions and objectives of the study. Some of the semi-structured interviews were conducted over the virtual conversation (via Messenger and telephone), and some were conducted face-to-face.

g. Aggregate Crushing Value

The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of pavement aggregate possessing low aggregate crushing value should be preferred. The aggregate crushing value of the coarse aggregates used for cement concrete pavement at surface should not exceed 30% and aggregates used for concrete other than for wearing surfaces, shall not exceed 45% as specified by Indian Standard (IS) and Indian Road Congress (IRC).

h. Aggregate Abrasion Value

Abrasion is a measure of resistance to wear or hardness. It is an essentially property for road aggregates especially when used in wearing coarse. Due to the movements of traffic, the road stones used in the surfacing course are subjected to wearing actions at the top. When traffic moves on the road the soil particle (sand) which comes between the wheel and road surface causes abrasion on the road stone. The abrasion test on aggregate is found as per I.S.-2386-part IV.

i. Specific Gravity of Fine Aggregate and Coarse Aggregate

The specific gravity of an aggregate is generally required for calculations in connection with cement concrete design work for determination of moisture content and for the calculations of volume yield of concrete. The specific gravity also gives information on the quality and properties of aggregate. The specific gravity of an aggregate is considered to be a measure of strength of quality of the material. Stones having low specific gravity are generally weaker than those with higher specific gravity values. The bulk density of an aggregate is used for judging its quality by comparison with normal density for that type of aggregate. It is required for converting proportions by weight into proportions by volume and is used in calculating the percentage of voices in the aggregate.

C. MARSHALL STABILITY TEST

As discussed earlier there are various layers in flexible pavement. Surface course, binder course and base course. All these courses are subjected to the stresses applied due to the moving vehicles above it and the stress decreases as it transfers downward. Among these three courses, surface course is subjected to highest amount of wear and tear due to the traffic loads. Also, the surface course is exposed to the adverse climatic factors such as water and temperatures. Therefore, in order to withstand high stress condition, wear and tear due to traffic loads a high quality bituminous mix (also known as Hot Mix Asphalt) is required at the surface course. The mix should also possess adequate resistance to low temperature cracking, moisture induced damage and resistance to permanent deformation during hot weather caused by climatic variation.

IV. RESULTS AND DISCUSSSIONS

Table 1 Aggregate Impact Value Test at 0% and 25% RCA

S.no	Details of Sample		
		Sample 1	**Sample 2**
1	Total weight of aggregate sample filling the cylinder = (W_1) gm	493	440
2	Weight of the aggregate passing through 2.36mm is sieve after the test = (W_2) gm	55	51
3	Aggregate Impact Value $=W_2 / W_1 *100$	11.15	11.59
4	**Mean Impact Value**	**11.35**	

From the testing of Aggregate, the impact value is 11.82 Therefore, this aggregate Is classified as exceptionally tough and it meet the criteria for used in road Construction as well as for bituminous concrete surface.

Table 2: Aggregate Crushing Value Test

S.No	Details of Sample		
		Sample 1	Sample 2
1	Total weight of aggregate sample filling the cylinder = (W_1) gm	2745	2720
2	Weight of the aggregate passing through 2.36mm is sieve after the test = (W_2) gm	519	480
3	Aggregate Impact Value $=W_2 / W_1 * 100$	18.90	17.64
4	**Mean Crushing Value**	**18.27**	

Our natural mix for this project was the crushing value is 18.27

Table 3: Loss Angles Value Test

S.No	Details of Sample		
		Sample 1	Sample 2
1	Weight of aggregate of 20mm-12.5mm sieve in gram	5000	5000
2	Weight of the aggregate12.5-10mm sieve in gram	4000	3900
3	Percentage wear	20	22
4	Mean Los Angeles value (%)	21	

Table 4: - Specific Gravity, Apparent Specific Gravity and Water Absorption of Coarse Aggregates

