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# Experimental Analysis of LDPE Modified Bituminous Mix with Partial Replacement of Steel Slag as Aggregate

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**ABSTRACT:** Waste production is increasing day by day to a very large extent. Most of the wastes are not being reused, instead simply dumped in large areas of land, polluting the environment. Converting these wastes into usable products is a much needed technique but at the same time they must not have a drawback due to their usage. This study analyses the use of steel slag as a partial replacement for coarse aggregate in the production of bituminous mix for road construction wherein the aggregates are coated with Low Density Poly Ethylene (LDPE) such as carry bags and polyethylene covers during the preparation of the mix. Three different percentages (10%, 20% & 30%) of steel slag aggregate were used and shredded pieces of LDPE of about 12% the weight of bitumen were coated over the heated aggregates. The proposed mix designs for bituminous asphalt mix were conducted in accordance with Marshall Mix design. The Marshall Stability tests were conducted on the modified mixes. It has been observed that LDPE and steel slag modified bituminous mix show better stability, heat bearing capacity and more resistant to water. Hence, this method will not only strengthen the roads but also increases the road life as well as will help to improve the environment.

**KEYWORDS:** Low Density Poly Ethylene (LDPE), Steel Slag, Marshall Stability, Modified Mix, Coated Aggregates.

### I. INTRODUCTION

Overseeing through decades we can observe that the growth of population has been overtaken by the growth of waste production. This enormous growth in generation of untreated waste production is a result of following improper practice of disposal methods and increasing the productivity rates without proper recycling. This way of lifestyle in today's trend pave to the environmental hazards impacting the health of the livings to a great extent. Central pollution board has estimated the generation of 15,342 tonnes of plastic waste in our country. Currently, total production of steel slag in India is around 12 million tonnes per annum (Indian Minerals (2006)). Plastics and Steel Slag are user friendly but not eco-friendly as they create disposal problems and are non- biodegradable products. These issues are resolved in recent years by using plastic waste in flexible pavement. Scientists and researchers are working to develop sustainable technologies and economical road construction, instead of increasing the maintenance expenditure on roads in India. Our work is to provide a key idea ensuring the sustainable development in road network which has its vitality in

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promoting the nation's transportation network to the next level of improvement for the future generation. In this project, attempt has been made to analyze the performance of modified bituminous mix with the utilization of plastic waste and partial use of steel slag as aggregate. It can be a better method for disposal of plastic wastes and steel slag and at the same time it enhances the performance of the pavement, reduces the road construction cost and protects the environment.

## II. LITERATURE REVIEW

Dr. R. Vasudevan, S. K. Nigam, R. Velkennedy, A. Ramalinga Chandra Sekar, and B. Sundarakanna (2006) found innovative techniques to utilize the plastic wastes and the tyre waste for the construction of flexible pavement, for making pathway blocks, and for making laminated roof sheets. The major polymers namely polyethylene, polypropylene, polystyrene show adhesion property in the molten state.

Minakshi Singhal, Yudhvir yadav, Ranadip Mandal carried out a comparative study between the polymer modified bitumen blend and polymer coated aggregates. They found that the polymer coated aggregate bitumen mix form better material for the flexible pavement construction. The optimum content of plastic to be used is between the ranges 5% to 10%. It shows higher Marshall Stability value.

Yash Menaria, Rupal Sankhla states that the utilization of plastic upto 8% improves the binding property, stability and durability of the mix to a great extent. They also added waste fibre to improve the bitumen properties.

## III. OBJECTIVES OF THE STUDY

Our intention is to utilize the plastic waste and steel slag in flexible pavement construction effectively and to be beneficial to the society.

1. To prepare a LDPE modified bituminous mix.
2. To prepare a LDPE and steel slag modified bituminous mix with partial replacement of steel slag.
3. To identify the properties of the steel slag modified LDPE bituminous mix.
4. To analyze and compare the results.

## IV. MATERIALS AND PROPERTIES

The materials used in this study are

- a) Aggregates
- b) Bitumen
- c) Filler
- d) LDPE (plastics)
- e) Steel Slag

### a) Aggregates

Coarse aggregate sizes are larger than 4.75 mm, while fine aggregates form the portion below 4.75 mm. In this project 16mm, 12.5mm and 6.75mm retained coarse aggregates and 2.36mm, 1.18mm retained fine aggregates were used.

