Strength and Stability Characteristics of Semi Dense Bituminous Concrete by using Cold Mix Design

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Abstract-This report presents the strengths and stability characteristic of Semi Dense Bituminous Concrete by using cold mix design. The report will be helpful for the engineers in public and private sector with responsibility for the design, construction and maintenance of Semi Dense Bituminous Concrete (SDBC) particularly to the cold region of India such as Northeast. In the present study Ground-Granulated Blast-Furnace Slag (GGBS or GGBFS) is used for better curing period.

Keywords- Marshall Stability Test, Ground-Granulated Blast-Furnace Slag (GGBS or GGBFS)

I.INTRODUCTION

Cold emulsified asphalt mixture is generally a mix made of emulsified asphalt with aggregate. It is produced by emulsifying the asphalt in water with (essentially) soap prior to mixing with the aggregate. Cold patch, also known as cold mix or cold asphalt, was first recognized as a way to make road repairs quickly because it can be applied right from the container without heating. Cold asphalt also doesn't require any special heavy rolling machines or special applicators as it can be shoveled or poured into a pothole or utility cut and tamped down with a hand tool. Cold asphalt is not dependent upon warm weather.

II. PRESENT INVESTIGATIONS

The present investigation is focused on the characteristics of Semi Dense Bituminous Concrete (SDBC) using additive Ground-Granulated Blast-Furnace Slag (GGBS or GGBFS) for achieving better curing period and bituminous emulsions SS-2 (Slow Setting) emulsion.

III. METHODOLOGY

Different materials are such as aggregates, Ground-Granulated Blast-Furnace Slag (GGBS or GGBFS) and bituminous emulsions are collected from their quarry and different tests on aggregates are being conducted such as Impact Test, Crushing Test, Los Angeles Abrasion Test and Specific Gravity and Water Absorption Test. Further with trial and error method gradation is obtained and Marshall Specimen is prepared and Marshall Stability Test is conducted and graphical and theoretical analysis is done.

IV. MATERIALS USED IN THE STUDY

The different materials used in the study are aggregates, Ground-Granulated Blast-furnace Slag (GGBS or GGBFS) and bituminous emulsions. The Proportion of aggregates used is 12.5 mm, 6.3mm and Stone dust which is brought from a quarry near Bangalore. The type of binders used in the present study is the SS-2 (Slow Setting) Emulsion which has Specific Gravity of 1.15. After procuring of aggregate different tests were conducted on aggregate and the results are as shown below in Table 1.

Table 1: Aggregate Test

Tests	Value
Los Angeles Abrasion	26.58%
Impact	20.87%
Water Absorption	.5%
Specific Gravity of Aggregates	2.8
Crushing	21.16%

V. OBTAINED GRADATION

The different sizes of aggregates i.e., 12mm, 6mm, and dust were selected from the heap and the sieve analysis was done to obtain the individual gradation of these aggregates. By trial and error method, using Microsoft excel, the desired gradation for SDBC mix is obtained as shown in the Table 2 and Figure1.The gradation adopted 30% of 12mm, 40% of 6mm and 30% of stone dust.

Table 2: Individual gradations by trial and error method for cold mix SDBC grade-II

Sieve Sizes	% Passing			Obtained Gradation	Desired Gradation as per MoRT&H[1]	
	12.5mm	6.3mm	Stone Dust		Lower Limit	Upper Limit
13.2	100	100	100	100	100	100
9.5	75	100	100	92.50	90	100
4.75	0	30.4	86.4	38.08	35	51
2.36	0	2	58.4	26.92	24	39
1.18	0	0	50.8	15.24	15	30
0.3	0	0	40.8	12.24	9	19
0.075	0	0	25.8	7.74	3	8

