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Impact Resistance Of Fibre Reinforced High Volumes Of Slag Concrete For Rigid Pavements

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Abstract : *The requirement of cement is rising day by day in construction industry which causes depletion of natural resources and at the same time increases environmental pollution. One of the solutions to reduce the usage of cement in concrete is by using GGBS as substituting material to OPC. Pavements are subjected to impact loads due to studded wheel tires. In this experimental investigation, High Volumes of Slag Concrete (OPC:GGBS is 50:50) of different water/binder ratios are ranging from 0.55 to 0.27 are considered. 100mm X 100 mm X 500 mm beams of High Volumes of Slag Concrete (HVSC) having different percentages of Crimped steel fibres are tested for impact strength. Fibres improve impact strength whereas GGBS improves durability of concrete. The impact strength HVSC with and without fibres is evaluated for 28, 90 and 180 days. The percentage improvement of HVSC for 90 and 180 days strength compared to 28-day impact strength and percentage improvement of impact strength of High Volumes of Slag Concrete (HVSC) with and without steel fibres are evaluated. From the results, it is found that HVSC with 1.5 % steel fibres exhibited appreciable increase in impact resistance for ultimate crack compared to HVSC without fibres for 180 days.*
Keywords: *High Volumes of Slag Concrete, GGBS, Ultimate Crack and Impact strength.*

I. Introduction

Concrete is most widely used material in construction of structures like buildings, pavements, bridges etc. worldwide. Cement is one of the important ingredients of concrete and hence the consumption of cement is increasing drastically which consumes more amounts of natural resources. In this scenario, there is a need to search for cement substituting material which produces strength and durable concrete. Ground Granulated Blast Furnace Slag (GGBS) is one of such materials, waste generated from Iron ore industry.

Steel Fibres in Concrete enhances the properties of concrete like flexural toughness, impact resistance and shear strength. It also improves the behavior of post cracking of concrete pavements. Fibre Reinforced Concrete (FRC) is recommended for pavements by IRC:SP:46-2013. The drawback of FRC being is the initial cost. However due to addition of fibres the concrete exhibits improved properties and make the concrete durable.

II. Fibre Reinforced Concrete

Pooja Shrivastava et al.,(2014)(1), Steel fiber reinforced concrete (SFRC) consists of hydraulic cements, fine and coarse aggregate and discontinuous discrete steel fibers as raw materials. Plain concrete or conventional concrete is mostly subjected to cracking due to intrinsic weakness of material while resisting tensile forces. Concrete allows transmitting micro cracks due to its poor tensile strength further leading the concrete to brittle fracture. Traditional reinforcement which is in the form of bars or mess at cracked section does not allow cracking, improves resistance against ultimate cracking successfully and also efforts in serviceability limit state to control cracking, rotations and deflections. In FRC, the short and discrete steel fibers act as discontinuous reinforcement in three directions which sustain load and distribute stress at the micro-cracks level. Steel fibers contribute in strength improvement and stiffness further making the concrete tough and durable against abrasion and impact loads.

Arvo Tinni(2013)(2), Steel Fibre Reinforced Concrete Pavement (SFCP) is used in the cases where increased resistance to cracking odd shaped and acute cornered slabs are required. It is appropriate for areas with high proportion of slabs of irregular shape, e.g. roundabouts. The maximum spacing for transverse and longitudinal joints is 6 m and dowel bars are not used for transverse and longitudinal contraction joints in SFCPs. The quantity of Steel fibre is usually mixed at about 70 kg/m^3 and the characteristic compressive strength of FRC is 40 to 45 MPa, and a flexural strength of 5 MPa. Minimum thickness of slab is 180 mm for FRC whereas the thickness is less than that of concrete without fibres.

Mohammed Yusuf Sagri et al., (2015)(3), contrastingly, fibre does not cause an increase in the flexural strength of concrete and hence it cannot be replaced to moment resisting or structural steel reinforcement. Volume Fraction typically ranges from 0.1 to 3%. Fibre with a non-circular cross section uses an equivalent diameter for the calculation of aspect ratio. The fibre with modulus of elasticity than the matrix (concrete or mortar binder) helps in increasing the tensile strength of the material. The fibres which are too long cause lumps in the mix and affects workability. The use of micro fibre offers better impact resistance when compared with the longer fibre.

