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PERFORMANCE OF CONCRETE WITH PARTIAL REPLACEMENTS OF SAND WITH STEEL SLAG AND CEMENT WITH WASTE GLASS POWDER

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Abstract: In the present scenario where the constructions are increasing, the need to find a supplementary cementing material for the improvement of strength and which has less environmental effects is of great significance. in this research we carried out concrete to improve strength and make concrete economical by fractional supplementing of sand with Granular Steel Slag (G.S.S) and bond with Waste Glass Powder (W.G.P).Granular Steel Slag (G.S.S) a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The Slag happens as a liquid fluid soften and is hit or miss arrangement of silicates and oxides that cements after cooling. Expansion of steel slag improves the mechanical properties of cement. Squander Glass Powder (W.G.P) may be a valuable mechanical squander. The particles of Glass Powder are fine, which fills the voids. Fine aggregate was partially supplanted with 15%, 30% and 45% Granular Steel Slag (G.S.S) and cement with 20% (steady) Waste Glass Powder (W.G.P) for M20 grade concrete. Tests will be performed for Hardened properties of concrete at 7, 28 and 56 days. Based on experimental investigation we are getting optimum Results at Mix-3.

Index Terms **–** Steel slag, Glass powder, Hardened Concrete , Compressive strength, Flexural strength, Split tensile strength

Introduction: Concrete, an essential building development material, is the world's most expended man made material. The world utilization was assessed at 11 billion tons, or roughly 1.7 tons for each living individual. Generation of bond (the folio in concrete) is vitality concentrated and exceptionally contaminating procedure, which contributes around 5–8% to worldwide CO2 discharges. This high commitment is because of that generation of every ton of concrete emanates 0.9 ton of carbon dioxide (CO2) to the climate from both of fuel and bond crude material consuming.

On a very basic level, concrete is conservative, solid and sturdy. Albeit solid innovation over the business keeps on ascending to the requests of a changing commercial center, the industry perceives that impressive upgrades are basic in profitability, item execution, vitality productivity, and natural execution. The business should confront and defeat various institutional, aggressive, and specialized difficulties. One of the significant difficulties, with the ecological mindfulness and shortage of room for land filling, is the squanders/result usage as an option in contrast to transfer.

All through the mechanical area, including the solid business, the expense of natural consistence is high. Prologue to utilization of modern side-effects, for example, slag, silica rage, fly debris, base debris and waste glass powder and so on can bring about critical enhancements in by and large industry vitality productivity and natural execution.

Replacement materials : The Following Are The Replacement Materials

1. Glass Powder
2. Steel Slag

1. Glass Powder: Glass Powder is a useful industrial waste. It exhibits pozzolanic behaviour when the particle size is less than 75 µ. The pozzolanic properties may be attributed to the high amount of silica. The particles of Glass Powder are very fine, filling voids between cement grains which results in more durable Concrete. The solid waste glass is considered one of the most major environmental problems all over the world because it occupies huge parts of the landfill spaces, and it has a non biodegradable nature. In addition to it causes serious environmental pollutions (air, water and soil pollutions) which spread all over the world, both in terms of quantity and associated health risks. In this context, early efforts were carried out for a long time to disposal or recycling of the crushed waste glass as a replacement for fine sand, coarse aggregate, and even cement in the concrete. In the last decade, the recycling of crushed waste glass in building materials has attracted many researchers due to its physical characteristics and chemical compositions. Solid industrial by-products, such as siliceous and aluminous materials, as well as some natural pozzolanic materials are increasingly being used in the cement and concrete industry. The incorporation of these materials in concrete has been giving encouraging results regarding the mechanical and durability properties of concrete

Table-1: Physical Properties of Glass Powder

CONSTITUENT	PERCENTAGE
SiO2	68
Al2O3	0.9
Fe2O3	0.6
CaO	14.5
Na2O	12.2
SO3	0.4
MgO	1.8
K2O	0.8

Table-2: Chemical Properties of Glass Powder

PROPERTIES	VALUES
Specific gravity	2.71
Surface area	2120 cm^2/gm
Fineness	6

2. Steel slag:

Steel slag, the by product of steel and iron production is generated in large quantities daily, and these products are considered problematic and hazardous for both the factories and the environment. In 2016, over 100million tonnes of steel slag were produced in China, and the amount is increasing every year, while the total utilization ratio of steel slag is only 10%. The accumulation of steel slag not only takes up a large area of land, but also pollutes the surrounding environment. To explore the utilization of steel slag, recycling technologies to use steel slag as construction material have received increasing attention. In addition, steel slag has been commonly used as aggregate in concrete, that is steel slag aggregate concrete. Several studies demonstrated that the use of steel slag as fine aggregate in concrete improves the mechanical properties of hardened concrete. The use of steel slag as fine aggregate in concrete mixes has a positive effect on both the compressive and tensile.

