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Experimental Study on Strength Properties of M30 Grade Self Compaction Concrete by Partial Replacement of Cement by Glass Powder and Fine Aggregate with Iron Slag

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ABSTRACT
The study aims at the utilization of industrial byproducts for value-added applications. Iron slag and glass powder is the industrial byproduct from the iron and glass industries. In addition to this byproduct, we can improve the properties of construction materials. The recycled glass has been used in the form of powder. The glass powder was tested with concrete and mortar. Cement was partial replaced by the glass powder in the proportion of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% for M30 grade of self-compaction concrete with 0.38 water-cement ratios respectively. Fine aggregate was partial replaced by the iron slag in the proportion of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% for M30 grade of self-compaction concrete respectively. The compressive strength, split tensile strength, and flexural strength was conducted for the above replacements. The results confirm that the use of iron slag and glass powder overcome the pollution problems in the environment. The result showed glass powder improves the mechanical properties and the iron slag added to the concrete had greater strength than the plain concrete. The advantages of this study is that the replacement of glass powder and iron slag is economically cheap as well as a superior concrete can be made.
Keywords - Compressive strength, Flexural strength, Glass Powder, Iron slag, Split Tensile strength.

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I. INTRODUCTION

The primary and main focus of an experimental investigation is to study strength properties of self-compaction concrete with locally available various supplementary materials for cement, aggregates (replacing partly), Experiments were conducted on self-compaction concrete prepared by partial replacement of fine aggregates by iron slag, and cement by waste glass powder of particle size 600 micron and downwards. The main objective of this investigation was to evaluate the effect of waste glass powder and iron slag on the compressive strength and the other properties of concrete and to evaluate the possibility of using glass powder and iron slag in concrete without sacrificing the strength and usage of industrial waste products.

1.1 GLASS POWDER

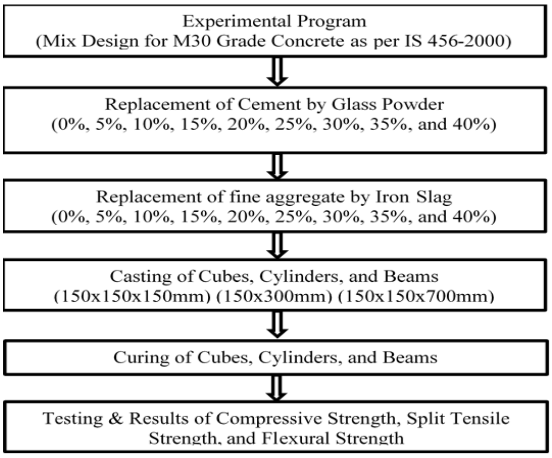
Glass is an amorphous (non-crystalline) that in essence, a super cooled liquid and not a solid. Glass can be made with excellent homogeneity in a variety of forms and sizes from small fibers to meter-sizes pieces. Primarily glass is made up of sand, soda ash, limestone, and other additives (Iron, Chromium, Alumina, Lead, and Cobalt). Glass has been used as aggregates in the construction of road, building, and masonry materials.

1.2 IRON SLAG

Iron and steel slag that is generated as a byproduct of iron and steel manufacturing processes can be broadly categorized into blast furnace slag and steelmaking slag. Iron and steel slag refers to the type of metal manufacturing slag that is generated during the process of manufacturing iron and steel products. The term "slag" originally referred to slag produced by metal manufacturing processes; however, it is now also used to describe slag that originates from molten waste material when trash and other substances are disposed of at an incinerator facility.

1.3 METHODOLOGY

An experimental program was planned to investigate the effect of iron slag and glass powder on compressive strength, split tensile strength, and flexural strength of concrete.



II. REVIEW OF LITERATURE

Alaa M. Rashad (2014) Recycled waste glass as fine aggregate replacement in cementations materials based on Portland cement. Disposal of waste glass derived from container or packaging glass, flat glass, domestic or tableware glass, and continuous

Prema Kumar W (2014) Effect of partial replacement of cement with waste glass powder on the properties of concrete Storage and safe disposal of waste glass is a huge problem for municipalities everywhere. Reuse of waste glass eliminates/reduces this problem. In this experimental work, the effect of partially replacing cement in concrete by glass powder is studied. The cement in concrete is replaced by waste glass powder in steps of 5% from 0% to 40% by volume and its effects on compressive strength, split tensile strength, workability and weight density are determined.