G. Niranjana et al., (2008)(4), The mechanical properties of concrete are improved by increasing the proportion of steel scrap up to 1.5%. But there is significant reduction in the mechanical strength of SSFRC at 2.0% of steel proportion. However, the pavement thickness is reduced by 41% which is economical when compared to plain cement concrete slab at 1.5%.

K.Anbuvelan, (2014)(5) stated that concrete structures are frequently subjected to short duration (static or dynamic) due to relatively low tensile strength, low fracture energy and poor impact resistance of concrete. The impact resistance of three grades of concrete with 0.1%, 0.2%, 0.3% dosage of Polypropylene fiber concrete are showing better results when compared to plain concrete.

G. Murali, (2014)(6) investigations are made on the impact resistance of fiber reinforced concrete (FRC), subjected to drop weight test according to the procedure suggested by ACI committee 544. The results indicate that 1.5% volume fraction of steel fiber enhances the impact energy in case of FRC when compared to plain concrete. The Weibull distribution facilitates to design the mix easily and eliminates the number of repetitions.

P.Sravana et al., (2009)(7) The concrete prepared with very low water content (water-binder ratio, w/b < 0.4) is possible due to the use of super plasticizer; minimum replacement level of Fly ash is 50 percent of the ordinary Portland cement by weight. The ultimate impact strength of high volume fly ash concrete (w/b = 0.36) with 1.5% steel fibres at 90 days was improved by 50% with respect to ordinary concrete with 1.5% steel fibres. The first crack strength and ultimate strength of high volume fly ash concrete with 1.5% steel fibres at 90 days was increased to 230% and 400 % with respect to without fibres respectively. The studies revealed that high volumes of fly ash concrete with steel fibres enhance the properties of concrete in terms of strength as well as in terms of performance.

V. S. Tamilarasan et al., (2012)(8) in all the replacement levels, the flexural strength of GGBS added concrete without and with Superplasticiser are higher than the flexural strength of conventional concrete in both M20 and M25 grade concretes. The increase in tensile and flexural strengths is found to be maximum at 60% replacement level. Replacement of cement by 60% GGBS helps to reduce the cement content of concrete thereby reducing the cost of concrete.

Md. Moinul Islam et al., (2010)(9) development of compressive strength for slag concrete is not significant at the early age of curing. The gain in strength occurs at relatively rapid rate at later ages of curing. Mix proportion of slag with cement has a significant effect on strength development of slag concrete. Among the mix proportions studied, the 70:30 mix slag concrete shows higher compressive strength.

Z C Muda et al., (2013)(10), In this research work, geogrid reinforcement is used in oil palm shells concrete(OPS) which improves the impact resistance of OPS under service (first) limit crack up to 5.9 times and at ultimate limit crack up to 20.1 times against the control concrete (without geogrid).

P.Srinivasa Rao, et al., (2010)(11), In this experimental investigation, the effect of addition of alkali resistance glass fibres on compressive, split tensile and flexural strength of M20, M30, M40 and M50 grades of concrete was found. Addition of glass fibres improves the surface integrity and homogeneity of concrete and reduces the probability of cracks. The percentage increase of compressive strength of various grades of glass fibre concrete mixes compared with 28days compressive strength is observed from 20 to 25% and the percentage increase of flexural and split tensile strength of various grades of glass fibre concrete mixes compared with 28 days is observed from 15 to 20%.

Dipan patel, (2013)(12), In the Experimental investigation, mechanical properties like compressive strength and tensile strength of Steel Fiber Reinforced Concrete (SFRC) of M-20 grade concrete containing fibers of 0.4% and 0.5% volume fraction of Crimped Steel fibers (aspect ratio is 50) were found. The compressive strength of steel fiber concrete is increased when compared to plain cement concrete. Addition of steel fiber increases the flexural strength of steel fiber concrete to a great extent. The pavement thickness is reduced by 23% by the addition of steel fiber in concrete which is economical when compared to plain cement concrete slab.