The physical properties of the aggregates are shown in Table1 and the results are compared with the MORTH specifications.

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**Table -1:** Properties of Aggregates

S. No.	Test	Conventional aggregate	Steel Slag aggregate	MORTH Specifications
1.	Crushing	25%	28%	< 30%
2.	Impact	26%	29%	< 30%
3.	Water Absorption	1%	10%	<= 20%
4.	Specific Gravity	2.78	2.8	2.68-2.98

Table 1 shows that the conventional aggregates and steel slag aggregates used in this study are within the MORTH limitation specifications.

## b) Bitumen

Asphalt also known as bitumen, is a sticky, black, and highly viscous liquid or semi-solid form of petroleum. The primary use (70%) of asphalt is in road construction, where it is used as the glue or binder mixed with aggregate particles to create asphalt concrete. 60/70 grade of bitumen is used in this study. The properties of this bitumen are shown in Table-2 in which the obtained results are compared with the standard values.



**Fig -1**

Fig -1 shows the Bitumen 60/70 grade used in this study heating to the pouring consistency.

**Table -2:** Properties of Bitumen

S. No	Test	Result	Standard Value
1.	Specific Gravity	1.085	Min. 0.99
2.	Penetration	61 mm	60-70 mm
3.	Ductility	90 cm	Min 40 cm
4.	Softening point	62.5 °C	Min.47 °C
5.	Flash point	220 °C	Min. 175 °C
6.	Fire point	260 °C	Min. 180 °C
7.	Viscosity	78 secs	Min. 70 secs

From the Table 2, it is observed that the properties of the bitumen are above the minimum standard requirement and are fitted to be used for the study.

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## c) Filler

Quarry dust was used as filler material



Fig -2(a)

Fig -2(b)

Fig – 2(a) shows IS Sieve 300 $\mu$  retained Quarry Dust passing through IS Sieve 600 $\mu$  and Fig -2(b) shows IS Sieve 150 $\mu$  retained Quarry Dust passing through IS Sieve 300 $\mu$ .

## d) Low Density Poly Ethylene (Plastic carry bags)

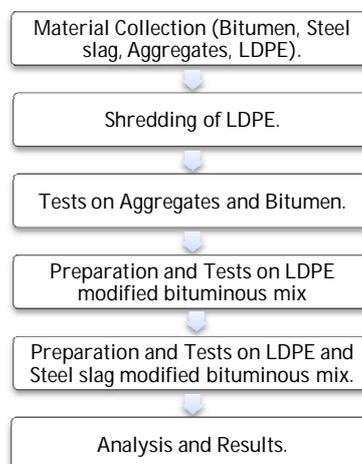
Low Density Poly Ethylene (LDPE) in the form of carry bag was used. Plastic covers were shredded to sizes ranging from 5- 10 mm.

## e) Steel Slag

Electric Arc Furnace Slag (EAF or steel furnace slag) produced when scrap metal and fluxes are oxidized by the use of an electric current.

Steel slag can be used by blending with many other products such as granulated slag, fly ash and lime to form pavement material, skid resistant asphalt aggregate and unconfined construction fill.

## V. METHODOLOGY



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## VI. PLASTIC COATED AGGREGATES

1200 grams of aggregates were heated to a temperature 160°C-170 °C. The shredded plastic was added to the hot aggregates with constant mixing to have a uniform distribution. The plastic gets softened and coated over the conventional aggregates as well as steel slag aggregates. Its properties were tested and given in Table 3.



Fig -3

Fig -3 shows the process of adding shredded LDPE over the aggregates heated at 160°-170°C to get the LDPE coated aggregates.