III. EXPERIMENTAL STUDY ON SCC

In this study, the strength behavior of self-compacting concrete of M30 grade prepared with glass powder and iron slag were studied. For each mix six numbers of cubes (150×150×150) mm, three numbers of cylinders (150×300) mm and six numbers beams (100×100×700) mm were cast and investigations were conducted to study the strength behavior for M30 grade of self-compacting concrete, Cement was partial replaced by the glass powder in the proportion of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% with 0.38 water-cement ratios respectively. Fine aggregate was partial replaced by the iron slag in the proportion of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% respectively. The basic tests carried out on concrete samples are discussed in this chapter, followed by a brief description about mix deign and curing procedure adopted. At the end, the various tests conducted on the specimens are discussed.

3.1 MATERIALS

The materials used in the experimental investigation are locally available cement, sand, coarse aggregate, mineral and chemical admixtures Iron Slag, Glass Powder.

S. No	Property	Test Method	Test Results	IS Standard
1.	Normal Consistency	Vicat Apparatus (IS:4031 Part-4)	28.5%	
2.	Specific Gravity	Sp. Gr Bottle (IS:4031 Part-4)	3.05	
3.	Initial Setting Time	Vicat Apparatus (IS:4031 Part-4)	86 minutes	Not less than 30 minutes
	Final Setting Time		510 Minutes	Not less than 10 hours
4.	Fineness	Sieve test on sieve no.9 (IS: 4031 Part -1)	4%	10%
5.	Soundness	Le-Chatlier method (IS: 4031 Part-3)	3mm	Not more than 10mm

Table: 3.1 Physical properties of Ordinary Portland Cement

S. No	Property	Method	Fine Aggregates	Coarse Aggregates
1.	Specific Gravity	Pycnometer IS:2386 Part3-1986	2.65	2.85
2.	Bulk Density Loose Compacted	IS:2386 Part 3-1986	1428 kg/m³ 1580 kg/m³	1651kg/m³ 1896kg/m³
3.	Bulking	IS:2386 Part 3-1986	10% water	---
4.	Flakiness Index	(IS:2386 Part 2-1963)	---	8.08%
5.	Elongation Index	(IS:2386 Part 2-1963)	---	0%
6.	Fineness Modulus	Sieve Analysis (IS:2386 Part 2-1963)	3.18	6.04

Table: 3.2 Physical properties of Coarse and Fine aggregate.

Fig: Glass Powder

Table: 3.6 Physical requirements of Glass Powder

S.No	Physical properties	Percentage
1	Colour	white
2	Specific Gravity	2.11

Table: 3.7 Chemical requirements of Glass Powder

S.No	Chemical Constituents	Percentage
1	Silicon dioxide (SiO_2)	70.22
2	Calcium oxide (CaO)	11.33
3	Magnesium Oxide (MgO)	---
4	Aluminum oxide(Al_2O_3)	1.64
5	Iron oxide (Fe_2O_3)	0.52
6	Total sulphur as sulphur trioxide(SO_3)	15.29
7	Potassium oxide (K_2O)	---
8	Density	2.42
9	Specific Surface Area	133

Fig : Iron Slag

Table: 3.8 Capacities of Iron and Steel Slag

S.No	Steel Plant	Capacity for Granulation (Tonnes Per Year)
1.	Rashtriya Ispat Nigam Ltd, Visakhapatnam, Andhra Pradesh	1440 TPY

Table: 3.9 Chemical and Physical Properties of Iron and Steel Slag

Chemical Properties		
S.No	Chemical Constituents	Percentage
1	Silicon dioxide (SiO_2)	17.69
2	Aluminium oxide (Al_2O_3)	1.07
3	Calcium oxide (CaO)	50.70
4	Magnesium oxide (MgO)	10.31
5	Manganese(II) oxide (MnO)	1.05
6	Iron(II) oxide (FeO)	16.50
7	sulphur (S)	1.40
8	Basicity (CaO/SiO_2)	-
Physical Properties		
1.	Iron and Steel Slag	Size : +10 mm to -60 mm
2.	Specific Gravity	2.10