III. Experimental Investigation

1. **Cement:** Locally available 53 grade of Ordinary Portland Cement (Ultratech Brand.) confirming to IS: 12269 was used in the investigations. The cement is tested for various properties like Normal consistency, specific gravity, Fineness, Soundness, Compressive Strength and Specific Surface area were found to be 28%, 3.10, 4%, 0.5 mm, 53Mpa and 3100 cm^2/g in accordance with IS:12269-1987.

2. **GGBS:** GGBS which is available in local was procured from Steel Plant, Visakhapatnam (Dt.), Andhra Pradesh. The physical requirements in accordance with IS 1727- 1967 (Reaffirmed2008) and chemical requirements in accordance with IS: 12089 – 1987 (Reaffirmed 2008). The GGBFS is tested for various properties like Specific gravity and Fineness were found to be 2.86 and 3500 cm^2/g.
3. **Super Plasticizer**: The Super plasticizer utilized was supplied by internationally reputed admixture manufactures. Endure flowcon04 was manufactured by Johnson. Endure flowcon04 is dark brown colored liquid and it is based as sulphonated naphthalene formaldehyde (SNF) super plasticizer. It complies with IS: 9103-1999, BS5075, ASTM C-494 was used. The super plasticizer is tested for properties like density and pH were found to be 1.2 and minimum 6.
4. **Fine Aggregate:** The locally available river sand is used as fine aggregate in the present investigation. The sand is free from clay, silt, and organic impurities. The sand is tested for various properties like specific gravity, water absorption and fineness modulus of fine aggregate were found to be 2.55, 1.72 and 2.74 in accordance with IS:2386-1963.
5. **Course Aggregate:** Machine crushed angular granite metal of 20mm nominal size from the local source is used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc., the coarse aggregate is also tested for its various properties. The specific gravity, water absorption and bulk density and fineness modulus of coarse aggregate were found to be 2.60, 0.38, 1490 kg/m^3 and 7.16 respectively.
6. **Water:** Locally available water used for mixing and curing which is potable, shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.
7. **Fibres:** In present investigation, the fibres of crimped whose length is 38 mm and diameter is 0.8 mm are used and their aspect ratio is 47.5. These fibres were purchased from M/s. Stewols India (P) Limited, Nagpur.

IV. Mix Design

TABLE.1 Quantities of Material required per One Cu. m. of High Volumes of Slag Concrete:

w/b ratio	Water (Lts)	Cement (kg)	GGBS (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Super Plasticizer (ml)	Slump Values (mm)
0.55	176	160	160	763	990	0	75
0.50	176	176	176	749	971	0	80
0.45	176	196	196	715	966	0	65
0.40	176	220	220	662	971	1732	90
0.36	176	244	244	625	961	2122	100
0.32	176	275	275	587	936	3873	120
0.30	176	293	293	529	959	3882	130
0.27	176	326	326	477	945	4698	140

V. Test Procedure

To study the impact strength test specimens of size 100 x 100 x 500 mm are cast with High Volumes of Slag Concrete with various water/binder ratios with and without steel fibres. After completion of curing period of 28, 90 and 180 days the specimens are tested for impact resistance.

The impact hammer was positioned at the mark for swung up to the mark which measured 20^0 swings by a right angle hook and was released for applying the impact load on the specimen. The blows are repeated in above manner till 1st crack. The crack propagation for each blow after 1st crack is marked on the specimens for clarity. The number of blows required for the crack propagation from one edge to other on the tension face was noted. The experiment was continued till the spalling of mortar occurring on the compression face of the specimen.