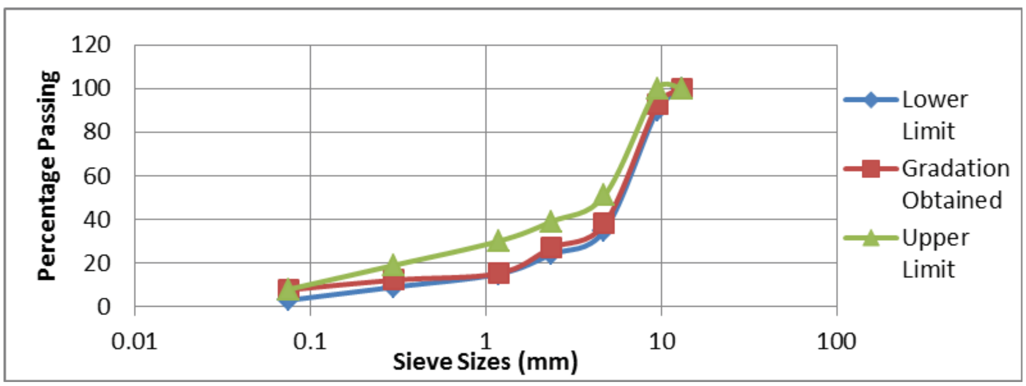

Figure 1: Graph of Gradation obtained for Semi Dense Bituminous Concrete mix

VII. PREPARATION OF MARSHALL SPECIMEN FOR COLD SDBC MIX

- 1200 grams of graded aggregates are taken (30% of 12mm, 40% of 6mm, and 30% of dust) in a tray.
- 3% water by weight of aggregates (36 grams) i.e., the OMC is added to the aggregates next.
- After this the aggregates are left to dry out for 5 to 10 minutes.
- Following this the bitumen is added and the materials are transferred to the mould.
- This is followed by hammering the material with 75 blows on each side.
- The moulds are then left for curing and are extracted after the curing period is over. Finally, the extracted moulds are tested for stability and flow values.

VIII. ANALYSIS OF TEST RESULTS

A. Optimum Moisture Content (OMC)

The moisture content is the percentage of water at which the aggregates are coated to the maximum without being in excess. In this study; we fixed the OMC by visual confirmation. Starting with 3% by weight of aggregate and then going on to 4% and finally 5%.After that 3% was found out to be the OMC by visual confirmation.

B. Optimum Bitumen Content (OBC)

Optimum Bitumen Content (OBC) is the percentage of bitumen by weight of aggregate, which gives the right strength and concentration combination. In the present study OBC is determined by taking average of three different values by trial and error method by taking fixed percentage of OBC 4.5, 5, 5.5 and 6 and stability 757.5, 765, 772.5 and 767as shown in Table 3. They are percentage of OBC versus Stability, percentage of OBC versus bulk density and percentage of OBC versus volume of voids and as shown in Figure 2, Figure 3 and Figure 4. The average value got is 5.3%.