Table: 3.10 Adopted Mix Proportions of SCC

Cement (kg/m^3)	Water (kg/m^3)	FA (kg/m^3)	CA (kg/m^3)	SP (kg/m^3)
510	193.8	672	778	4.98
1	0.38	1.31	1.52	0.018

3.2 TEST METHODS

Fresh Concrete Test:

Table: 3.12 Acceptance criteria for Self-Compacting Concrete.

S.No	Method	Property	Typical range of values	
			Minimum	Maximum
1.	Slump flow test	mm	650	800
2.	T50cm Slump flow	sec	2	5
3.	V-funnel test	sec	6	12
4.	V-Funnel at T5 minutes	sec	6	15
5.	L-Box test	H2/H1	0.8	1.0
6.	U - Box test	(H2-H1) mm	0	30
7.	Fill box apparatus test	%	90	100
8.	J-Ring	mm	0	10
9.	Orimet test	sec	0	5
10.	GTM screen stability test	%	0	15

Harden Concrete Test:

1. Compressive Strength Test
2. Split Tensile Strength Test
3. Flexural Strength Test

IV. EXPERIMENTAL RESULTS OBTAINED

4.1 Mix Design Procedure by Nam-Su Method:

The procedures of the proposed mix design method can be summarized in the following steps.

Step 1: Calculation of coarse and fine aggregate contents.
Step 2: Calculation of cement content.
Step 3: Calculation of mixing water content required by cement.
Step 4: Calculation of Iron Slag (IS) and Glass Powder (GP) contents.
Step 5: Calculation of mixing water content needed in SCC.
Step 6: Calculation of SP dosage.
Step 7: Adjustment of mixing water content needed in SCC.
Step 8: Trial mixes and tests on SCC properties.

4.2Mix proportions for SCC

The mix proportioning was done based on the Nan Su approach [2001]. The mix proportion is given in Table 5.1, for M30 grade self-compaction concrete.

Table 5.1 Mix Proportion and Quantities M30 grade of SCC

Grade	Mix	W/B	Water (Kg/m³)	Cement (Kg/m³)	FA (Kg/m³)	CA (Kg/m³)	SP (%)
M30	Trial -1	0.38	193.8	510	795.6	637.5	0.918
	Trial -2			512	797.8	639.2	0.918
	Trial -3			511	796.6	638.4	0.918

Table 5.2 Mix Proportion of M30 grade SCC with partial replacement of Glass Powder

Grade	Mix	W/B	Water (Kg/m³)	Cement (Kg/m³)	GP (%)	GP (Kg/m³)	FA (Kg/m³)	CA (Kg/m³)	SP (%)
M30	Trial -1	0.38	193.8	510	0	0	795.6	637.5	0.918
	Trial -2				5	25.5			
	Trial -3				10	51			
	Trial -4				15	76.5			
	Trial -5				20	102			
	Trial -6				25	127.5			
	Trail -7				30	150			
	Trail -8				35	178.5			
	Trail -9				40	204			

Table 5.3 Mix Proportion of M30 grade SCC with partial replacement of Iron Slag

Grade	Mix	W/B	Water (Kg/m³)	Cement (Kg/m³)	IS (%)	IS (Kg/m³)	FA (Kg/m³)	CA (Kg/m³)	SP (%)
M30	Trial -1	0.38	193.8	510	0	0	795.6	637.5	0.918
	Trial -2				5	39			
	Trial -3				10	78			
	Trial -4				15	117			
	Trial -5				20	156			
	Trial -6				25	195			
	Trail -7				30	234			
	Trail -8				35	273			
	Trail -9				40	312			

4.3 Fresh properties of SCC

The details of the fresh properties are shown in Table 5.4, for M30 Grade self-compaction concrete.

