Use of Industrial Wastes as A Cost Effective Material For Maintenance of Flexible Pavement

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Abstract- *Now-a-days disposal of different wastes produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. In recent years, applications of industrial wastes have been considered in road construction with great interest in many industrialised and developing countries. The use of these materials in road making is based on technical, economic, and ecological criteria. India has a large network of industries located in different parts of the country and many more are planned for the near future. Several million metric tons industrial wastes are produced in these establishments. If these materials can be suitably utilised in highway construction, the pollution and disposal problems may be partly reduced. Keeping in mind the need for bulk use of these solid wastes in India, it was thought expedient to test these materials and to develop specifications to enhance the use of these industrial wastes in road making, in which higher economic returns may be possible. The possible use of these materials should be developed for construction of low-volume roads in different parts of our country. Pavements represent an important infrastructure facility in all countries. Two important parameters for good pavements arepavement design and materials. A good design of bituminous mix is expected to result in a mix which is adequately strong, durable and at the same time environment friendly and economical in order to maintain the pavement. This work is undertaken to prepare cost effective material for maintenance of flexible pavement. By using industrial wastes such as steel slag and foundry sand as a replacement material for fine aggregate in bituminous mix and ground granulated blast furnace slag as a replacement material for fillers in bituminous mix. Fillers play an important role in engineering properties of bituminous paving mixes. Conventionally stone dust, cement and lime are used as fillerplay an important role in engineering properties of bituminous paving mixes. Conventionally stone dust, cement and lime are used as fillers.*

Keywords- Industrial Wastes, steel slag, ground granulated blastfurnaceslag, foundry sand

I. INTRODUCTION

Now-a-days disposal of different wastes produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. In recent years, applications of industrial wastes have been considered in road construction with great interest inmany industrialised and developing countries. The use of these materials in road making is based on technical, economic, and ecological criteria. The lack of traditional road materials and the protection of the environment make it imperative to investigate the possible use of these materials carefully. India has a large network of industries located in different parts of the country and many more are planned for the near future. Several million metric tons industrial wastes are produced in these establishments. Traditionally soil, stone aggregates, sand, bitumen, cement etc. are used for road construction. Natural materials being exhaustible in nature, its quantity is declining. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for highway construction, and industrial wastes product is one such category. If these materials can be suitably utilised in highway construction, the pollution and disposal problems may be partly reduced. Roads are very important national investment and require maintenance to keep them in a satisfactory condition and ensure safe passage at an appropriate speed and with low road user cost. Late or insufficient maintenance will increase the ultimate repair costs, inconvenience and reduce safety. Pavement maintenance is therefore an essential function and should be carried out on timely basis. From the budget allocation plan of India the amount for maintenance and repair of highways is RS.1089.49 crores in 2011-12 and RS. 1272.49 in 2012-13 for length of 33,20,596 km. Hence amount of maintenance per km in 2011-12 is RS. 3281 and for year 2012-13 is RS. 3832. So it is necessary to develop cost effective material for maintenance of flexible pavements.

Generally a bituminous mixture is a mixture of coarse aggregates, fine aggregate, filler and binder. Two things are of major considerations in flexible pavement engineering, pavement design and the mix design. A good design of bituminous mix is expected to result in a mix which is adequately (i) Strong (ii) Durable (iii) Resistive to fatigue and permanent deformation (iv) Environment friendly (v) Economical. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one.

Objective of Bituminous Mix Design:

Bituminous concrete consists of a mixture of aggregate continuously graded from maximum size, typically less than 25 mm, fine filler that is smaller than 0.075 mm. Sufficient bitumen is added to the mix so that the compacted mix will have acceptable elastic properties. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregate, and coarse aggregate to produce a mix which is workable, strong, durable and economical. The objective of the mix design is to produce a bituminous mix by proportioning various components so as to have-

1. Sufficient bitumen to ensure a durable pavement
2. Sufficient strength to resist shear deformation under traffic at higher temperature
3. Sufficient air voids in the compacted bitumen to allow for additional compaction by traffic
4. Sufficient durability
5. Should be economical.

II. INTRODUCTION TO FLEXIBLE PAVEMENT MAINTAINANCE

2.1 Meaning of Flexible Pavements:

Flexible pavements are constructed of several layers of natural granular material covered with one or more water-proof bituminous surface layers, and as the name imply, are considered to be flexible. A flexible pavement will flex (bend) under the load of a tyre. In flexible pavements, the load distribution pattern changes from one layer to another, because the strength of each layer is different. The strongest material (least flexible) is in the top layer and the weakest material (most flexible) is in the lowest layer.