Table -3: Properties of Plastic Coated Aggregates

S.No	Test	LDPE coated Conventional aggregate	LDPE coated Steel Slag aggregate	Requirement as per Table 500-14 of MORTH (IV Revision)Specification
1.	Crushing	24%	27.5%	< 30%
2.	Impact	24%	28%	< 30%
3.	Water Absorption	0.1%	2%	<= 20%
4.	Specific Gravity	2.8	2.85	2.68-2.98

Table -3 shows the properties of the LDPE coated Conventional aggregates and LDPE coated Steel slag aggregates in which it depicts that both the aggregates show good results within the MORTH specification. Plastic coated aggregates show improved properties than the conventional aggregates.

## VII. MARSHALL METHOD OF MIX DESIGN

The mix design should aim at an economical blend, with proper gradation of aggregates and adequate proportion of bitumen so as to fulfill the proportion of mix.

### Proportioning of aggregates and filler for mix

Total weight = 1200 g.

1) LDPE Modified Bituminous Mix without Steel Slag

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**Table -4:** Aggregates and Filler proportions in Mix without Steel Slag

Aggregates passing sieve sizes	Aggregates retained on sieve sizes	Weight(g)
20 mm	16 mm	150
16 mm	12.5 mm	190
12.5 mm	6.7 mm	240
4.75 mm	2.36 mm	80
2.36 mm	1.18 mm	60
600 $\mu$	300 $\mu$	200
300 $\mu$	150 $\mu$	150
150 $\mu$	75 $\mu$	130

Table -4 shows the size of the conventional aggregates and weight of the aggregates taken for the study based on the Marshall Mix Design using the IS Sieves 20mm, 16mm, 12.5mm, 6.7mm, 4.75mm, 2.36mm, 1.18mm, 600  $\mu$ , 300  $\mu$ , 150  $\mu$ , and 75  $\mu$ .

### 2) LDPE Modified Bituminous Mix with Steel Slag

**Table -5:** Aggregates and Filler proportions in Mix with Steel Slag

Aggregates passing sieve sizes	Aggregates retained on sieve sizes	Percentage of steel slag replacement in conventional aggregate		
		10% (g)	20% (g)	30% (g)
20 mm	16 mm	150	150	150
16 mm	12.5 mm	190	190	190
12.5 mm	6.7 mm	216	192	168
12.5 mm (steel slag)	6.7 mm	24	48	72
4.75 mm	2.36 mm	80	80	80
2.36 mm	1.18 mm	60	60	60
600 $\mu$	300 $\mu$	200	200	200
300 $\mu$	150 $\mu$	150	150	150
150 $\mu$	75 $\mu$	130	130	130

Table -5 shows the size of the conventional aggregates and steel slag aggregates and their weight taken for the study based on the Marshall Mix Design using the IS Sieves 20mm, 16mm, 12.5mm, 6.7mm, 2.36mm, 1.18mm, 600  $\mu$ , 300  $\mu$ , 150  $\mu$ , 75  $\mu$ .

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## VIII. MIX PREPARATION AND TESTING

Aggregates including the steel slag of approximately 1200g is heated upto 160°-170°C. Shredded LDPE of 5-10mm size is added partly and slowly to the heated aggregates to form a uniformly coated aggregates. Bitumen is heated to 120°C and mixed to the coated aggregates and heated. The mix is poured into the preheated moulds and 50 blows are given on the each side of the mix and kept undisturbed for 24hrs. After 24 hours the specimen is removed from the mould and kept in water bath at 60°C for 30min. Then the specimen is tested immediately within 30 seconds in the Marshall Stability machine. The stability and flow value of the mix is noted from the proving ring and the dial gauges.



Fig - 4



Fig - 5



Fig - 6



Fig - 7

Fig -4 shows the final stage of mix preparation which consists of the mixture of LDPE coated aggregates, bitumen, and dust. Fig - 5 shows the pouring of mix in the compaction setup for compaction. Fig- 6 shows the compaction process in which the blows are given on each side of the mix. Fig -7 shows the casted briquettes which is undisturbed for 24hrs and demoulded.

## IX. TEST RESULTS AND ANALYSIS

The results obtained from the Marshall Stability Test are shown in Table 6.

