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Mix Design of Fiber Reinforced Concrete (FRC) Using Slag & Steel Fiber

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Abstract: *Concrete is probably the most extensively used construction material in the world. The main ingredient in the conventional concrete is Portland cement. The amount of cement production emits approximately equal amount of carbon dioxide into the atmosphere. Cement production is consuming significant amount of natural resources. That has brought pressures to reduce cement consumption by the use of supplementary materials. Availability of mineral admixtures marked opening of a new era for designing concrete mix of higher and higher strength. GROUND GRANULATED BLAST FURNACE SLAG (GGBS) is a new mineral admixture, whose potential is not fully utilized. Moreover only limited studies have been carried out in India on the use of slag for the development of high strength concrete with addition of steel fibers.*

The study focuses on the compressive strength performance of the blended concrete containing different percentage of slag and steel fiber as a partial replacement of OPC. The cement in concrete is replaced accordingly with the percentage of 10 %, 20%, 30%, and 40% by weight of slag and 0.5%, 1%, 1.5%, 2% by weight of steel fiber. Concrete cubes are tested at the age of 3, 7, and 28 days of curing. Finally, the strength performance of slag blended fiber reinforced concrete is compared with the performance of conventional concrete. From the experimental investigations, it has been observed that, the optimum replacement of Ground Granulated Blast Furnace Slag Powder to cement and steel fiber without changing much the compressive strength is 20 % & 1.5 % respectively for M20, M30&M40 grade resp.

Keywords: *Concrete, GGBS, steel fibres, Compressive strength, UTM, CTM*

I. INTRODUCTION

In the recent years, there is great development in the area of admixtures and now a day, the pozzolanic admixtures like fly ash, micro silica are commonly used to enhance performance characteristics of concrete. It is need of time to design and construct the structures which will have greater durability and strength and which have led to develop concept of high performance concrete. The major intension in developing high performance concrete is to have adequate resistance to aggressive environments and to make the structure impermeable. However, use of pozzolanic admixtures like micro silica adds to the cost of concrete which directly affects the cost of the project.

It is need to find out the substitute to micro silica without sacrificing the quality and performance of High performance concrete. One of the better alternatives to Micro silica is GGBS.Civil structures made of steel reinforced concrete normally suffer from corrosion of the steel by the salt, which results in the failure of those structures. Constant maintenance and repairing is needed to enhance the life cycle of those civil structures. There are many ways to minimize the failure of the concrete structures made of steel reinforce concrete. The custom approach is to adhesively bond fibre polymer composites onto the structure. This also helps to increase the toughness and tensile strength and improve the cracking and deformation characteristics of the resultant composite. But this method adds another layer, which is prone to degradation. These fibre polymer composites have been shown to suffer from degradation when exposed to marine environment due to surface blistering. As a result, the adhesive bond strength is reduced, which results in the de-lamination of the composite. The principal reason for incorporating fibres into a cement matrix is to increase the toughness and tensile strength, and improve the cracking deformation characteristics of the resultant composite. In order for fibre reinforced concrete (FRC) to be a viable construction material, it must be able to compete economically with existing reinforcing systems. As GGBS is good in resisting salt corrosion & chemical reactions it enhances the properties of FRC.

1.1 Ground Granulated Blast Furnace Slag (GGBS):

Ground granulated blast furnace slag or slag is the by-product of smelting ore to purify metals. They can be considered to be a mixture of metal oxides. However, they can contain metal sulphidesand metal atoms in the elemental form. Slag is generally used as a waste removal mechanism in metal smelting but they can also serve other purposes such as assisting in smelt temperature control and to minimize re-oxidation of the final product before casting. Slag has a pozzolanic reaction which allows the increase of concrete strength. Slag has proven to produce very good and dense concrete allowing increased durability. it is observed from the studies, concrete made with GGBS continues to gain strength over time, and has been shown to double its 28-day strength over periods of 10 to 12 years.

1.2 Steel Fibres:

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to the concrete would act as crack arrester and would substantially improve its Compressive and flexural strength properties. This type of concrete is known as fiber reinforced concrete.The crimped flat steel fibers were used in this study. The sizes (Length/aspect ratio) of the steel fibers are of 30mm/ 60.