S. No	Description of Items	Wt of Items
1	Weight of empty pycnometer (W_1)	645 g
2	Weight of pycnometer + coarse aggregate (W_2)	1047 g
3	Weight of pycnometer + Coarse aggregate + water (W_3)	1783 g
4	Weight of pycnometer + water (W_4)	1536 g
5	Specific Gravity = $(W_2 - W_1) / (W_4 - W_1) - (W_3 - W_2)$	2.59

Table 5: Specific Gravity, Apparent Specific Gravity and Water Absorption fine Coarse Aggregates

S.No	Description of Items	Wt. of Items
1	Weight of empty pycnometer (W_1)	645 g
2	Weight of pycnometer + fine aggregate (W_2)	884 g
3	Weight of pycnometer + fine aggregate + water (W_3)	1684 g
4	Weight of pycnometer + water (W_4)	1536 g
5	**Specific Gravity =** $(W_2 - W_1) / (W_4 - W_1) - (W_3 - W_2)$	**2.63**

Table 6: Specific Gravity of Bitumen Test

S.No	Description of Items	Results
1	Specific Gravity of bitumen at 0% plastic replacement	1.006
2	Specific Gravity of bitumen at 2% plastic replacement	1.09
3	Specific Gravity of bitumen at 4% plastic replacement	1.12
4	Specific Gravity of bitumen at 6% plastic replacement	1.16
5	Specific Gravity of bitumen at 8% plastic replacement	1.21

Table 7: Penetration Test of Bitumen at Plastic Replacement

Description of Items	At 0% Plastic			At 2% Plastic			At 4% Plastic			At 6% Plastic			At 8% Plastic		
Penetrometer dial reading	T 1	T 2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Initial reading (a)	0	0	0	36	69	109	0	0	0	0	0	0	10	10	10
Final reading (b)	49	46	46	64	94	142	26	26	25	23	19	20	27	28	27
Penetration value (b-a)	49	46	46	28	34	33	26	26	25	23	19	20	17	18	17
Average penetration	47			31.66			25.66			19.66			17.33		

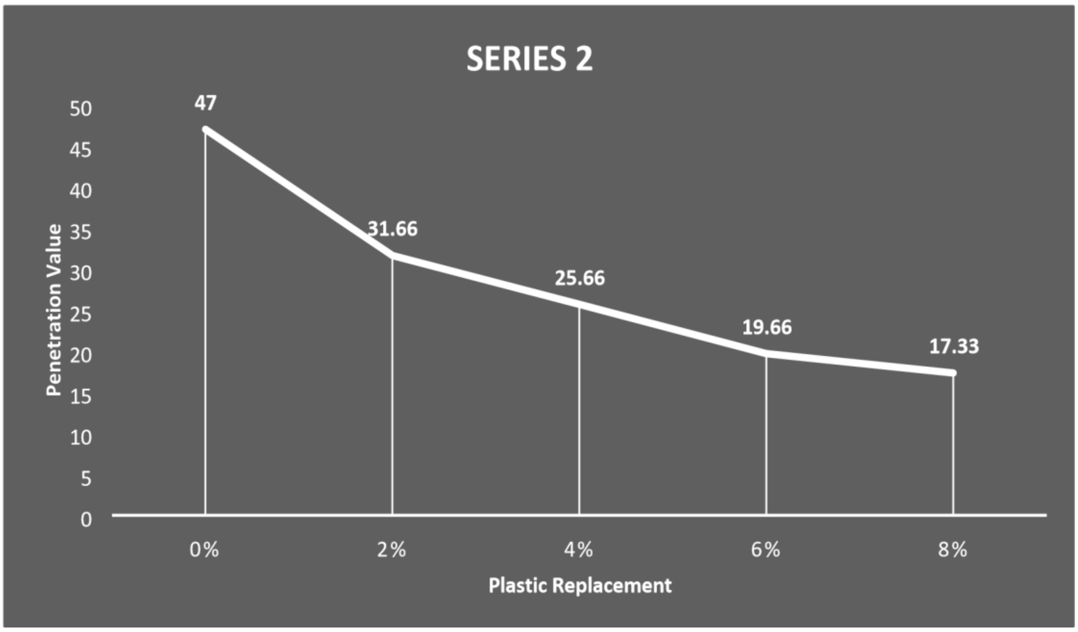

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Table 8: Softening point of Bitumen at plastic Replacement