Table -6: Marshall Test Results

Percentage of Steel Slag in Mix	Bitumen Content %	Plastic Content %	Stability Value ( KN )	Flow ( mm )
0 %	5.5	12	12.5	2.8
10 %	5.5	12	19.7	3.8
20%	5.5	12	19.95	3.5
30 %	5.5	12	21.5	2.35

According to IRC 29: 1988,

Minimum Stability value = 6.4 KN

Flow value = 2 – 4 mm

Table -6 shows the percentage of the steel slag content, bitumen content and LDPE content taken in the mix and their respective Marshall Stability value and Flow value. From the table we can observe that 30% replacement of steel slag shows higher Marshall Stability value and flow value within the limit.

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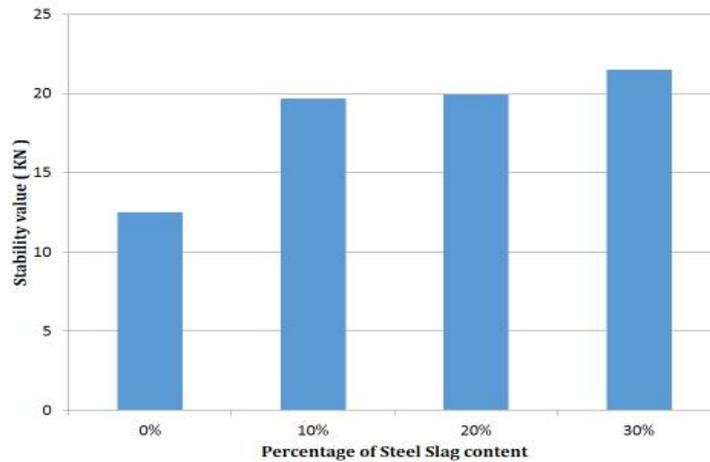


Chart – 1: Steel Slag content vs Stability

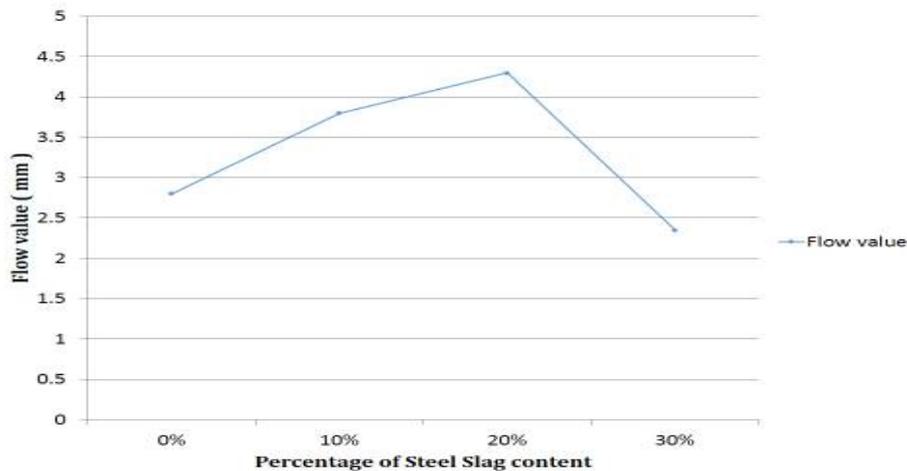


Chart – 2: Steel Slag content vs Flow value

Chart -1&2 is plotted by using the tabulated values from the table -6. In this chart-1, stability is plotted against the steel slag percentage. We can clearly observe that 30% of Steel slag replacement shows higher stability value. In chart -2, Flow value is plotted against the Steel slag percentage here 20% replacement of Steel slag shows higher flow value which is not within the permissible limit where 30% shows flow value within the permissible limit.

## X. CONCLUSION

With a view to improve the properties of the LDPE modified bituminous mix using steel slag as a partial replacement for coarse aggregates, the following conclusions are made.

1. From the test results 30% usage of steel slag was found to be effective.
2. Use of steel slag showed a considerable increase in Marshall Stability value and less deformation.
3. Thus this modified bituminous mix can be used for laying roads.
4. The steel slag retains heat more than the normal aggregates. It reduces the energy required to heat HMA.

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- Thus this method reduces the demand for natural aggregates and is a sustainable way to dispose plastic wastes and steel slag.

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