2.2 Pavement deterioration and its types:

Pavement deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. Distresses in flexible pavement are as follows:

1. Fatigue (Alligator) Cracking
1. Polished Aggregate
2. Bleeding
3. Potholes
4. Block Cracking
5. Raveling
6. Corrugation and shoving
7. Rutting
8. Depression
9. Stripping
10. Longitudinal cracking
11. Transverse cracking
12. Patching
13. Polished aggregates
14. Water bleeding and pumping

2.3 Main Causes of Distresses In Pavement:

1) Traffic
2) Environmental condition
3) Method of construction and quality of construction material
4) Moisture infiltration.

Pavements fail prematurely because of many factors, there are four primary reasons pavements fail prematurely:

- Failure in design
- Failure in construction
- Failure in material
- Failure in maintenance

2.4 Conventional Material used for Maintenance of Flexible Pavement:

1. Slurry Seal Coat:

Slurry seal consists of a mixture of sand, Portland cement, water and emulsified asphalt mixed to a rich consistency. It is spread in a thin layer over the pavement. Portland cement is added for stabilizing and setting the slurry. Slurry seal coats are normally used to fill cracks and minor depressions in older AC pavement.

2. Emulsified asphalt:

Emulsified asphalt is a mixture of asphalt cement and water. This asphalt/water ratio is about 60/40. The bitumen content in the emulsion is around 60% and the remaining is water. Sometimes a special type of emulsified asphalt is specified in the Special Provisions. The special type of emulsified asphalt is 50/50 mixture of water and emulsified asphalt. An asphalt emulsion consists of three basic ingredients: asphalt, water, and an emulsifying agent.

3. Final seal (Rubber crumb slurry):

A slurry seal, using rubber crumbs instead of aggregate can be used to fill the wider active cracks. Hand tools are used to mix and apply this slurry seal.

The slurry consisted of the following mix by volume:

- Rubber crumbs 60%
- Stable grade bitumen emulsion 35%
- Cement 5%.

4. Micro surfacing:

Micro surfacing is a mix of polymer-modified emulsion, well-graded crushed mineral aggregate, mineral filler (normally Portland cement), water, and chemical additives. The aggregate, mineral filler, emulsion, and water are mixed in a truck-mounted travelling plant, which is deposited into a spreader box. No compaction is needed, traffic may be al-lowed over the application within an hour after placement.

5. Pothole repair material:

The four components of a typical mix are:

- Coarse aggregate (retained on 4.75mm sieve)
- Fine aggregate (passing 4.75mm sieve but retained on 75µ)
- Filler (passing 75µ), may be cement.
- Binder: Bitumen etc.

6. Stone Mastic Asphalt (SMA) Mortar:

Mixture of asphalt cement (and any additives), filler (all material passing through 75 µ sieve) and fibres blended by volume.

III. EXPERIMENTAL STUDY

3.1 Material Used:

1. Steel Slag:

Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces.

2. Ground granulated blast furnace slag:

Blast Furnace Slag is a byproduct obtained in the manufacturing of Pig iron in the Blast furnace and is formed by the combination of earthy constituents of iron ore with lime stone flux. Quenching process of molten slag by water is converting it into a fine, granulated slag of whitish colour.

3. Foundry sand:

Sand is used in the foundry industry mainly for making moulds for the casting. This sand is generally recycled. After a repeated use, they lose their characteristics and thereby becoming unsuitable for further use in manufacturing process. This sand is usually discarded and dumped in the landfill as a waste.

4. Course aggregate:

The mineral aggregates most widely used in bitumen mixes are crushed stone, crushed or uncrushed gravel. Since mineral aggregate constitutes of approximately 80% to 96% by weight and approximately 80% by volume of the total mix. Their influence upon the final characteristics of bituminous mixes is very great.

5. Fine aggregate:

It shall be fraction passing 4.75 mm and retained on 75 µ sieve consisting of crushed stone or natural sand. Its function is to fill up the voids of the coarse aggregate. Here in this work natural sand is used as fine aggregate. It should be clean, hard, strong, free of organic impurities and free of silt and clay.

6. Filler:

It is the filler material used in bituminous mix which passes through 75 µ sieve. The fillers should be inert material. The cement should be fresh, have uniform consistency and free of lumps and foreign matter.