Table 3: Stability values for cold SDBC mix

Percentage of OBC	Stability (kg)
4.5	757.5
5	765
5.5	772.5
6	767

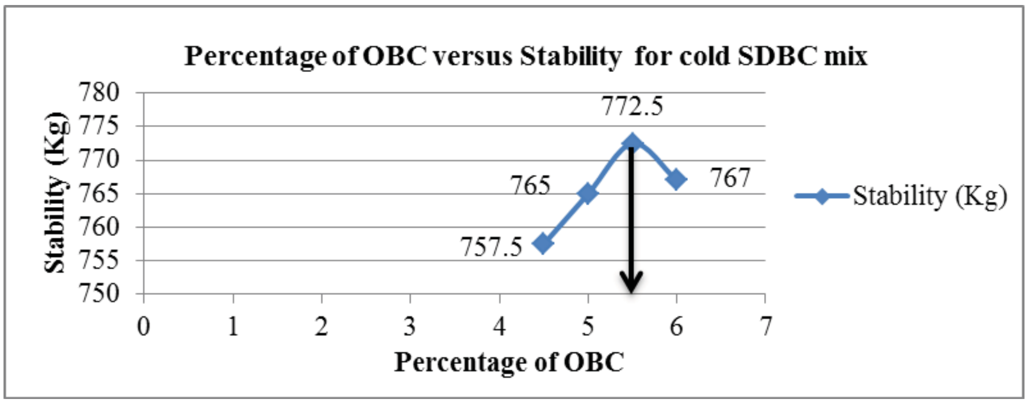

Figure 2: Graph of percentage OBC versus stability for cold SDBC mix

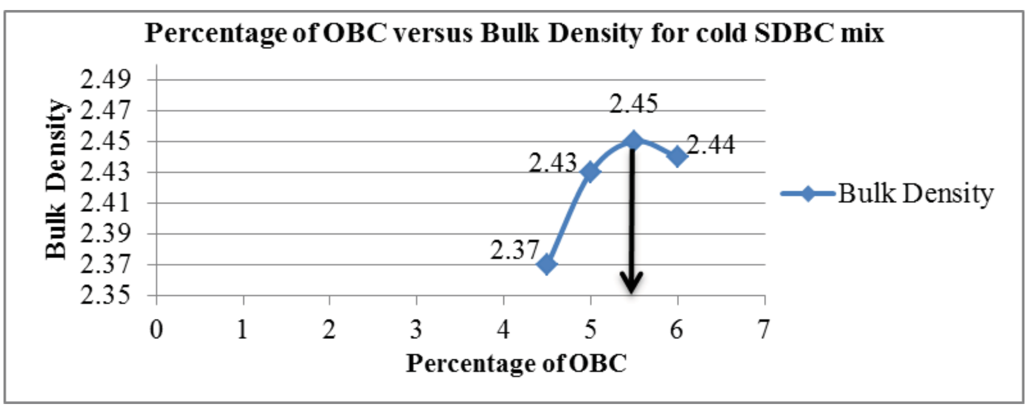

Figure 3: Graph of percentage OBC versus bulk density for SDBC cold mix

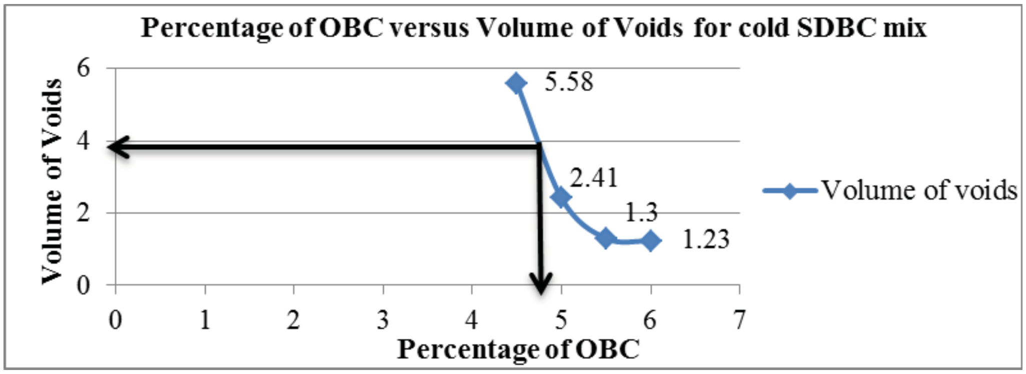

Figure 4: Graph of percentage OBC versus volume of voids for cold SDBC mix

B. Percentage variation of GGBS (additive) with different bituminous emulsion content in cold SDBC mix

Table 4: Obtained stability with varying percentage of GGBS with OBC fixed as 4.3% for cold SDBC mix

OBC (%)	OMC (%)	GGBS (%)	Height (cm)	Weight in Air (kg)	Weight in Water (kg)	Stability (kg)	Flow (mm)
4.3	3	2	6.8	1.172	0.650	1275	5.5
		4	6.2	1.178	0.658	1428.75	6
		6	6.4	1.181	0.653	1031.25	7.5
		8	6.5	1.163	0.668	1455	5