II. Experimental study:

In order to achieve the stated objectives, this study was carried out in few stages. On the initial stage, all the materials and equipments needed must be gathered or checked for availability. Then, the concrete mixes according to the predefined proportions. Concrete samples were tested through concrete tests such as cube test. Finally, the results obtained were analyzed to draw out conclusion.

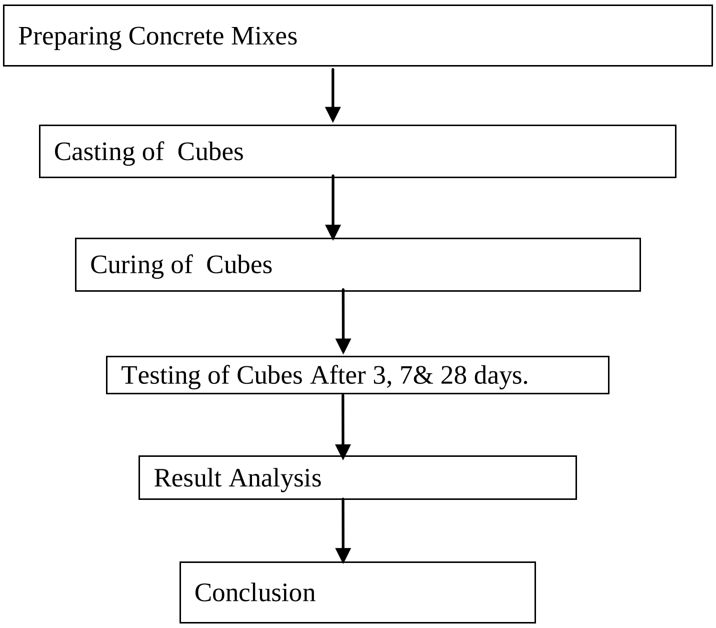

Figure3.1: Flow Chart of Experimental Program

High performance concrete was designed by using Indian Standard method. Trial control mixes for grades M20, M30, M40 grade concrete with replacement of cement by slag in concrete with different dosages i.e. 10%,20%,30%,40%. In addition of steel fibres with different dosages i.e. 0.5%, 1%, 1.5%, 2% respectively. The properties like compressive strength, flexural strength, split tensile strength of concrete using combinations of optimum values of slag and steel fibres are studied.

IS code method of mix design was used for mix design of M20, M30 &M40 grade of concrete. Concrete specimens with various percentages of slag& steel fiber were prepared. The details of various mix proportions for different replacement levels of cement by slag & steel fiber are shown in Table below.

Table 2.1: Details of concrete Mix Proportions for (M20) Grade of Concrete for slag

SN	Slag (%)	W/C Ratio	Mix Proportion (Kg/M^3)				
			Cement	slag	Sand	Agg.	Water
1	0	0.5	360	0	584	1224	180.42
2	10	0.5	324	36	584	1224	180.42
3	20	0.5	288	72	584	1224	180.42
4	30	0.5	252	108	584	1224	180.42
5	40	0.5	216	144	584	1224	180.42

Table 2.2: Mix Proportions for (M20) Grade for steel fiber

S N	S F (%)	W/C Ratio	Mix Proportion (Kg/M^3)				
			Cement	S f	Sand	Agg.	Water
1	0	0.5	360	0	584	1224	180.42
2	0.5	0.5	358.2	1.8	584	1224	180.42
3	1.0	0.5	356.4	3.6	584	1224	180.42
4	1.5	0.5	354.6	5.4	584	1224	180.42
5	2.0	0.5	352.8	7.2	584	1224	180.42

Table 2.3: Mix Proportions for (M20) Grade for optimum strength (slag & steel fiber)

S N	Slag+S F(%)	W/C Ratio	Mix Proportion (Kg/M^3)				
			Cement	Slag+S f	Sand	Agg.	Water
1	0	0.5	360	0	584	1224	180.42
2	20 + 1	0.5	284.40	72+3.6	584	1224	180.42

Table 2.4: Mix Proportions for (M30) Grade for slag

S N	Slag (%)	W/C Ratio	Mix Proportion (Kg/M^3)				
			Cement	slag	Sand	Agg.	Water
1	0	0.42	380	0	711	1283	160
2	10	0.42	342	38	711	1283	160
3	20	0.42	304	76	711	1283	160
4	30	0.42	266	114	711	1283	160
5	40	0.42	228	152	711	1283	160