Table: 5.4 Fresh properties of M30 grade Self Compaction concrete

S. No	Grade	MIX	Slump Flow value	T_{50}	V-Funnel	V-Funnel at T_5 Minutes	L-Box H2/H1 (blocking ratio)
1.	M30	Trial -1	710	5sec	9.3sec	9sec	0.97
		Trial -2	700	5sec	10.1sec	9sec	0.92
		Trial -3	688	4sec	11.2sec	8sec	0.91

Table: 5.5 Fresh properties of SCC with partial replacement of Glass Powder with Cement

S. No	Grade	MIX	Slump Flow value	T_{50}	V-Funnel	V-Funnel at T_5 Minutes	L-Box H2/H1 (blocking ratio)
1.	M30	Trial -1	710	5sec	9.3sec	9sec	0.97
		Trial -2	692	5sec	9.3sec	9sec	0.97
		Trial -3	685	4sec	8.6sec	8sec	0.90
		Trial -4	680	4sec	8.6sec	8sec	0.90
		Trial -5	676	3sec	8.0sec	7sec	0.85
		Trial -6	670	3sec	8.0sec	7sec	0.85
		Trial -7	665	3sec	8.0sec	7sec	0.85
		Trial -8	658	2sec	7.5sec	6sec	0.80
		Trial -9	654	2sec	7.5sec	6sec	0.80

Table: 5.6 Fresh properties of SCC with partial replacement of Iron Slag with fine aggregate

S. No	Grade	MIX	Slump Flow value	T_{50}	V-Funnel	V-Funnel at T_5 Minutes	L-Box H2/H1 (blocking ratio)
1.	M30	Trial -1	710	5sec	9.3sec	9sec	0.97
		Trial -2	705	4.5sec	9.3sec	9sec	0.97
		Trial -3	705	4.5sec	9sec	8.5sec	0.95
		Trial -4	700	4sec	9sec	8.5sec	0.95
		Trial -5	700	4sec	8.5sec	8.5sec	0.87
		Trial -6	694	3.5sec	8.5sec	8sec	0.87
		Trial -7	694	3.5sec	8.5sec	8sec	0.87
		Trial -8	690	3sec	8sec	7sec	0.85
		Trial -9	690	3sec	8sec	7sec	0.85

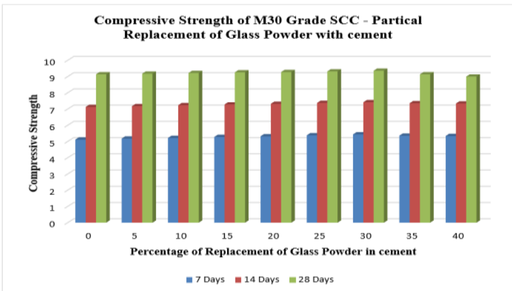
4.4 Mechanical properties of SCC with Partial replacement of glass powder and iron slag for different grade of Concrete

4.4.1. Compressive strength

Cubes of size 150mm×150mm×150mm are casted for different proportions of 0% to 40% with 5% of increment. For each proportion three cubes were casted and the surface of the cubes is allowed to dry for 24 hours in saturated condition. Curing of the cubes was done for 7, 14 and 28 days. A gradual load is applied on the surface on the cube to obtain maximum compressive load. The cubes are tested under universal testing machine (UTM). Readings are noted and graphs are drawn.

Table: 5.7 Compressive strength of SCC Partial Replacement of Glass Powder with cement

MIX	GLASS POWDER (%)	COMPRESSIVE STRENGTH (Mpa)		
		7 Days	14 Days	28 Days
M30	0	26.44	32.395	45.48
	5	27.2	36.68	48.65
	10	28.14	42.45	52.45
	15	30.54	48.78	55.65
	20	32.48	50.84	57.20
	25	34.28	52.42	59.68
	30	36.42	54.32	60.24
	35	36.58	54.84	60.84
	40	35.14	53.25	56.68