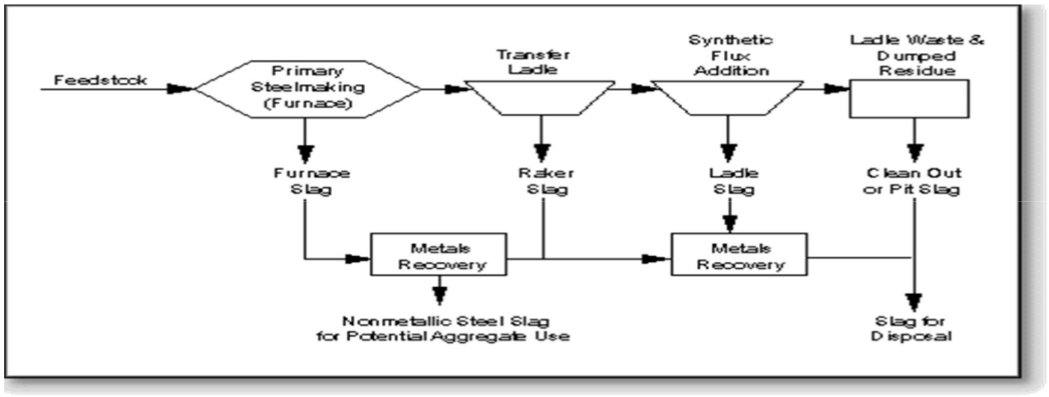

Fig-1: Manufacturing of steel slag

Table-3: Physical Properties of steel slag

PROPERTIES	VALUES
Specific gravity	3.2-3.6
Unit weight	1600-1920
Absorption	Up to 3%

Objective of this Work

This study is aimed at investigating the Fresh and Hardened Concrete properties when Granular Steel Slag and Glass Powder are used in combination as Fine aggregate and Cement replacement respectively.

- To investigate the combined effect of Glass Powder and Steel Slag on Fresh properties of concrete .
- To study the combined influence of Glass Powder and Slag on Hardened properties of Concrete i.e. Compressive Strength, Split tensile strength, Flexural strength .

Scope of the present study

The scope of the present study includes the following aspects:

Laboratory tests for determination of physical properties of Cement, Fine Aggregate, Coarse Aggregate and Water are conducted. In the present study M20 grade of concrete was prepared based on the IS:10262-2019 Guidelines. The same grade was partially replaced with Glass powder (20%) in cement and Steel Slag 25%, 50% and 75% in Fine Aggregate. Investigations were carried out for fresh and hardened properties of self compacting concrete specimens cured for 7, 28 and 56 days. The cubes of size 150mm × 150mm ×150mm were used for the determination of compressive strength of concrete. Cylinders of size 150mm× 300mm were used for the determination of split tensile strength of concrete and modulus of elasticity. Beams of size 100mm ×100mm × 500mm were used for the determination of flexural strength of concrete.

Materials used and basic tests:

The following materials are used in the experimental work

- Cement: 53 grade is used in this entire investigation.
- Fine aggregate: Locally available sand confirming to Indian standards (Zone-II) is used.
- Coarse aggregate: Locally available quarry stone passing through 12mm and retained on 10mm sieve.
- Glass powder: WGP was obtained from Sri Sairam Fiber Glass Industries, Enikepadu, Vijayawada, Andhra Pradesh.
- Steel slag: Steel slag was obtained from Madhuri Steel Enterprises, Bhavanipuram, Vijayawada.

Table -4: Properties Of AURAMIX 400 PLUS

Appearance	Light yellow colored liquid
pH	Minimum 6.0
Volumetric mass @ 20^0 C	1.09 kg/litre
Chloride content	Nil to IS: 456
Alkali content	Typically less than 1.5g Na2O equivalent / liter of admixture.