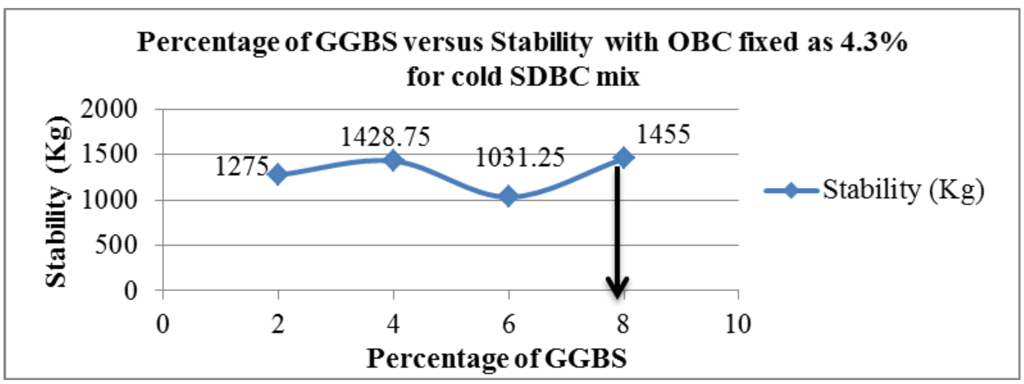

Figure 5: Graph of percentage GGBS versus stability with OBC fixed as 4.3% for cold SDBC mix

Table 5: Obtained stability with varying percentage of GGBS with OBC fixed as 5.3% for cold SDBC mix

OBC (%)	OMC (%)	GGBS (%)	Height (cm)	Weight in Air (kg)	Weight in Water (kg)	Stability (Kg)	Flow (mm)
5.3	3	2	6.5	1.199	0.662	1162.5	5.5
		4	6.6	1.192	0.657	1233.5	6
		6	6.3	1.170	0.638	1518.75	8
		8	6.7	1.198	0.666	1091.25	5

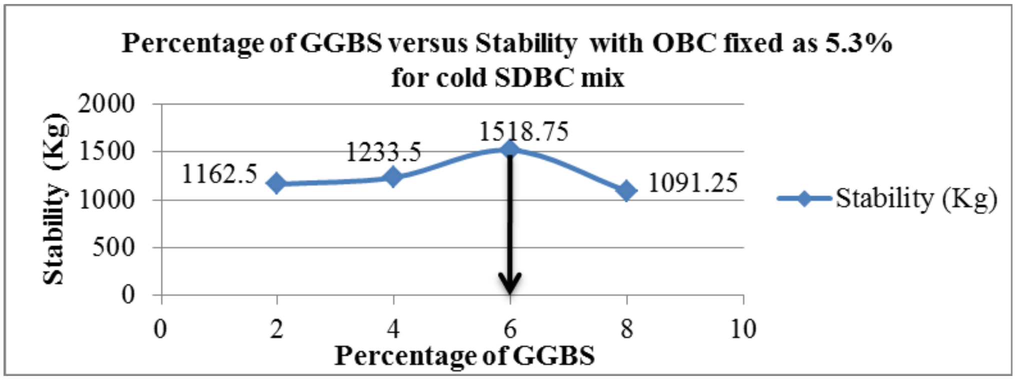

Figure 6: Graph of percentage GGBS versus stability with OBC fixed as 5.3% for cold SDBC mix

Table 6: Obtained stability with varying percentage of GGBS with OBC fixed as 6.3% for cold SDBC mix

OBC (%)	OMC (%)	GGBS (%)	Height (cm)	Weight in Air (kg)	Weight in Water (kg)	Stability (Kg)	Flow (mm)
6.3	3	2	6.5	1.198	0.651	1012.5	7.5
		4	6.8	1.177	0.643	1050	7
		6	6.5	1.229	0.673	1350	5.5
		8	6.3	1.203	0.661	1125	6