S. No		Observation	At 0% Plastic		At 2% Plastic		At 4% Plastic		At 6% Plastic		At 8% Plastic	
			B1	B1	B2	B2	B2	B2	B2	B2	B2	B2
1		Temperature at which the ball touches the bottom plate (°c)	51	52	58	59	65	66	68	69	72	74
2		Average softening point	51.5		58.5		65.5		68.5		73	

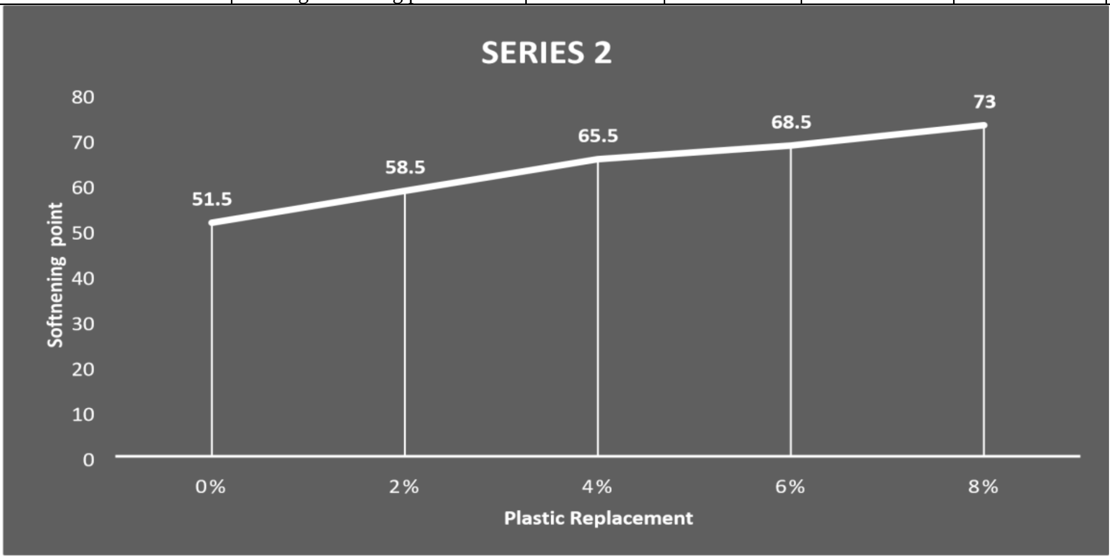
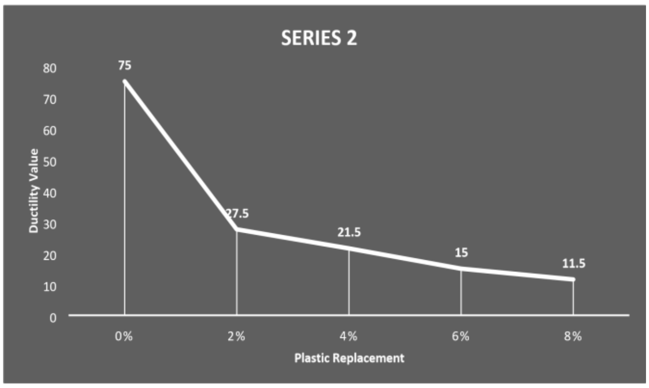


Table 9: Ductility Test of Bitumen at Plastic Replacement

Observation	At 0% Plastic		At 2% Plastic		At 4% Plastic		At 6% Plastic		At 8% Plastic	
	B1	B2	B3	B4	B1	B2	B1	B2	B1	B2
Initial reading (a)	0	0	0	0	0	0	0	0	0	0
Final reading (b)	> 75	> 75	33	22	23	20	14	16	10	13
Ductility = (b-a)	> 75	> 75	33	22	23	20	14	16	10	13
Average Ductility	>75		27.5		21.5		15		11.5	