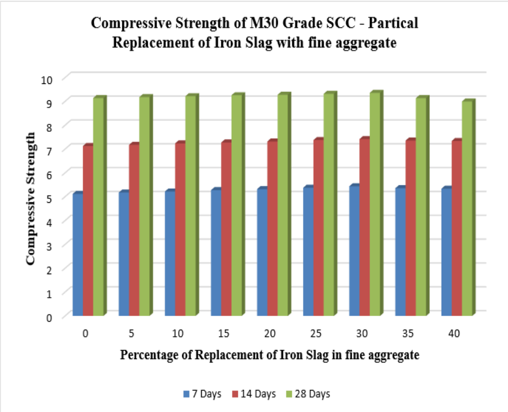
Graph: 5.1 Compressive strength of SCC Partial Replacement of Glass Powder with cement

The compressive strength for M30 grade of self-compaction concrete on cube specimen with 0%, 5%, 10%,15%, 20%, 25%, 30 %, 35%, and 40% of glass powder mix in cement their values are observed to be varied from 45.48 to 60.84 N/mm2 with 0% glass powder, 26.44 to 45.48 N/mm2 later on the percentage of glass powder is increase with

5% ratio, the strength is also increase up to 35% of partial replacement of glass powder 36.58 to 60.84 N/mm2 then later the strength is decreases at 40% of glass powder.

Table: 5.8 Compressive strength of SCC Partial Replacement of Iron Slag with fine aggregate

MIX	IRON SLAG (%)	COMPRESSIVE STRENGTH (Mpa)		
		7 Days	14 Days	28 Days
M30	0	26.44	32.395	45.48
	5	27.32	33.44	46.32
	10	28.48	34.54	47.24
	15	29.64	35.35	48.48
	20	30.24	36.64	49.36
	25	31.68	37.24	50.24
	30	32.14	38.62	51.64
	35	30.62	36.88	49.32
	40	28.12	34.46	47.42



Graph: 5.2 Compressive strength of SCC Partial Replacement of Iron Slag with fine aggregate

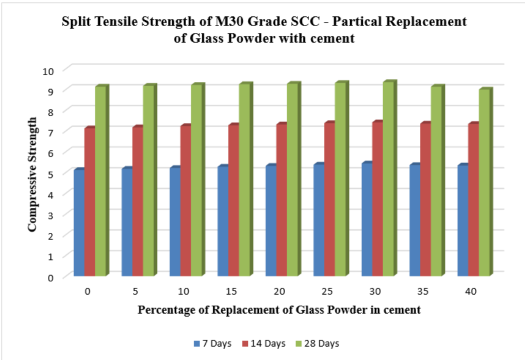
The compressive strength for M30 grade of self-compaction concrete on cube specimen with 0%, 5%, 10%,15%, 20%, 25%, 30 %, 35%, and 40% of Iron Slag mix in fine aggregate their values are observed to be varied from 45.48 to 51.64 N/mm2 with 0% iron slag, 26.44 to 45.48 N/mm2 later on the percentage of iron slag is increase with 5% ratio, the strength is also increase up to 30% of partial replacement of iron slag 32.14 to 51.64 N/mm2 then later the strength is decreases at 35 % and 40% of iron slag.

4.4.2 Split tensile strength

Cylinders of size 500 mm × 150 mm were casted for different proportions. For each proportion two cylinders were casted and allowed to dry for 24 hours in saturated condition. Curing was done at 3, 7 and 28 days. After curing was done samples are allowed to dry to remove the moisture content. Testing of samples at different stages was done and readings are noted. Graphs are drawn for strength verses replacement. Table 5.9 shows the details of the split tensile strength of M30 grade of SCC.

Table: 5.9 Split tensile strength of SCC Partial Replacement of Glass Powder with cement

MIX	GLASS POWDER (%)	SPLIT TENSILE STRENGTH (Mpa)		
		7 Days	14 Days	28 Days
M30	0	2.24	4.945	6.65
	5	2.31	5.01	6.76
	10	2.39	5.115	6.88
	15	2.51	5.125	6.96
	20	2.64	5.213	7.12
	25	2.76	5.204	7.68
	30	2.84	5.346	7.84
	35	2.96	5.384	7.92
	40	2.71	5.268	7.42