VI. Results

TABLE 2 Average First Crack and Ultimate Crack Strength of High Volumes of Slag Concrete with and without Fibres Based on Number of Blows

S. No.	Type of Specimen	First Crack			Ultimate Crack		
		28 days	90 days	180 days	28 days	90 days	180 days

1	High Volumes of Slag Concrete +0% fibres w/b=0.55	2	2	3	3	3	5
2	High Volumes of Slag Concrete +0.5% fibres w/b=0.55	3	4	5	7	10	12
3	High Volumes of slag Concrete + 1% fibres w/b=0.55	5	7	9	10	14	18
4	High Volumes of Slag Concrete + 1.5% fibres w/b=0.55	9	15	17	21	35	40
5	High Volumes of Slag Concrete + 0% fibres w/b=0.5	3	4	5	4	6	7
6	High Volumes of Slag concrete + 0.5% fibres w/b=0.5	4	6	7	8	12	15
7	High Volumes of slag Concrete + 1% fibres w/b=0.5	6	10	11	15	25	28
8	High Volumes of slag Concrete + 1.5% fibres w/b=0.5	11	19	21	25	44	48
9	High Volumes of Slag Concrete +0% fibres w/b=0.45	4	6	7	5	8	9
10	High Volumes of Slag Concrete +0.5% fibres w/b=0.45	5	8	9	9	15	17
11	High Volumes of slag Concrete + 1.5%fibres w/b=0.45	8	14	15	17	30	32
12	High Volumes of Slag Concrete + 1.5% fibres w/b=0.45	15	27	30	29	52	58
13	High Volumes of Slag Concrete + 0% fibres w/b=0.4	6	9	11	7	11	13
14	High Volumes of Slag concrete + 0.5% fibres w/b =0.4	7	12	13	10	17	19
15	High Volumes of slag Concrete + 1% fibres w/b=0.4	9	16	17	20	36	39
16	High Volumes of slag Concrete + 1.5% fibres w/b=0.4	17	31	36	33	61	70
17	High Volumes of Slag Concrete +0% fibres w/b=0.36	7	11	13	8	13	15
18	High Volumes of Slag Concrete +0.5% fibres w/b=0.36	8	14	15	11	19	21
19	High Volumes of Slag Concrete + 1%fibres w/b=0.36	11	20	21	25	46	49
20	High Volumes of Slag Concrete + 1.5% fibres w/b=0.36	19	35	42	36	67	80
21	High Volumes of Slag Concrete + 0% fibres w/b=0.32	8	13	15	10	17	19
22	High Volumes of Slag concrete + 0.5% fibres w/b=0.32	9	16	17	12	21	24
23	High Volumes of slag Concrete + 1% fibres w/b=0.32	14	26	27	26	48	52
24	High Volumes of slag Concrete + 1.5% fibres w/b=0.32	21	40	50	39	74	93
25	High Volumes of Slag Concrete +0% fibres w/b=0.3	9	15	17	11	19	21
26	High Volumes of Slag Concrete +0.5% fibres w/b=0.3	10	18	19	14	26	28
27	High Volumes of slag Concrete + 1%fibres w/b=0.3	16	30	31	29	55	59
28	High Volumes of Slag Concrete + 1.5% fibres w/b=0.3	23	45	57	41	80	105
29	High Volumes of Slag Concrete + 0% fibres w/b=0.27	10	17	19	12	21	23
30	High Volumes of Slag concrete + 0.5% fibres w/b=0.27	11	20	21	15	28	31
31	High Volumes of slag Concrete + 1% fibres w/b=0.27	17	33	35	32	61	67
32	High Volumes of slag Concrete + 1.5% fibres w/b=0.27	29	57	75	45	88	117

TABLE 3 Percentage Improvement in First Crack and Ultimate Strength of High Volumes of Slag Concrete With & Without Fibres over 28 Days Impact Strength (w/b=0.55)

w/b ratio	Percentage of fibre	First Crack		Ultimate Crack	
		90 days	180 days	90 days	180 days
0.55	0	0	50	0	67
	0.5	33	67	43	71
	1	40	80	40	80
	1.5	67	89	67	90

Fig.1 Percentage Improvement in First Crack and Ultimate Strength of High Volumes of Slag Concrete With & Without Fibres over 28 Days Impact Strength (w/b=0.55)