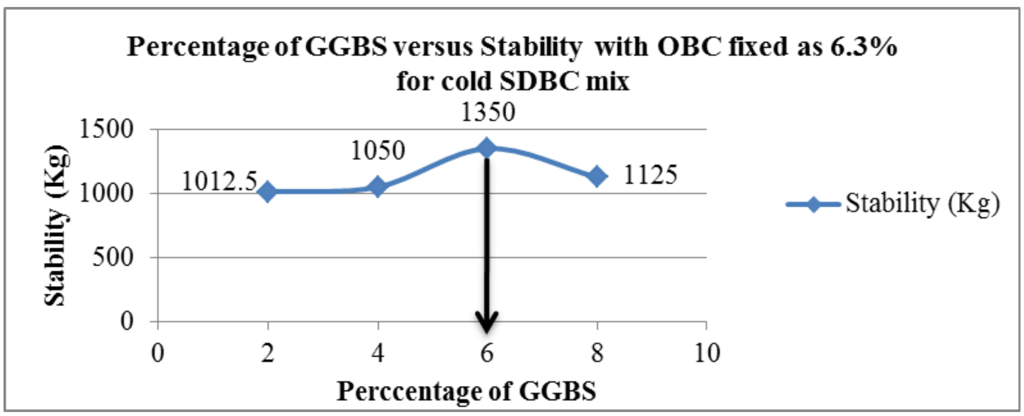

Figure 7: Graph of percentage GGBS versus stability with OBC fixed as 6.3% for cold SDBC mix

Table 7: Obtained stability with varying percentage of OBC with GGBS fixed as 2% for cold SDBC mix

Percentage of OBC	Stability (Kg)
4.3	1275
5.3	1162.5
6.3	1012.5

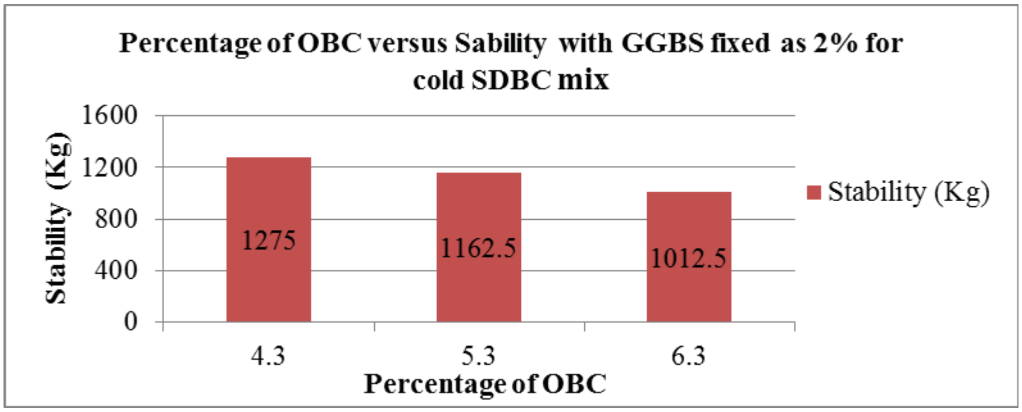

Figure 8: graph of percentage OBC versus stability with GGBS fixed as 2% for cold SDBC mix

Table 8: obtained stability with varying percentage of OBC with GGBS fixed as 4% for cold SDBC mix