7. Bitumen:

Bitumen is the residue or by-product when the crude petroleum is refined. Bitumen is act as a binder in bituminous mix. Different grade of bitumen are used in different mix. Here we used 30/40 bitumen for preparation of bituminous

3.2 Test Results:

1. Coarse Aggregate:
   1. Water Absorption= 1.4985%
   2. Specific Gravity= 2.90
   3. Fineness modulus = 2.43
   4. loss Angelis=15.25%
   5. Impact value=5.28%

2. Fine Aggregate:
    1. Water Absorption= 1 .69%
    2. Specific Gravity= 2.85
    3. Fineness modulus = 5.66
3. Cement:
    1. Fineness Test = 7%
    2. Specific gravity= 3.15
4. Steel slag:
    1. Water Absorption= 0.95%
    2. Specific Gravity= 2.69
    3. Fineness modulus = 4.545
5. Foundry sand:
    1. Specific Gravity= 2.59
    2. Fineness modulus =2.21
6. Ground granulated blast furnace slag:
    1. Specific Gravity= 2.17
    2. Fineness test=2.08%

IV. TESTING OF BITUMINOUS MIX AND RESULTS

4.1: Brief Procedure of Marshall Test:

1) 1200gm aggregate are weighted and heated up to 154-160 degree C.
2) Bitumen is heatedupto175 -190 degree C.
3) Aggregate & Bitumen are mixed thoroughly until a uniform grey colour is obtained.
4) Marshall Mould diameter 100mm & 64 mm height compacted with 75 blows on each face.
5) Mould is taken out kept under normal laboratory temp for 12 hours.
6) It is immersed in water bath kept at a constant temp. 60 degrees for 30 minutes.
7) Load is applied vertically at the rate of 50mm per minute.
8) The maximum load at sample fails is recorded as the Marshall Stability value.
9) Corresponding vertical strain is termed as the flow value.

4.2: Test Procedure:

A specimen from the Water bath is removed and placed in the lower segment of the testing head. The upper segment of the testing head on the specimen is placed, and the complete assembly is paced in position in the loading machine. The dial gauge is placed in position over one of the guide rods. Read-ings of dial gauge and proving ring are recorded.

4.3: Parameters used:

1. Theoretical Maximum Specific Gravity of Mix:

Gt = 100/ (W1/G1+W2/G2+W3/G3+W4/G4)
Where,
W1 = Percentage by weight of coarse aggregate in total mix
W2 = Percentage by weight of fine aggregate in total mix
W3 = Percentage by weight of filler in total mix
W4 = Percentage by weight of bitumen in total mix
G1 = Specific gravity of coarse aggregate
G2= Specific gravity of fine aggregate
G3= Specific gravity of filler
G4= Specific gravity of bitumen.

2 Bulk Density of mix:

Gm = weight in Air / (weight in air – weight in water) * 1 gm/ cm^3

3 Volume of air voids:

Vv = ((Gt – Gm) / Gt) * 100

4 Voids in Mineral Aggregate (VMA):

VMA = Vv + Vb
Where,
Vv = Volume of air voids, Vb = Volume of bitumen.

5 Voids Filled With Bitumen (VFB):

Vb= Gm*(W4/G4)
Where,
Gm = Bulk Density
W4 = Percent by weight of bitumen in total mix.
G4= Specific gravity of bitumen.

4.4: Marshall Test Results:

The results of the Marshall test of samples and average Marshall Properties of Samples prepared with conventional mix for varying bitumen contents have been presented below:

TABLE 4.1 RESULTS OF MARSHALL TEST FOR CONVENTIONAL MIX

Bitumen %	Sample No.	Wt. in Air (gm)	Wt. in water (gm)	Flow Value (mm)	Stability Value (kg)	Corrected Stability value	G_t	Unit Wt (g/cc) G_{mm}	% Air Voids (V_v)	VMA (%)	V_b (%)	VFB (%)
6%	1	1232	748	6	410	446.9	2.62	2.54	3.05	18.13	15.08	83.17
6%	2	1103	669	7	415	518.75	2.62	2.54	3.05	18.13	15.08	83.17
6%	3	1129	656	7	425	425	2.62	2.38	9.16	23.29	14.13	60.66
6.25%	1	1180	699	6	419	477.66	2.61	2.45	6.13	21.29	15.16	71.20
6.25%	2	1182	689	9	430	490.2	2.61	2.39	8.429	23.22	14.79	63.7
6.25%	3	1179	715	7	421	558.89	2.61	2.54	2.681	18.40	15.72	85.43
6.5%	**1**	**1177**	**689**	**5**	**490**	**612.5**	**2.59**	**2.41**	**6.94**	**22.44**	**15.50**	**69.67**
6.5%	**2**	**1182**	**697**	**7**	**503**	**573.42**	**2.59**	**2.43**	**6.17**	**21.8**	**15.63**	**71.69**
6.5%	**3**	**1178**	**700**	**4**	**480**	**547.2**	**2.59**	**2.46**	**5.01**	**20.84**	**15.83**	**75.95**
6.75%	1	1225	741	5	415	493.85	2.63	2.53	3.80	20.7	16.90	81.64
6.75%	2	1105	610	8	431	491.34	2.63	2.23	15.2	30.1	14.9	49.50
6.75%	3	1133	653	7	419	523.75	2.63	2.36	10.26	26.03	15.77	60.58
7%	1	1184	704	9	407	463.98	2.57	2.46	4.28	21.32	17.04	79.92
7%	2	1181	701	8	416	495.04	2.57	2.46	4.28	21.32	17.04	79.92
7%	3	1179	686	6	384	437.76	2.57	2.39	7	23.56	16.5	70.28

From the test results optimum binder content selected as 6.5 %

Table 4.2 Results of Marshall test for 50 % replacement of fine aggregates and filler material (steel slag as a fine aggregates and GGBFS as a filler material).

Bitumen (%)	Sample No:	Wt in Air (gm)	Wt in water (gm)	Flow Value (mm)	Stability Value (kg)	Corrected Stability value	Gt	Unit Wt (g/cc) G_{mm}	% Air Voids (Vv)	VMA (%)	Vb (%)	VFB (%)
6.5%	1	1161	695	4	500	570	2.54	2.49	1.97	17.99	16.024	89.072
	2	1212	720	4	480	571.20	2.54	2.46	3.15	18.98	15.83	83.404
	3	1181	700	5	482	525.38	2.54	2.46	3.15	18.98	15.83	83.404

Table 4.3 Results of Marshall test for 60 % replacement of fine aggregates and filler material (steel slag as a fine aggregates and GGBFS as a filler material).

Bitumen (%)	Sample No:	Wt in Air (gm)	Wt in water (gm)	Flow Value (mm)	Stability Value (kg)	Corrected Stability	Gt	Unit Wt (g/cc) G_{mm}	% Air Voids (Vv)	VMA (%)	Vb (%)	VFB (%)
6.5	1	1198	706	4	495	589.05	2.49	2.43	2.41	18.04	15.63	86.265
	2	1178	672	5	492	560.8	2.49	2.32	6.82	21.76	14.93	70.54
	3	1193	692	5	492	560.8	2.49	2.38	4.418	19.735	15.31	77.61

Table 4.4 Results of Marshall test for 70 % replacement of fine aggregates and filler material (steel slag as a fine aggregates and GGBFS as a filler material.)

Bitumen (%)	Sample No:	Wt in Air (gm)	Wt in water (gm)	Flow Value (mm)	Stability Value (Kg)	Corrected stability Kg	Gt	Unit Wt (g/cc) G_{mm}	% Air Voids (Vv)	VMA (%)	Vb (%)	VFB (%)
6.5	1	1182	686	5	490	583.1	2.47	2.38	3.641	18.96	15.31	80.79
	2	1187	671	5	485	552.9	2.47	2.30	6.88	21.68	14.80	68.28
	3	1198	708	6	484	575.96	2.47	2.44	1.23	16.93	15.70	92.74

Table 4.5 Results of Marshall test for 80 % replacement of fine aggregates and filler material (steel slag as a fine aggregates and GGBFS as a filler material).

Bitumen (%)	Sample No:	Wt in Air (gm)	Wt in water (gm)	Flow Value (mm)	Stability Value (kg)	Corrected Stability value	Gt	Unit Wt (g/c c) G_{mm}	% Air Voids (Vv)	VMA (%)	Vb (%)	VFB (%)
6.5	1	1172	680	5	480	547.2	2.45	2.38	2.86	18.18	15.32	84.27
	2	1197	690	5	475	541.5	2.45	2.36	3.67	18.86	15.19	80.54
	3	1140	650	6	478	597.5	2.45	2.42	1.22	16.79	15.57	92.73

Table 4.6 Results of Marshall test for 50 % replacement of fine aggregates and filler material (foundry sand as a fine aggregates and GGBFS as a filler material).