Mix Design of concrete:

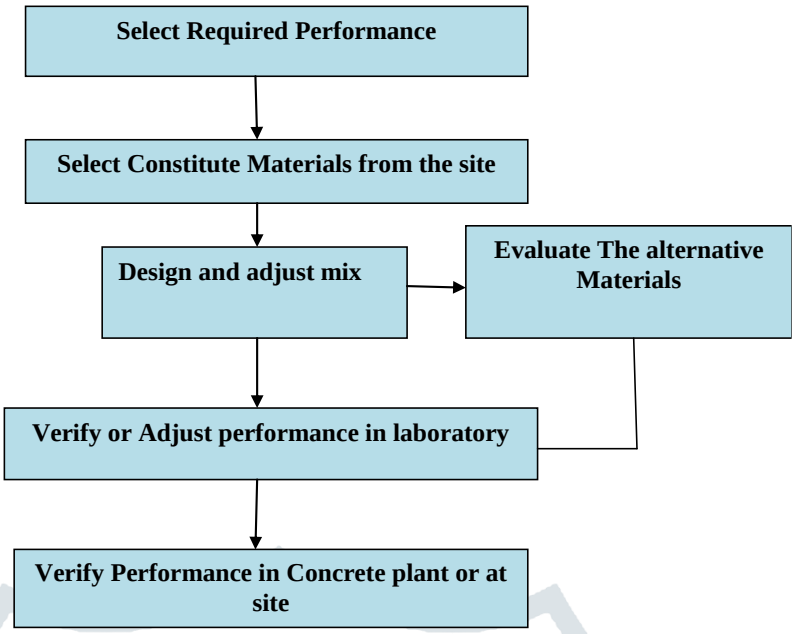

Fig-2: Mix Design Procedure

Design Steps:

The mix design generally based on the approach outlined given below

- Determine the Target average compressive strength
- Select the air content based on the specified nominal size of the aggregate and concrete grade
- Select the water cement ratio
- Select the proportions for initial trail mix
- Select the water content and the cement content
- Select the admixture content
- Select the powder content and fine aggregate content
- Select the coarse aggregate content
- Calculate volume of powder content and determine the water powder ratio by volume and make adjustments if required
- Work out the mix proportions for trail one
- Produce the Concrete in the laboratory in the laboratory mixture and perform the laboratory tests required
- Test the properties of Concrete in the hardened state

Table-5: Quantities of proposed mix

S.No	% of Replacement	Binder (kg/m^3)	Cement (kg/m^3)	G.P (kg/m^3)	S.S (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	Water (lt/m^3)	S.P (lt/m^3)
1	M0	430	430	0	0	858	917.4	172	3.44
2	M1	430	344	86	0	858	917.4	172	3.44
3	M2	430	344	86	128.7	729.3	917.4	172	3.44
4	M3	430	344	86	257.4	600.6	917.4	172	3.44
5	M4	430	344	86	386.4	471.6	917.4	172	3.44

Experimental Investigation:

It was proposed to investigate the properties of concrete, cast with partial replacement of cement with glass powder by 20% and steel slag by 0%, 15%, 30%, and 45% and cured in potable water. In this experimental work, physical properties of materials used in the experimental work were determined.

Procedure for Making Concrete Trail Mixes:

The following mixing sequence was arrived at after several trails optimizing the workability.

- All the ingredients were first mixed in dry condition in the concrete drum mixer for one minute.
- Then 70% of calculated amount of water was added to the dry mix and mixed thoroughly for one minute.
- The remaining 30% of water was mixed with the super plasticizer and poured into the mixer at the final stage and mixed thoroughly for another one minute before the concrete is taken from the mixer.
- The concrete was filled in the cube moulds of 150mm×150mm×150mm. Because strengths of concrete were cast in each mix.

- A minimum of 3 cubes were tested to ascertain any particular value and the mean thereof was taken as the result.

Results And Discussions: The experimental investigation has been carried out on the test specimens to study the fresh and mechanical properties of concrete by replacing the cement by 20% of Glass powder and 0%, 15%, 30% and 45% of Steel slag for arriving optimum percentage of Glass powder and Steel Slag that gives maximum strength. The test Specimens are cast in steel moulds. The inside of the mould is applied with oil to facilitate the easy removal of specimens. The raw materials are weighed accurately. The concrete is mixed thoroughly in dry condition. The mixing is continued until a uniform color is obtained. Fresh concrete is placed in the mould. The concrete specimen cast is a 150 × 150 ×150-mm cubes, After 24 h from casting, the test specimens are taken out and placed in a curing tank, for 7 days age of the specimens. The specimens are tested for compression under UTM for arriving optimum % of Glass powder and steel slag that gives maximum strength. The following tests were conducted on specimens