TABLE 4 Percentage Improvement in First Crack and Ultimate Crack Strength of High Volumes of Slag Concrete with & without Fibres over 28 Days Impact Strength (w/b=0.36)

w/b ratio	Percentage of fibre	First Crack		Ultimate Crack	
		90 days	180 days	90 days	180 days
0.36	0	57	86	63	88
	0.5	75	88	73	91
	1	82	91	84	96
	1.5	84	121	86	122

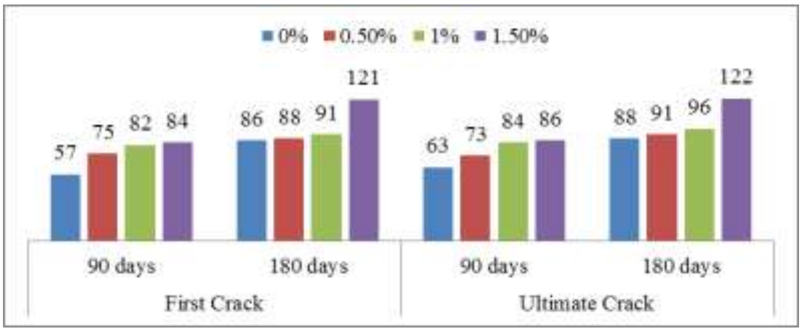

Fig.2 Percentage Improvement in First Crack and Ultimate Strength of High Volumes of Slag Concrete With & Without Fibres over 28 Days Impact Strength (w/b=0.36)

TABLE 5 Percentage Improvement in First Crack and Ultimate Crack Strength of High Volumes of Slag Concrete with & without Fibres over 28 Days Impact Strength (w/b=0.27)

w/b ratio	Percentage of fibre	First Crack		Ultimate Crack	
		90 days	180 days	90 days	180 days
0.27	0	70	90	75	92
	0.5	82	91	87	107
	1	94	106	91	109
	1.5	97	159	96	160

Fig.3 Percentage Improvement in First Crack and Ultimate Strength of High Volumes of Slag Concrete With & Without Fibres over 28 Days Impact Strength (w/b=0.27)

TABLE 6 Percentage Improvement in First Crack and Ultimate Crack Strength of High Volumes of Slag Fibre Concrete over High Volumes of Slag Concrete (w/b=0.55)

S.No.	Type of Specimen	First Crack			Ultimate Crack		
		28days	90 days	180 days	28 days	90 days	180 days
1	High volumes of slag Concrete + (w/b=0.55) 0.5% Fibres	50	100	67	133	233	140
2	High volumes of slag Concrete (w/b=0.55) +1% Fibres	150	250	200	233	367	260
3	High volumes of slag Concrete (w/b=0.55) + 1.5% Fibres	350	650	467	600	1067	700

Fig. 4 Percentage Improvement in First Crack and Ultimate Crack Strength of High Volumes of Slag Fibre Concrete over High Volumes of Slag Concrete (w/b=0.55)

TABLE 7 Percentage Improvement in First Crack and Ultimate Crack Strength of High Volumes of Slag Fibre Concrete over High Volumes of Slag Concrete (w/b=0.36)

S.No.	Type of Specimen	First Crack			Ultimate Crack		
		28 days	**90 days**	**180 days**	**28 days**	**90 days**	**180 days**
1	High volumes of slag Concrete + (w/b=0.36) 0.5% Fibres	14	27	15	38	46	40
2	High volumes of slag Concrete (w/b=0.36) +1% Fibres	57	82	62	213	254	227
3	High volumes of slag Concrete (w/b=0.36) + 1.5% Fibres	171	218	223	350	415	433

Fig. 5 Percentage Improvement In First Crack and Ultimate Crack Strength of High Volumes of Slag Fibre Concrete over High Volumes of Slag Concrete (w/b=0.36)

TABLE 8 Percentage Improvement in First Crack and Ultimate Crack Strength of High Volumes of Slag Fibre Concrete over High Volumes of Slag Concrete (w/b=0.27)