Table 2.5: Mix Proportions for (M30) Grade for steel fiber

S N	S F (%)	W/C Ratio	Mix Proportion (Kg/M^3)				
			Cement	S f	Sand	Agg.	Water
1	0	0.42	380	0	711	1283	160
2	0.5	0.42	378.10	1.9	711	1283	160
3	1.0	0.42	376.20	3.8	711	1283	160
4	1.5	0.42	374.30	5.7	711	1283	160
5	2.0	0.42	372.40	7.6	711	1283	160

Table 2.6: Mix Proportions for (M30) Grade for optimum strength (slag & steel fiber)

S N	Slag+S F(%)	W/C Ratio	Mix Proportion (Kg/M^3)				
			Cement	Slag+Sf	Sand	Agg.	Water
1	0	0.42	380	0	711	1283	160
2	20 + 1.5	0.42	298.30	76+5.7	711	1283	160

Table 2.7: Mix Proportions for (M40) Grade for slag

S N	Slag (%)	W/C Ratio	Mix Proportion (Kg/M^3)				
			Cement	slag	Sand	Agg.	Water
1	0	0.40	400	0	660	1168	160
2	10	0.40	360	40	660	1168	160
3	20	0.40	320	80	660	1168	160
4	30	0.40	280	120	660	1168	160
5	40	0.40	240	160	660	1168	160

Table 2.8: Mix Proportions for (M40) Grade for steel fiber

SN	S F (%)	W/C Ratio	Mix Proportion (Kg/M^3)				
			Cement	S f	Sand	Agg.	Water
1	0	0.40	400	0	660	1168	160
2	0.5	0.40	398	2	660	1168	160
3	1.0	0.40	396	4	660	1168	160
4	1.5	0.40	394	6	660	1168	160
5	2.0	0.40	392	8	660	1168	160

Table 2.9 Mix Proportions for (M40) Grade for optimum strength (slag & steel fiber)

S N	**Slag+S F(%)**	**W/C Ratio**	**Mix Proportion (Kg/M^3)**				
			Cement	**Slag+Sf**	**Sand**	**Agg.**	**Water**
1	0	0.40	400	0	660	1168	160
2	20 + 1.5	0.40	314	80+6	660	1168	160

Tests and Results Interpretation: A number of tests were carried out to ascertain the design mix properties of concrete in the laboratory.

These tests are based on strength as well as durability concern. The overall performance of any concrete is measured on the basis of mainly two criteria's viz strength and durability of hardened concrete. In case of HPC, strength is major governing attribute whereas durability is a measure of performance. In the present work, the strength of the hardened concrete is ascertained.

The strength criterion includes measurement of following parameters:
- Compressive Strength on cubes
- Flexural Strength
- Split Tensile Strength on Cylinders

Compressive Strength Test:

Compressive strength test is carried out on specimen cubes of concrete blended with various percent replacements to cement by GGBS & steel fiber (varying percentages) and conventional concrete at 3, 7 and 28 days of curing with compression testing machine. Optimized Results of Trial Mixes are as shown in tables from the results of trial mix, it is seen that the compressive strength of Concrete for all percentage remains nearly same withreplacement of cement by GGBS and S F and found maximum for 20% and 1.5% slag & S F respectivelyreplacement of cement.

After testing the concrete (compressive strength) for M20,M30& M40 grade concrete separately for replacement of slag & steel fiber by cement respectively finally combined percentage of slag & steel fiber mix in which maximum strength is obtained was used to get optimized strength.