Bitumen (%)	Sample No:	Wt in Air (gm)	Wt in water (gm)	Flow Value (mm)	Stability Value (kg)	Corrected stability value	Gt	Unit Wt (g/cc) G_{mm}	% Air Voids (Vv)	VMA (%)	Vb (%)	VFB (%)
6.5	1	1183	703	4	472	538.08	2.49	2.46	1.2	17.03	15.83	92.95
	2	1182	680	5	470	559.3	2.49	2.35	5.62	20.74	15.12	72.90
	3	1185	711	4	472	538.08	2.49	2.50	0.4	16.49	16.08	97.57

Table 4.7 Results of Marshall test for 60 % replacement of fine aggregates and filler material (foundry sand as a fine aggregates and GGBFS as a filler material).

Bitumen (%)	Sample No:	Wt in Air (gm)	Wt in water (gm)	Flow Value (mm)	Stability Value (kg)	Corrected stability value	Gt	Unit Wt (g/cc) G_{mm}	% Air Voids (Vv)	VMA (%)	Vb (%)	VFB (%)
6.5	1	1101	653	5	468	617.76	2.47	2.45	0.81	16.58	15.77	95.11
	2	1169	694	6	465	581.125	2.47	2.46	0.4	16.23	15.83	97.54
	3	1215	700	6	485	577.15	2.47	2.36	4.45	19.64	15.19	77.34

Table 4.8 Results of Marshall test for 70 % replacement of fine aggregates and filler material (foundry sand as a fine aggregates and GGBFS as a filler material).

Bitumen (%)	Sample No:	Wt in Air (gm)	Wt in water (gm)	Flow Value (mm)	Stability Value (kg)	Corrected stability value	Gt	Unit Wt (g/cc) G_{mm}	% Air Voids (Vv)	VMA (%)	V_b (%)	VFB (%)
6.5	1	1142	673	6	460	575	2.47	2.43	1.62	17.26	15.63	90.61
	2	1199	706	6	454	494.86	2.47	2.43	1.62	17.26	15.63	90.61
	3	1196	727	6	458	522.12	2.47	2.39	3.24	18.62	15.38	82.60

Table 4.9 Results of Marshall test for 80 % replacement of fine aggregates and filler material (foundry sand as a fine aggregates and GGBFS as a filler material**).**

Bitumen (%)	Sample No:	Wt in Air (gm)	Wt in water (gm)	Flow Value (mm)	Stability Value (kg)	Corrected stability value	Gt	Unit Wt (g/cc) G_{mm}	% Air Voids (Vv)	VMA (%)	V_b (%)	VFB (%)
6.5	1	1172	680	6	450	462.5	2.43	2.39	1.69	17.07	15.38	90.09
	2	1197	690	6	447	590.04	2.43	2.36	2.88	18.06	15.18	84.05
	3	1140	650	6	445	529.55	2.43	2.33	4.12	19.11	14.99	78.44

6.2.3 Interpretation of results

1. From the result of stability vs Bitumen it is learnt that optimum binder content for samples prepared with normal mix is found to be 6.5 %
2. From the flow value result of different bitumen content, it is observed that the flow value for the bitumen content 6.5 % is 5.33 mm which less as compare to 6 % , 6.25 %, 6.75 % & 7 % bitumen content so optimum bitumen content 6.5 %.
3. The result for Marshall stability with 70 % replacement of fine aggregates using steel slag are more as compared to other trials made using steel slag; the stability values obtained are 583.1 kg, 552.9 kg, and 575.96 kg.
4. The result for Marshall stability with 60 % replacement of fine aggregates using foundry sand are more as compared to other trials made using foundry sand, the stability values obtained are 617.6 kg, 581.125 kg, and 577.15 kg.
5. Therefore optimum percentage replacement obtained from Marshall Test results for steel slag is 70% and for foundry sand is 60%.