Percentage of OBC	Stability (Kg)
4.3	1428.75
5.3	1233.5
6.3	1050

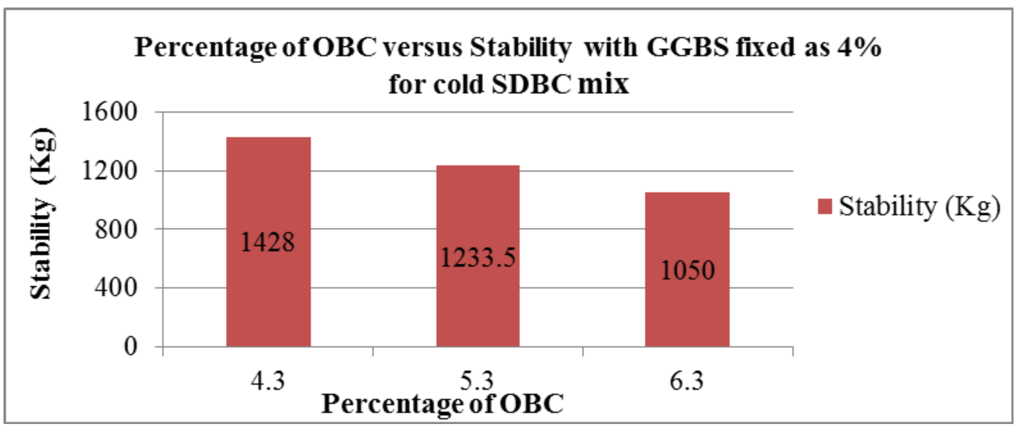

Figure 9: Graph of percentage OBC versus stability with GGBS fixed as 4% for cold SDBC mix

Table 9: Obtained stability with varying percentage of OBC with GGBS fixed as 6% for cold SDBC mix

Percentage of OBC	Stability (Kg)
4.3	1031.25
5.3	1518.75
6.3	1350

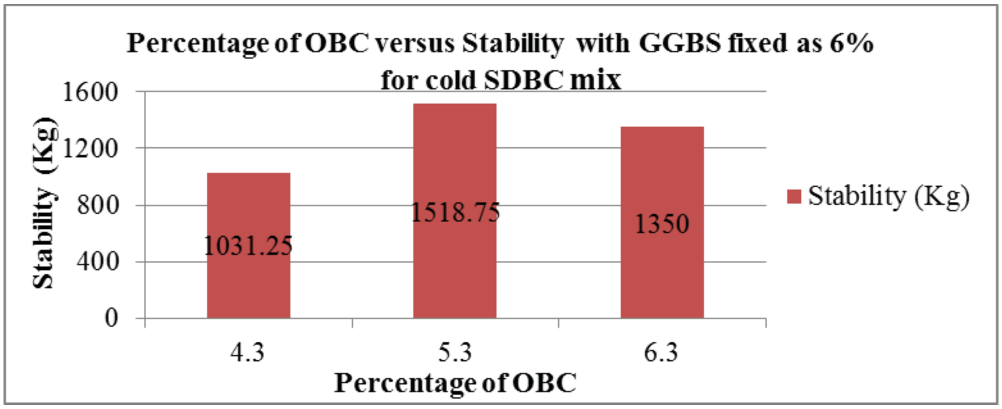

Figure 10: Graph of percentage OBC versus stability with GGBS fixed as 6% for cold SDBC mix

Table 10: Obtained stability with varying percentage of OBC with GGBS fixed as 8% for cold SDBC mix