i) Compressive strength ii)Split Tensile strength iii) Flexural strength

Table- 6: Compressive Strength Test Results

S.No	% replacement	7 days (MPa)	% Variation	28 days (MPa)	% Variation	56 days (MPa)	% Variation
1	M0	17	-	26.8	-	29.67	-
2	M1	17.4	2.35	27.38	2.16	30.34	2.26
3	M2	18.25	7.35	28.74	7.23	33.05	11.4
4	M3	20.5	20.58	30.2	12.7	35	17.96
5	M4	19.3	13.53	29.6	10.45	34.04	14.73

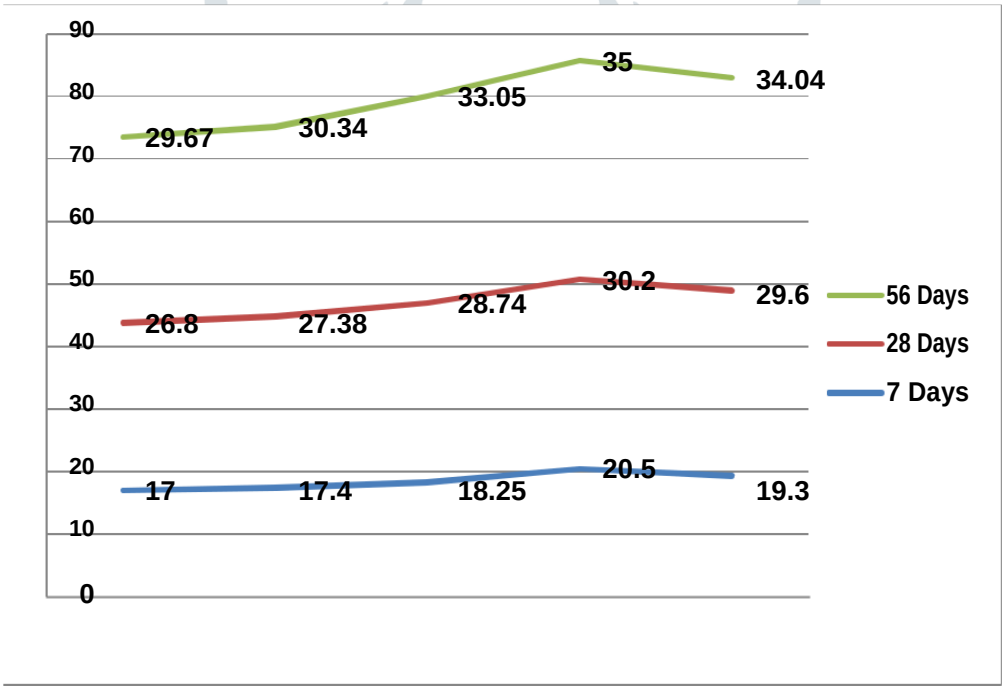

Fig-7: % Replacement Vs Compressive Strength

Discussion:

The graph is drawn between the percentages of replacement vs. compressive strength of concrete.

- At 7days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the compressive strength increases by 2.35% in the same way, the gradual increase of replacement by 15% of steel slag i.e. at 20% Glass Powder and 15% Steel Slag the compressive strength is increased by 7.35%.
- The compressive strength increases by 20.58% for 20% Glass Powder and 30% Steel Slag replacement and compressive strength decreases by 13.53% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 50% Steel Slag we got maximum strength.
- At 28days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the compressive strength increases by 2.16% in the same way, the gradual increase of replacement by 15% of Steel Slag i.e. at 20% Glass Powder And 15% Steel Slag the compressive strength is increased by 7.23%.
- The compressive strength increases by 12.7% for 20% Glass Powder and 30% Steel Slag replacement and compressive strength decreases by 10.45% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 30% Steel Slag we got maximum strength.
- At 75days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the compressive strength increases by2.26% in the same way, the gradual increase of replacement by 15%

of Steel Slag i.e. at 20% Glass Powder and 15% Steel Slag the compressive strength is increased by 11.4%. The compressive strength increases by 17.96% for 20% Glass Powder and 30% Steel Slag replacement and compressive strength decreases by 14.73% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 300% Steel Slag we got maximum strength.