Optimized % of Slag & Steel Fiber for Compressive Strength of Concrete

Table 4.10:-compressive strength of cube for M-20 Grade **(20 % SLAG & 1 % STEEL FIBER**)

SN	**% Of Slag & Steel Fiber**		**Compressive Strength (N/mm^2)**		
			3 days	**7 days**	**28days**
1	0	0	9.35	17.12	26.33
2	20	1	7.15	15.39	25.25

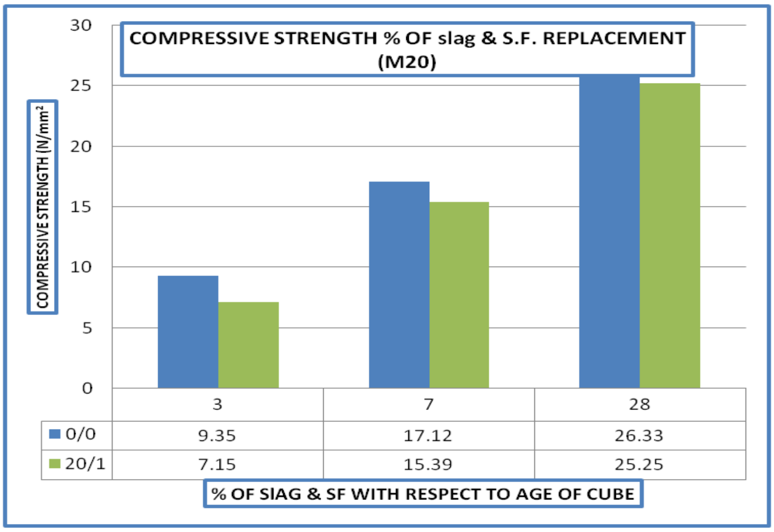

Figure 4.7: Optimized % of Slag & Steel Fiber for Compressive Strength (M20)

Table 4.11:-compressive strength of cube for M-30 Grade (**20 % SLAG & 1.5 % STEEL FIBER**)

SN	% Of Slag & Steel Fiber		Compressive Strength (N/mm^2)		
			3 days	7 days	28days
1	0	0	12.07	22.39	34.27
2	20	1.5	14.55	21.00	33.48

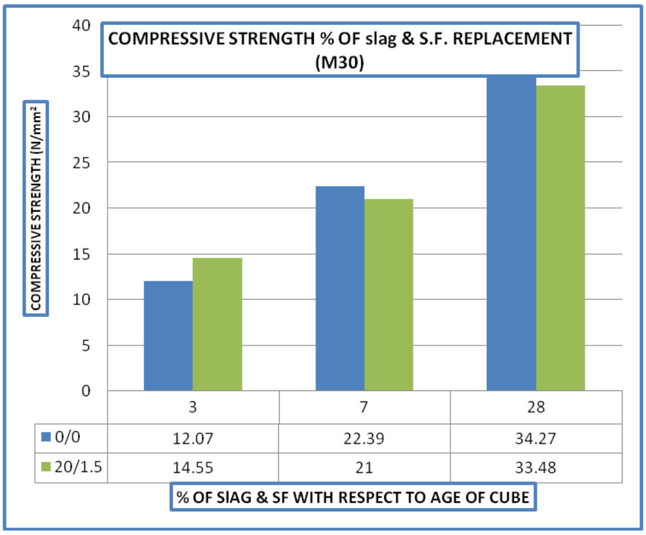

Figure 4.8: Optimized % of Slag & Steel Fiber for Compressive Strength (M30)

Table 4.12:-compressive strength of cube for M-40 Grade (**20 % SLAG & 1.5 % STEEL FIBER**)

SN	% Of Slag & Steel Fiber		Compressive Strength (N/mm^2)		
			3 days	7 days	28days
1	0	0	16.03	31.20	44.59
2	20	1.5	15.90	28.73	45.67

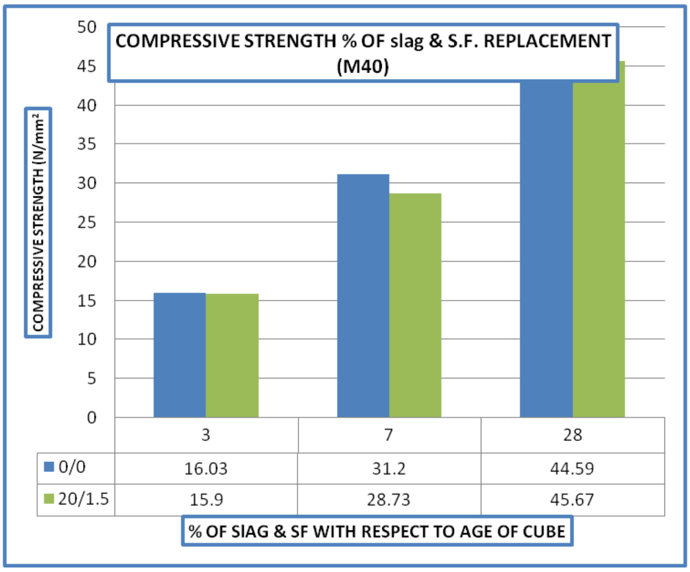

Figure 4.9: Optimized % of Slag & Steel Fiber for Compressive Strength (M40)