S.No.	Type of Specimen	First Crack			Ultimate Crack		
		28 days	**90 days**	**180 days**	**28 days**	**90 days**	**180 days**
1	High volumes of slag Concrete + (w/b=0.27) 0.5% Fibres	10	18	11	25	33	35
2	High volumes of slag Concrete (w/b=0.27) +1% Fibres	70	94	84	167	190	191
3	High volumes of slag Concrete (w/b=0.27) + 1.5% Fibres	190	235	295	275	319	409

Fig. 6 Percentage Improvement In First Ultimate Crack Strength of High Volumes of Slag Fibre Concrete over High Volumes of Slag Concrete (w/b=0.27)

Fig. 7 Casting and Testing of Specimens of HVSC with Steel Fibres

Fig. 8 Specimens of HVSC before and after curing

Fig.9 Failure at Ultimate Crack of Specimen of HVSC

VII. Discussions

1. **Mix Design:** The quantities of materials for one cubic meter of High Volumes of Slag Concrete (HVSC) are shown in TABLE 1. And also using the data obtained from the tests on cement, GGBS, aggregates, admixture and water.
2. **Workability:** The workability of different concrete mixes of HVSC was measured using slump test. It can be seen from the TABLE 1 that a medium workability was maintained for almost all the mixes by addition of suitable quantities of super plasticizer.
3. **Studies on Impact Resistance of High Volumes of Slag Fibre Reinforced Concrete**

In this experimental investigation, High Volumes of Slag Concrete of different w/b ratios are ranging from 0.55 to 0.27 of 100mm X 100 mm X 500 mm beams with different percentage of Crimped steel fibres are cast and tested for impact strength are shown in Fig. 7 to Fig. 9. The percentage of the addition of steel fibres to the concrete is 0%, 0.5%, 1%, and 1.5% of weight of concrete. The no. of blows required for first crack and ultimate crack for HVSC with 0%, 0.5%, 1%, and 1.5% for various w/b ratios ranging from 0.55 to 0.27 are shown in TABLE 2. The percentage improvement in impact Strength for 90 and 180 days with respect to 28 day strength and percentage improvement of HVSC with steel fibres for 28, 90 and 180 days to HVSC with 0% fibre are evaluated for w/b ratios 0.55, 0.36 and 0.27. The results are shown in TABLE 3 to TABLE 8 and Fig.1 to Fig.6.

3.1 Impact Strength of High Volumes of Slag Concrete with and without Steel Fibres

Impact Strength (First crack & Ultimate Crack) of High Volumes of Slag Concrete at 28, 90 and 180 days for 20 degree angle of swing respectively and the values are given in TABLE 2.

The number of blows required for First crack of HVSC without fibres is 2 to 10 for 28 days, 2 to 17 for 90 days, and 3 to 19 for 180 days. Whereas for Ultimate crack, the number of blows required is 3 to 12 for 28 days, 3 to 21 for 90 days, and 5 to 23 for 180 days for w/b ratios varying 0.55 to 0.27 respectively.

The number of blows required for First crack of HVSC with 1.5% fibres is 9 to 29 for 28 days, 15 to 57 for 90 days, and 17 to 75 for 180 days and in case of Ultimate crack, the number of blows required is 21 to 45 for 28 days, 35 to 88 for 90 days, and 40 to 117 for 180 days for w/b ratios varying 0.55 to 0.27 respectively.

From the results, it is observed that the number of blows required for first crack and ultimate crack of HVSC increase with decrease in w/b ratio and increase with percentage of fibres. HVSC with 1.5% fibres shows higher impact resistance.

3.2 Percentage Improvement in First crack Strength of High volumes of Slag Concrete with & without Steel Fibers over 28 days strength

Percentage improvements in first crack strength and Ultimate Crack Strength of High Volumes of Slag Concrete with 0%, 0.5%, 1% and 1.5% fibres for 90 and 180 days strength over 28 days strength are shown in TABLE 3 to TABLE 5 and Fig. 1 to Fig. 3.