6.4 COST COMPARISON FOR MATERIAL

1. For conventional mix:

Considering for 10 m^2 area
Quantities of aggregates for 10 m^2 area is 0.27 m^3
54.07 kg bitumen used per m^3 aggregates.
For 0.27 m^3 of aggregates, 14.6 kg bitumen is required.
Volume of aggregates = 0.27 m^3
1. Coarse aggregates = 0.135 m^3 × 820 = RS. 110.7
2. Fine aggregates = 0.0918 m^3 × 1500 =RS. 137.7
3. Filler = 0.0432 m^3 × 434 = RS. 18.74
Total cost of aggregates (0.27 m^3) = RS. 267.15
Cost of bitumen (54.07 kg) = 14.6 x 32.763 = RS. 478.30
Total cost of mix = **RS. 745.43**
It is the cost for normal mix.

From the Marshal Stability result of different mix we conclude that;

60% replacement of fine aggregates by foundry sand and filler by GGBFS gives maximum value of Marshal Stability.

70% replacement of fine aggregates by steel slag and filler by GGBFS gives maximum value of Marshal Stability.
So considering these two materials for cost comparison

2. Cost for mix with foundry sand:

Volume of aggregates = 0.27 m^3
1. Coarse aggregates = 0.135 m^3 × 820 = RS. 110.7
2. Fine aggregates = 0.03672m^3 × 1500 =RS. 55.08
3. Foundry sand=0.05508 m^3 ×150= RS. 8.26
4. Filler = 0.01728m^3 × 434 = RS. 7.50
5. GGBFS = 0.02592m^3 × 300= RS. 7.78
Total cost of aggregates = 0.27 m^3 = RS. 189.32
Cost of bitumen = 14.6 x 32.763 = RS. 478.30
Total cost of mix = **RS. 667.62**

Therefore saving in cost for 10 m^2 is **RS. 77.81** by using 60 % foundry sand replacement for fine aggregates and filler by GGBFS in bituminous mix. Hence saving in cost per m^3 is **RS.7.78**.

3. Cost for mix with steel slag:

Volume of aggregates = 0.27 m^3
1. Coarse aggregates = 0.135 m^3 × 820 = RS. 110.7
2. Fine aggregates = 0.02754 m^3 × 1500 = RS. 41.31
3. Steel slag = 0.06426 m^3 ×80 = RS. 5.14
4. Filler = 0.01296 m^3 × 434 = RS. 5.62
5. GGBFS = 0.03024 m^3 × 300 = RS. 9.072
Total cost of aggregates (0.27 m^3) = RS. 171.212
Cost of bitumen = 14.6 x 32.763 = RS. 478.30
Total cost of mix = **RS 649.51**

Therefore saving in cost for 10 m^2 is **RS. 95.91** by using 70 % steel slag replacement for fine aggregates and filler by GGBFS in bituminous mix. Hence saving in cost per m^3 is **RS.9.59**.

(All the rates are taken as per DSR 2016-17)

So, from above cost comparison, mix prepared with 70 % replacement of fine aggregates by steel slag and 70 % replacement of filler by GGBFS was found to be most cost effective mix.

V. CONCLUSION

1. From the result and analysis of various properties of steel slag and foundry sand it is found that these materials can be used as fine aggregates as replacement for natural sand and ground granulated blast furnace slag can be used as replacement for fillers in bituminous mix.
2. Bituminous mixes prepared using conventional mix and different bitumen content gives the optimum bitumen content as 6.5 %.
3. Bituminous mixes prepared with 60 % replacement of fine aggregates with foundry sand and 60 % replacement of filler with GGBFS gives the Marshall Stability value as 591.87 kg which is almost 50 kg more as compared to the other mixes with different % of foundry sand and GGBFS.
4. Bituminous mixes prepared with 70 % replacement of fine aggregates with steel slag and 70 % replacement of filler with GGBFS gives the Marshall stability value as 570.65 kg which are high as compared to the other trials of steel slag.
5. Saving in cost per 1m^2 is Rs.9.59 for bituminous mixes prepared with 70 % replacement of fine aggregates with steel slag and filler by GGBFS.
6. Saving in cost per 1m^2 is Rs.7.78 for bituminous mixes prepared with 60% replacement of fine aggregates with Foundry sand and filler by GGBFS.
7. By using steel slag and foundry sand in bituminous mix an environment effects from wastes and disposal problems of waste can be reduced.
8. By using foundry sand more than 60% replacement for fine aggregates and 60 % replacement of filler with GGBFS gives less result for Marshall stability in next trials.
9. By using steel slag more than 70 % replacement for fine aggregates and 70 % replacement of filler with GGBFS gives less result for Marshall stability in next trials.
10. So final conclusion is that cost effective material is 70 % replacement of fine sand by steel slag and 70 % replacement of filler by GGBFS

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