For partial replacement of cement with slag (20%) + Steel fiber (1.5%) fiber reinforced concrete got maximum compressive strength as compared to conventional concrete, the strength development of the concrete is increases slightly as its age increases. This can be clearly shown in above figures for all the three grades.

Flexural strength test on Beam

For finding flexural strength of concrete beam, load is applied uniformly on beam. The load was increased until the specimen fails, and maximum load applied to the specimen during the test, was recorded. Table below shows results of flexural strength test.

After testing the concrete (flexural strength) for M20, M30 & M40 grade concrete separately for replacement of slag & steel fiber by cement respectively finally combined percentage of slag & steel fiber mix in which maximum strength is obtained was used to get optimized strength.

OPTIMIZED % OF SLAG & STEEL FIBER FOR FLEXURAL STRENGTH OF CONCRETE

Table 4.19:- Flexural strength for M-20 Grade (**20 % SLAG & 1.5 % STEEL FIBER**)

SN	**% Of Slag & Steel Fiber**		**Flexural Strength (N/mm^2) 28days**
1	0	0	5.30
2	20	1.5	6.38

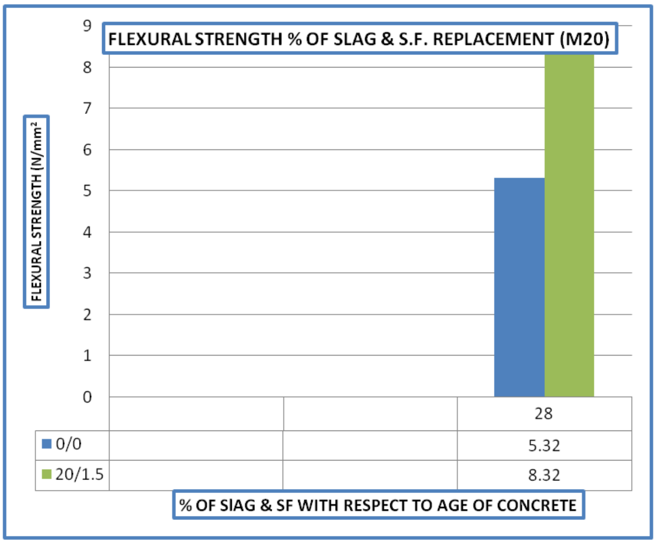

Figure 4.16: Optimized % of Slag & Steel Fiber for Flexural Strength (M20)

Table 4.20:- Flexural strength for M-30 Grade (**20 % SLAG & 1.5 % STEEL FIBER**)

SN	**% Of Slag & Steel Fiber**		**Flexural Strength (N/mm^2) 28days**
1	0	0	6.07
2	20	1.5	7.61

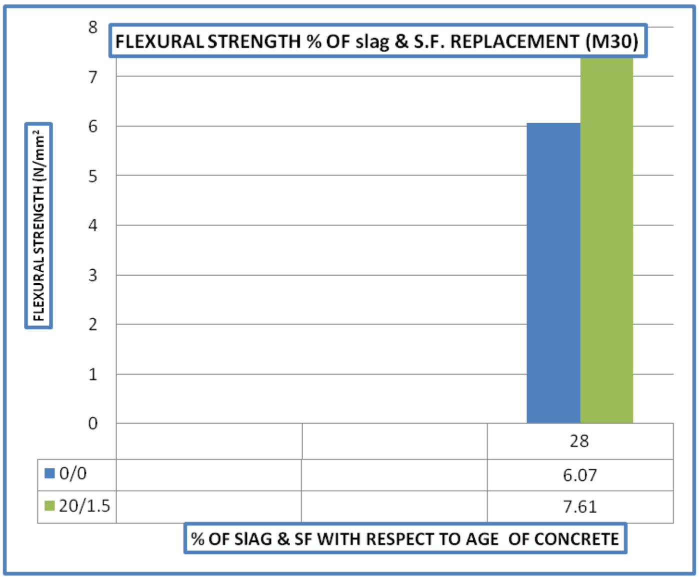

Figure 4.17: Optimized % of Slag & Steel Fiber for Flexural Strength (M30)