Figure: 2 - LDPE Replaced in Bitumen

Figure: 3 - LDPE Replaced in Bitumen



Marshall Stability value

Symbol used: - Gt – Theoretical Specific Gravity

W1 - Weight of coarse aggregate in the mix

W2 - Weight of fine aggregate in the mix

W3 - Weight of filler in the total mix

Wb - Weight of bitumen in the total mix

G1 - Specific Gravity of coarse aggregate

G2 - Specific Gravity of the aggregate

G3 - Specific Gravity of filler

Gb - Specific Gravity of bitumen

G_m - Bulk specific gravity of mix Wm - Weight of mix in air

Ww - Weight of mix in water

V_v - Air voids

V_b - Volume of Bitumen

VMA - Voids in mineral aggregate VFB - Voids filled with bitumen

Formula used for: -

1. Gt – Theoretical Specific Gravity

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

2. G_m - Bulk specific gravity of mix

$$G_m = \frac{W_m}{W_m - W_w}$$

3. V_v - Air voids

$$V_v = \frac{(G_t - G_m)100}{G_t}$$

4. V_b - Volume of Bitumen

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1 + W_2 + W_3 + W_b}{G_m}}$$

5. VMA - Voids in mineral aggregate

$$VMA = V_v + V_b$$

6. VFB - Voids filled with bitumen

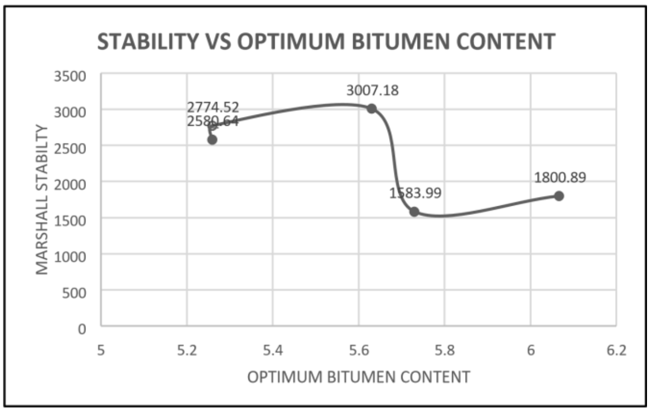
$$VFB = \frac{V_b \times 100}{VMA}$$

Table 10: Summary of all the Results of Marshall Stability Test without Replacement

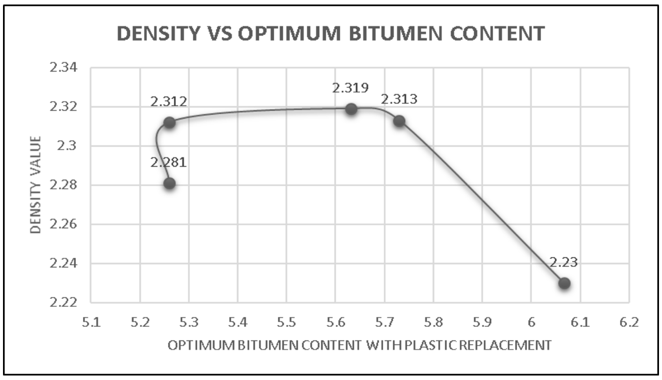
S.no	% of Bitumen	Marshall Stability Value	Flow Value	Bulk Density (Gm)	Air Void % (Vv)	% of Bitumen (Vb)	VMA	VFB
1	4.5	1244.936	1.2	2.242	8.94	9.6	18.53	51.77
2	5	1267.49	1.1	2.307	5.63	10.92	16.55	65.98
3	5.5	1658.03	1.4	2.318	4.56	12.01	16.57	72.49
4	6	1497.08	2.1	2.308	4.3	12.99	17.29	75.11
5	6.5	1466.98	2	2.35	1.92	14.26	16.18	88.14