Percentage of OBC	Stability (Kg)
4.3	1455
5.3	1091.25
6.3	1125

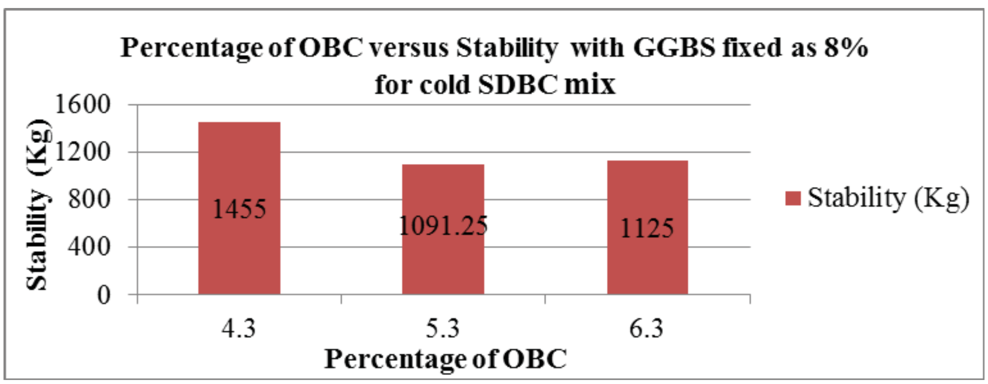

Figure 11: Graph of percentage OBC versus stability with GGBS fixed as 8% for cold SDBC mix

IX. DISCUSSIONS ON TEST RESULTS

A. Effect on volume of voids

It was found that at 5% OBC volume of voids decreased by 56.81% as compared to 4.5% OBC also, at 5.5% OBC volume of voids decreased by 76.70% as compared to 4.5% OBC and at 6.0% OBC volume of voids decreased by 77.96% as compared to 4.5% OBC as shown in Figure 4.

B. Effect of stability of Marshall SDBC Specimen without GGBS as additive

At 5% OBC the stability of the specimen increased by 0.99% as compared to 4.5% OBC, Also at 5.5% OBC the stability of the specimen increased by 0.91% as compared to 5.0% OBC and at 6% OBC the stability of the specimen decreased by 0.65% as compared to 5.5% OBC as shown in Figure 2.

C. Effect on stability of Marshall Specimen at 4.3%obc with GGBS as additive

At 4% GGBS the stability of the specimen increased by 12.06% as compared to 2% GGBS but, at 6% GGBS the stability of the specimen decreased by 27.82% as compared to 4% GGBS and again at 8% GGBS the stability of the specimen increased by 41.09% as compared to 6% GGBS and attains maximum stability (From Figure 8 to 11).

D. Effect on stability of Marshall Specimen at 5.3%obc with GGBS as additive

At 4% GGBS the stability of the specimen increased by 6.11% as compared to 2% GGBS also at 6% GGBS the stability of the specimen increased by 23.13% as compared to 4% GGBS and attains its maximum stability and at 8% GGBS the stability of the specimen decreased by 28.15% as compared to 6% GGBS but doesn't reach its maximum value (From Figure 8 to 11).

E. Effect on stability of Marshall Specimen at 6.3%obc with GGBS as additive

At 4% GGBS the stability of the specimen increased by 3.70% as compared to 2% GGBS also at 6% GGBS the stability of the specimen increased by 28.57% as compared to 4% GGBS and attains its maximum stability and at 8% GGBS the stability of the specimen decreased by 16.67% as compared to 6% GGBS but, doesn't reach its maximum value (From Figure 8 to 11).

A pattern in the results was found and can be clearly seen in the graphs that the stability decreases after 6% GGBS. The optimum GGBS percentage for the calculated OBC 5.3% is 6% since the stability is the maximum. The results obtained are in random with our objectives i.e., there is a substantial increase in the early strength.

X. CONCLUSIONS

- The results obtained from the above study are that the maximum value of stability was found at 5.3% OBC with 6%GGBS as additive. There was a substantial increase in the stability after using GGBS as an additive. The result show a 96% increase in the stability values at 6% GGBS for 5.3% OBC. Voids in total mix, flow and voids in Mineral aggregates reduced with increase in curing period and with the addition of GGBS as filler. Curing rate and mechanical properties of cold mix can be improved. GGBS can be used in cold mix to make its properties comparable to the properties of hot mix design.
- Cold mix can be laid on low to medium volume road as a green paving mix. Mixture can be produced by using conventional plant or by hand. So it can be laid as surface course or bituminous base course for rural road construction. When incorporating cement, the cold mix should be compacted soon after mixing to maximize the results and to avoid workability problems.

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