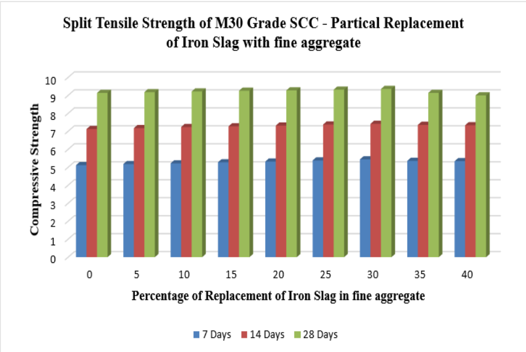


Graph: 5.3 Split Tensile strength of SCC Partial Replacement of Glass Powder with cement

The split tensile strength for M30 grade of self-compaction concrete on cube specimen with 0%, 5%, 10%,15%, 20%, 25%, 30 %, 35%, and 40% of glass powder mix in cement their values are observed to be varied from 6.65 to 7.42 N/mm2 with 0% glass powder, 2.24 to 6.65 N/mm2 later on the percentage of glass powder is increase with 5% ratio, the strength is also increase up to 35% of partial replacement of glass powder 2.96 to 7.92 N/mm2 then later the strength is decreases at 40% of glass powder.

Table: 5.10 Split tensile strength of SCC Partial Replacement of Iron Slag with fine aggregate

MIX	IRON SLAG (%)	SPLIT TENSILE STRENGTH (Mpa)		
		7 Days	14 Days	28 Days
M30	0	2.24	4.945	6.65
	5	2.3	4.96	6.68
	10	2.32	4.98	6.92
	15	2.34	5.1	7.24
	20	2.38	5.2	7.48
	25	2.42	5.25	7.62
	30	2.46	5.28	7.86
	35	2.36	5.23	7.63
	40	2.32	5.18	7.46



Graph: 5.4 Split tensile strength of SCC Partial Replacement of Iron Slag with fine aggregate

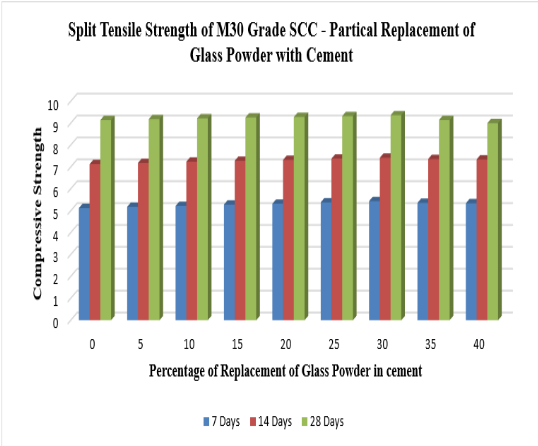
The Split tensile strength for M30 grade of self-compaction concrete on cube specimen with 0%, 5%, 10%,15%, 20%, 25%, 30 %, 35%, and 40% of Iron Slag mix in fine aggregate their values are observed to be varied from 6.65 to 7.46 N/mm2 with 0% iron slag, 2.24 to 6.65 N/mm2 later on the percentage of iron slag is increase with 5% ratio, the strength is also increase up to 30% of partial replacement of iron slag 2.46 to 7.86 N/mm2 then later the strength is decreases at 35 % and 40% of iron slag.

4.4.3 Flexural strength

Prisms of size 700 mm × 100 mm × 100 mm were casted for different proportions. For each proportion samples were casted and allowed to dry for 24 hours in saturated condition. Curing was done for 28 days. After curing was done samples were allowed to dry to remove the moisture content. Testing of samples at different stages was done and readings are noted. Graphs are drawn for strength verses replacement. In chapter 3 the figures show the flexural strength of the prism. Table 5.11 shows the details of the flexural strength of M30 grade of SCC.