Percentage improvement in strength is observed at First Crack and at Ultimate Crack for w/b ratio of 0.55 as shown in TABLE 3 and Fig. 1. It is observed that the percentage improvement in impact strength for First Crack is 0% to 50% and for Ultimate Crack is 0% to 67% for HVSC with 0% fibre for 90 and 180 days with respect to 28 days. Whereas the percentage improvements in impact strength for First Crack and Ultimate Crack are 67% to 89% for HVSC with 1.5% fibre for 90 and 180 days with respect to 28 days.

Percentage improvement in impact strength is observed at First Crack and at Ultimate Crack for w/b ratio of 0.36 as shown in TABLE 4, and Fig. 2. It is observed that the percentage improvements in impact strength for First Crack are 57% to 86% and for Ultimate Crack are 63% to 88% for HVSC with 0% fibre for 90 and 180 days with respect to 28 days. In case of HVSC with 1.5% fibre, the percentage improvements in impact strength for First Crack are 84% to 121% and for Ultimate Crack are 86% to 122% for 90 and 180 days with respect to 28 days.

Percentage improvement in impact strength is observed at First Crack and at Ultimate Crack for w/b ratio of 0.27 as shown in TABLE 5 and Fig. 3. It is observed that the percentage improvements in impact strength for First Crack are 70% to 90% and for Ultimate Crack are 75% to 92% for HVSC with 0% fibre for 90 and 180 days with respect to 28 days. Whereas the percentage improvements in impact strength for First Crack are 97% to 159% and for Ultimate Crack are 96% to 160% for HVSC with 1.5% fibre for 90 and 180 days with respect to 28 days.

From the results, it is revealed that HVSC with 1.5% fibre exhibits more impact strength and more percentage improvement for 90 and 180 days with respect to 28 days than HVSC with 0%, 0.5% and 1.0% fibres

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3.3 Percentage Improvement in First Crack Strength and Ultimate Crack Strength of HVSC with Steel Fibres over HVSC without Steel Fibres 28, 90 and 180 Days strength

Percentage **i**mprovement in First Crack Strength and Ultimate Crack strength of High Volumes of Slag Concrete with fibres over High Volumes of Slag Concrete without fibres 28, 90 and 180 days strength of w/b ratio of 0.55 are given in TABLE 6 and Fig. 4.

Percentage improvements in First Crack strength are 50%, 100% and 67% for HVSC with 0.5% fibres, 150%, 250% and 200% for HVSC with 1.0% fibres, and 350%, 650%, and 467% for HVSC with 1.5% fibres over HVSC without fibres for 28, 90 and 180 days respectively. Whereas the percentage improvements in Ultimate Crack strength are 133%, 233% and 140% for HVSC with 0.5% fibres, 233%, 367% and 260% for HVSC with 1.0% fibres, and 600%, 1067%, and 700% for HVSC with 1.5% fibres over HVSC without fibres for 28, 90 and 180 days respectively.

Percentage improvement in First Crack Strength and Ultimate Crack strength of High Volumes of Slag Concrete with fibres over High Volumes of Slag Concrete without fibres 28, 90 and 180 days strength of w/b ratio of 0.36 are shown in TABLE 7 and Fig. 5. Percentage improvements in First Crack strength are 14%, 27% and 15% for HVSC with 0.5% fibres, 57%, 82% and 62% for HVSC with 1.0% fibres, and 171%, 218%, and 223% for HVSC with 1.5% fibres over HVSC without fibres for 28, 90 and 180 days respectively. In case of the percentage improvements in Ultimate Crack strength are 38%, 46% and 40% for HVSC with 0.5% Fibres, 213%, 254% and 227% for HVSC with 1.0% Fibres, and 350%, 415%, and 433% for HVSC with 1.5% Fibres when compared to HVSC without fibres for 28, 90 and 180 days respectively.