Table 4.21:- Flexural strength for M-40 Grade (**30 % SLAG & 2 % STEEL FIBER**)

SN	% Of Slag & Steel Fiber		Flexural Strength (N/mm^2) 28days
1	0	0	5.32
2	30	2	8.32

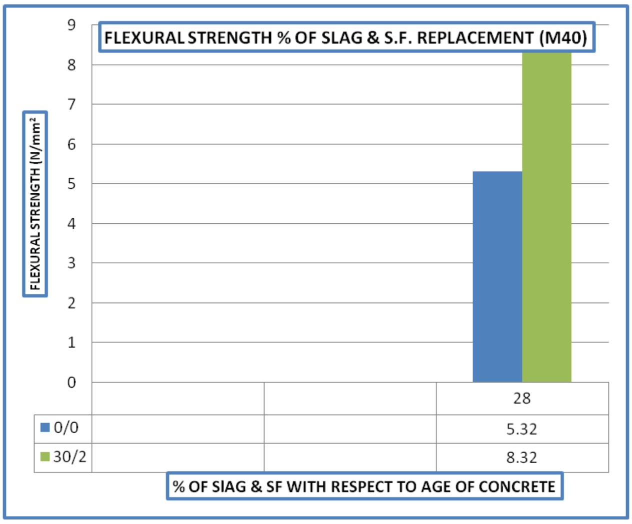

Figure 4.18: Optimized % of Slag & Steel Fiber for Flexural Strength (M40)

For partial replacement of cement with slag (20%) + Steel fiber (1.5%) fiber reinforced concrete got maximum flexural strength as compared to conventional concrete, the strength development of the concrete is increases slightly as its age increases. This can be clearly shown in above figures for all the three grades

4.2.3 Cylinder split tensile strength test

By conducting splitting tensile strength on cylinder following results were obtained which is given in table. After testing the concrete (split tensile strength) for M20, M30 & M40 grade concrete separately for replacement of slag & steel fiber by cement respectively finally combined percentage of slag & steel fiber mix in which maximum strength is obtained was used to get optimized strength.

OPTIMIZED % OF SLAG & STEEL FIBER FOR SPLIT TENSILE STRENGTH OF CONCRETE

Table 4.28:- Split tensile strength for M-20 Grade (**20 % SLAG & 2 % STEEL FIBER**)

SN	% Of Slag & Steel Fiber		Tensile Strength (N/mm^2) 28days
1	0	0	2.01
2	20	2	3.22

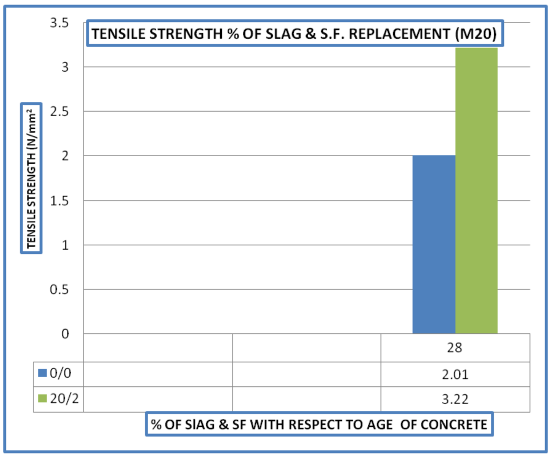

Figure 4.25: Optimized % of Slag & Steel Fiber for Tensile Strength (M20)

Table 4.29:- Split tensile strength for M-30 Grade (**30 % SLAG & 1.5 % STEEL FIBER**)

SN	**% Of Slag & Steel Fiber**		**Tensile Strength (N/mm^2) 28days**
1	0	0	3.32
2	30	1.5	5.27