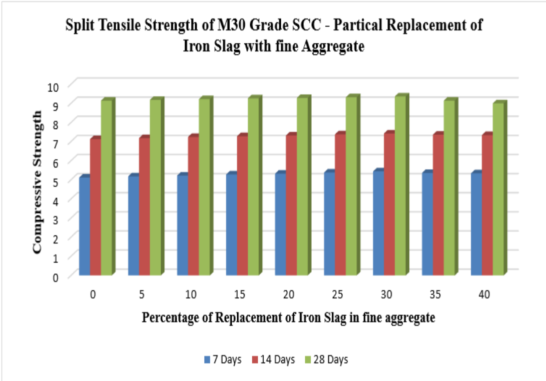
Table: 5.11 Flexural strength of SCC Partial Replacement of Glass Powder with cement

MIX	GLASS POWDER (%)	FLEXURAL STRENGTH (Mpa)		
		7 Days	14 Days	28 Days
M30	0	5.12	7.13	8.86
	5	5.28	7.255	9.23
	10	5.36	7.355	9.35
	15	5.42	7.4	9.42
	20	5.56	7.52	9.54
	25	5.68	7.68	9.66
	30	5.72	7.76	9.74
	35	5.88	7.84	9.86
	40	5.62	7.54	9.46



Graph: 5.5 Flexural strength of SCC Partial Replacement of Glass Powder with cement

The flexural strength for M30 grade of self-compaction concrete on cube specimen with 0%, 5%, 10%,15%, 20%, 25%, 30 %, 35%, and 40% of glass powder mix in cement their values are observed to be varied from 8.86 to 9.46 N/mm2 with 0% glass powder, 5.12 to 8.86 N/mm2 later on the percentage of glass powder is increase with 5% ratio, the strength is also increase up to 35% of partial replacement of glass powder 5.88 to 9.86 N/mm2 then later the strength is decreases at 40% of glass powder.



Graph: 5.6 Flexural strength of SCC Partial Replacement of Iron Slag with fine aggregate

The flexural strength for M30 grade of self-compaction concrete on cube specimen with 0%, 5%, 10%,15%, 20%, 25%, 30 %, 35%, and 40% of Iron Slag mix in fine aggregate their values are observed to be varied from 9.14 to 9.34 N/mm2 with 0% iron slag, 5.12 to 9.14 N/mm2 later on the percentage of iron slag is increase with 5% ratio, the strength is also increase up to 30% of partial replacement of iron slag 5.44 to 9.36 N/mm2 then later the strength is decreases at 35 % and 40% of iron slag.

V. CONCLUSION

1. The strength and durability characteristics of concrete mixtures have been computed in the present work by replacing 5%,10%, 15%, 20%, 25%, 30%, 35% and 40% of iron slag with the sand and glass powder with the fine aggregate

2. The material properties of the cement, coarse aggregates, and fine aggregates are within the acceptable limits hence these materials are suitable for the research.

3. The present study shows that there is a great potential for the utilization of glass powdering concrete as partial replacement of cement. About 35% of cement may be replaced with glass powder without any sacrifice on the fresh properties to increase workability and flow ability.

4. The present study shows that there is a great approaching for the utilization of iron slag concrete as partial replacement of fine aggregate. About 30% of fine aggregate may be replaced with iron slag without any expense on the strength properties to increase compressive strength.

5. After adding 30% iron slag in the mix, there is an increase in compressive strength after 7 days, 14 days and 28 days respectively as compare to control mix. After 30% there is decrease in compressive strength. At 30% there is enormous increase in compressive strength of cube. The optimum value of compressive strength comes at 30% replacement.

6. The slump of concrete decreases monotonically as the replacement cement with glass powder increases. The workability increases when cement is replaced partially with glass powder.

7. Considering the strength criteria, the replacement of cement by glass powder is feasible. Therefore, we can conclude that the utilization of waste glass powder in concrete as cement replacement is possible.

8. The Compressive strength tends to increase with increase percentages of iron slag in the mix. The optimum strength of cube is obtained at 30% replacement of iron slag in fine aggregate.

9. The optimum value of compressive, split tensile and flexural strength of concrete was observed at 35% replacement of cement by glass powder.

10. The optimum value of compressive, split tensile and flexural strength of concrete was observed at 30% replacement of fine aggregate by iron slag.

11. The 7 days, 14 days and 28 days' compressive strengths, flexural strength, split tensile strength of concrete increase initially as the replacement percentage of cement with glass powder increases, and become maximum at about 35% and later decreases.

12. The 7 days, 14 days and 28 days' compressive strengths, flexural strength, split tensile strength of concrete increase initially as the replacement percentage of fine aggregate with iron slag increases, and become maximum at about 30% and later decreases.

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