Percentage improvement in First Crack Strength and Ultimate Crack strength of High Volumes of Slag Concrete with fibres over High Volumes of Slag Concrete without fibres 28, 90 and 180 days strength of w/b ratio of 0.27 are shown in TABLE 8 and Fig. 6**.** Percentage improvements in First Crack strength are 10%, 18% and 11% for HVSC with 0.5% Fibres, 70%, 94% and 84% for HVSC with 1.0% fibres, and 190%, 235%, and 295% for HVSC with 1.5% Fibres when compared to HVSC without fibres for 28, 90 and 180 days respectively. The percentage improvements in Ultimate Crack strength are 25%, 33% and 35% for HVSC with 0.5% Fibres, 167%, 190% and 191% for HVSC with 1.0% Fibres, and 275%, 319, and 409% for HVSC with 1.5% Fibres over HVSC without fibres for 28 days, 90 days and 180 days respectively.

The Photographs of casting, curing, the apparatus and Test set up for impact specimens are shown in Fig.7 to Fig.9**.**

From the observations, it can be seen that for most of the cases, the percentage improvement in impact strength for HVSC with steel fibres on HVSC without steel fibres for First Crack as well as Ultimate crack is more in the case of 90 days. Which means the improvement in strength is predominantly seen by addition of steel fibres. The influence of fibres is more than hydration in gaining of strength for 90 days for all mixes.

It is noticed that crack propagation from tension side and spalling of concrete near compression face while conducting experiments. There is an appreciable difference between number of blows required for first crack and ultimate crack. This means Fibres improve the flexural strength of concrete obviously. So, it is concluded that Fibre Reinforced High Volumes of Slag Concrete is having good impact resistance.

VIII. Conclusion

The following conclusions are made from the experimental Investigations

- GGBS used in this investigation exhibits good pozzolanic properties and can be used in the production of high strength High Volumes of Slag Concrete. Further addition of slag makes the concrete more impermeable due to micro filler action.
- High Volumes of Slag Concrete achieved good workability for higher w/b ratios without addition of super plasticizer having lower content of cement.
- Impact strength increased due to addition of steel fibres to High Volumes of Slag Concrete and also appreciable increase is observed for lower w/b ratios.
- The Ultimate impact strength of High Volumes of Slag Concrete for w/b ratio varying from 0.55 to 0.27 with 0% steel fibres for 90 days increased up to 75% with respect to 28 days strength; for 180 days, it increased from 67% to 92% with respect to 28 days strength.
- In the case of HVSC with 0.5% steel fibres for w/b ratio varying from 0.55 to 0.27, the Ultimate impact strength increased from 43% to 87% for 90 days with respect to 28 days strength; from 71% to 107% for 180 days with respect to 28 days strength.
- Increments from 40% to 91% and from 80% to 109% are observed in the Ultimate impact strength of High Volumes of Slag Concrete for w/b ratio varying from 0.55 to 0.27 with 1.0% steel fibres for 90 days and 180 days with respect to 28 days strength respectively.
- For 90 days and 180 days, the Ultimate impact strength of High Volumes of Slag Concrete for w/b ratio varying from 0.55 to 0.27 with 1.5% steel fibres increased from 67% to 96% and from 90% to 160% with respect to 28 days strength.
- An increase in impact strength of HVSC with and without steel fibres is observed in later ages and this phenomenon is more visible in the case of HVSC with 1.5% fibres.
- An enormous increase in the Ultimate impact strength of High Volumes of Slag Concrete of w/b varying from 0.55 to 0.27 with 1.5% steel fibres is observed by the addition of steel fibres for 180 days is between 700% and 389% with respect to HVSC without fibres.
- From the results, it is revealed that HVSC with 1.5% steel fibre exhibits more Impact strength and more percentage improvement in impact strength for 90 and 180 days with respect to 28 days than HVSC with 0%, 0.5% and 1.0% steel fibres.
- It is revealed that the flexural strength of HVSC increase by the addition of steel fibres.
- In Concrete pavements, the utilization of industrial waste products such as GGBS, Fly ash etc., are cost effective, eco-friendly and efficient. Shrinkage cracks can be minimized by introducing steel fibres in High Volumes of Slag Concrete Pavements.
- From the above results, HVSC for w/b ratio 0.27 with fibre for all percentages are recommended for rigid pavements. HVSC without fibre for lower w/b ratios and HVSC with fibres for higher w/b ratios are exhibiting good strength for later ages, so, it can be recommended for precast constructions.

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