Table 11: Summary of Optimum Bitumen Content of Bitumen with Plastic Replacement

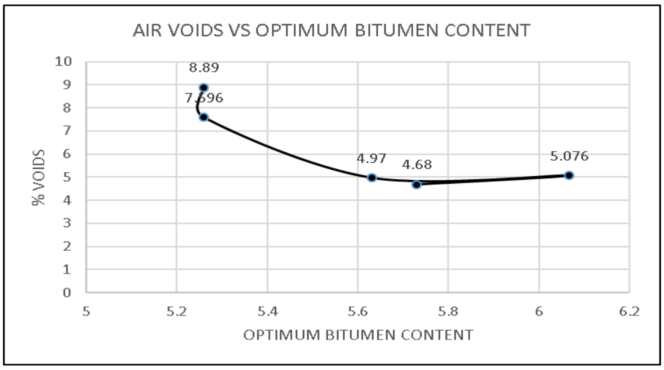
	% Air Void	Bulk Density (Gm)	Marshall Stability Value	OBC (%)
OBC at 0% plastic replacement of bitumen	5.2	2.35	1658.03	5.73
OBC at 2% plastic replacement of bitumen	5.7	2.33	3220.91	6.067
OBC at 4% plastic replacement of bitumen	4.9	2.32	3425.88	5.631
OBC at 6% plastic replacement of bitumen	4.8	2.82	3146.29	5.26
OBC at 8% plastic replacement of bitumen	4.8	2.32	3146.29	5.26



Optimum Bitumen Content (B1) = 5.73 At 4 % Plastic Replacement



Optimum Bitumen Content (B2) = 5.63 At 4 % Plastic Replacement



Optimum bitumen content (B3) = 5.519 at 4 % plastic replacement Optimum bitumen content = (B1+B2+B3)/3 = 5.6

Therefore, Obtimum Bitumen Content Comes Out As 5.6% And Optimum Bitumen Content of Plastic Is 4%

V. CONCLUSION

The conclusion that we arrived from the project are as follows:

1) The Aggregate impact value, crushing value, Los Angeles Abrasion value and the
Specific gravity of all the material is found to be within limit.

2) The characteristics of the mix of Bitumen Binder and plastic powder (LDPE) such
As ductility value, penetration value, softening point value was not in limit
According to the specifications. It was due to the lack of homogenous mix between
Them. Lack of homogeneity was due to absence of shear mixer.

3) Marshall stability value increased with the replacement by plastic up to 4% by wt. Of bitumen then reduced on replacing further.

4) The bulk density of the mix also increased in the same manner as that of the Marshall stability value.

5) The conversion of the plastic powder (LDPE) into smaller forms to mix in the
Bitumen binder was also easier which when addition in mix up to certain limit Enhanced the properties.

6) The cost of proper construction of road pavement in actual practical consideration
also reduces as partially replacement of Bitumen by plastic powder (LDPE) has
proved to be economical.

7) The void percentage of the mix reduced in addition of the plastic powder (LDPE)
up to certain percentage then on further increment it increased

5.1 Future scope

1. The replacement of 25% RCA in bituminous concrete mix is acceptable and
can be used, that reduces the cost of construction.

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2.The replacement of Bitumen with LDPE by 4% by weight enhanced the
Properties of mix. Hence that percentage can be replaced.
3. The overall mix made by replacement in Natural Aggregate and Bitumen
Binder found out to be within specified limit as per IS institute procedure
Hence it can be used in practical field in near future.
4. As the project mainly focus on sustainability and preservation of
Environment it should be used as far as possible in near future.
5. The best way of management of waste plastic is utilizing it in flexible
Pavement which reduces environment pollution.
6. Demolition of concrete structure and use of LDPE both is never going to
End. Hence this project helps in the proper management of those waste.

DECLARATION STATEMENT

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Conflicts of Interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	I am only the sole author of the article.

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AUTHOR PROFILE

Pramatma Ram Shah, Ishwarpur-2, Salahi, Nepal **Academic Background**: B. Tech in Civil Engineering (Punjab Technical University, Punjab) (2015-2019), M. Tech in Structural Engineering (2021-2023) **Research Work:** Partial replacement of RCA and LDPE in Bituminous Pavement **Membership:** Nepal Engineering Council (NEC Registration No: 22846 Civil "A").