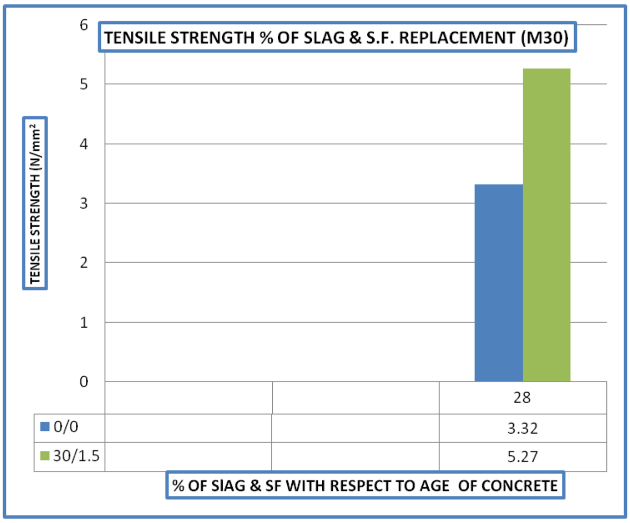

Figure 4.26: Optimized % of Slag & Steel Fiber for Tensile Strength (M30)

Table 4.30:- Split tensile strength for M-40 Grade (**20 % SLAG & 1.5 % STEEL FIBER**)

SN	**% Of Slag & Steel Fiber**		**Tensile Strength (N/mm^2) 28days**
1	0	0	4.27
2	20	1.5	7.1

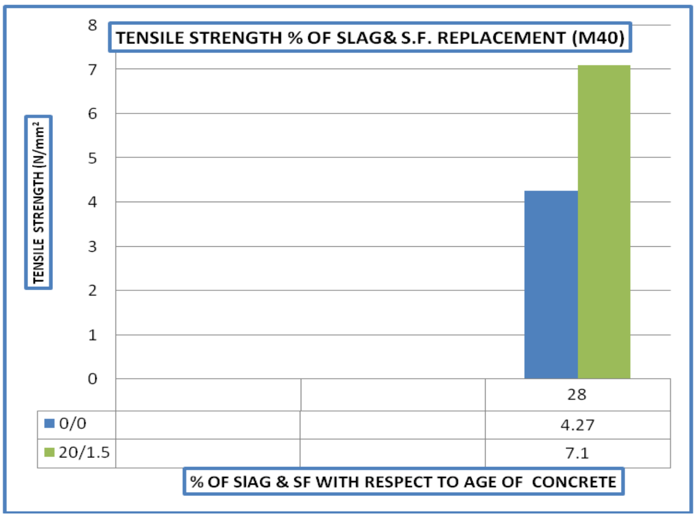

Figure 4.27: Optimized % of Slag & Steel Fiber for Tensile Strength (M40)

For partial replacement of cement with slag (20%) + Steel fiber (1.5%) fiber reinforced concrete got maximum split tensil strength as compared to conventional concrete, the strength development of the concrete is increases slightly as its age increases. This can be clearly shown in above figures for all the three grades

II. CONCLUSION

1) The optimum dosage for partial replacement of cement by ground granulated blast furnace slag is 20%
2) The optimum dosage for addition of steel fibred is 1.5%

3) The percentage of increase in compressive strength for M20,M30 & M40 grade for partial replacement of cement by GGBS (20%) + addition of steel fibred (1.5%) are nearly same for M20,M30 & 2.4% for M40 respectively for 28 days of curing.
4) The percentage of increase in flexural strength for M20, M30& M40 grade for partial replacement of cement by GGBS (20%) + addition of steel fibred (1.5%) are 20.37%, 25.37% & 56.39% respectively for 28 days of curing.
5) The percentage of increase in split tensile strength for M20,M30 & M40 grade for partial replacement of cement by GGBS (20%) + addition of steel fibred (1.5%) are 60.19%,58.73% & 66.27% respectively for 28 days of curing
6) The rate of gain of compressive strength of GGBS concrete is slow in the initial Stage i.e. up to 14 days & as the curing period increases strength also increases.
7) Test results reveal that higher fiber content has brought about increased compressive strength, flexural strength, abrasion resistance, and fiber crack-control effect. Hence the addition of steel fiber within FRC is more helpful for the flexural strength than the compressive strength.

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