Table -7: Split Tensile Strength Test Results

S.No	% replacement	7 days (MPa)	% Variation	28 days (MPa)	% Variation	56 days (MPa)	% Variation
1	M0	1.27	-	2.1	-	2.42	-
2	M1	1.3	2.36	2.16	2.86	2.5	3.3
3	M2	1.35	6.3	2.23	6.2	2.56	5.8
4	M3	1.63	28.34	2.54	20.95	3	24
5	M4	1.41	11.02	2.36	12.38	2.72	12.4

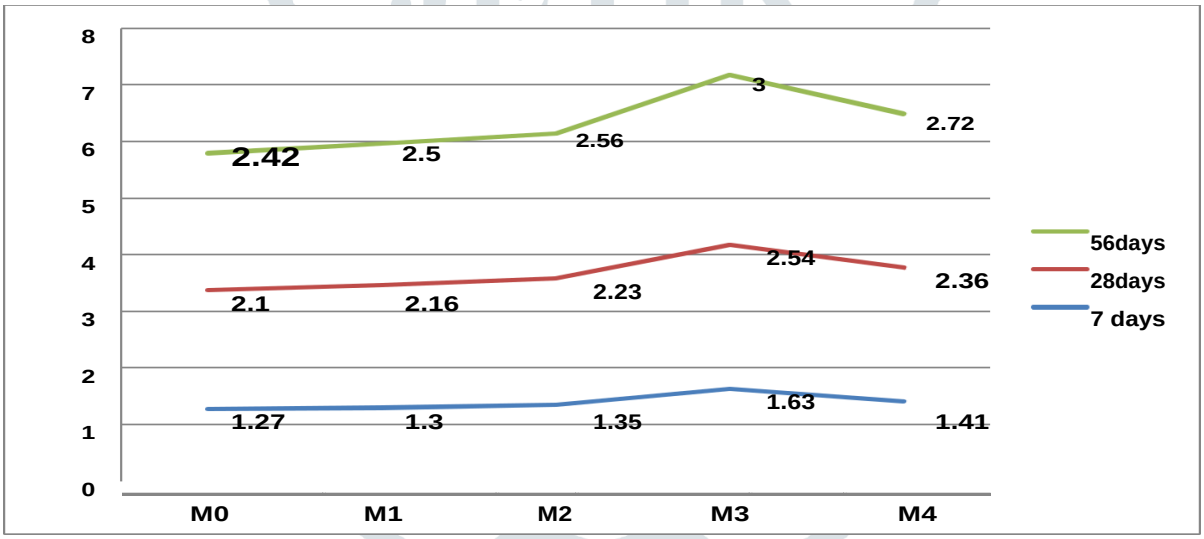

Fig-8: Replacement Vs Split Tensile Strength

Discussions:

The graph is drawn between the percentages of replacement vs. split tensile strength of concrete.

- At 7days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the split tensile strength increases by 2.36% in the same way, the gradual increase of replacement by 15% of Steel Slag i.e. at 20% Glass Powder and 30% Steel Slag the split tensile strength is increased by 6.3%.
- The split tensile strength increases by 20.58% for 20% Glass Powder and 30% Steel Slag replacement and split tensile strength decreases by 11.02% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 30% Steel Slag we got maximum strength.
- At 28days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the split tensile strength increases by 2.86% in the same way, the gradual increase of replacement by 15% of Steel Slag i.e. at 20% Glass Powder and 30% Steel Slag the split tensile strength is increased by 6.2%.
- The split tensile strength increases by 20.95% for 20% Glass Powder and 30% Steel Slag replacement and split tensile strength decreases by 12.38% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 50% Steel Slag we got maximum strength.
- At 56days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the split tensile strength increases by 3.3% in the same way, the gradual increase of replacement by 15% of Steel Slag i.e. at 20% Glass Powder and 15% Steel Slag the split tensile strength is increased by 5.8%.
- The split tensile strength increases by 24% for 20% Glass Powder and 30% Steel Slag replacement and split tensile strength decreases by 12.4% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 30% Steel Slag we got maximum strength.

Table-8: Flexural Strength Test Results

S.No	% replacement	7 days (MPa)	% Variation	28 days (MPa)	% Variation	56 days (MPa)	% Variation
1	M0	2.37	-	4.5	-	5.17	-
2	M1	2.4	1.26	4.6	2.22	5.3	2.5
3	M2	2.6	9.7	4.8	6.66	5.52	6.77
4	M3	3.2	35.02	5.6	24.44	6.45	24.8
5	M4	2.9	22.36	5.2	15.55	6	16.05

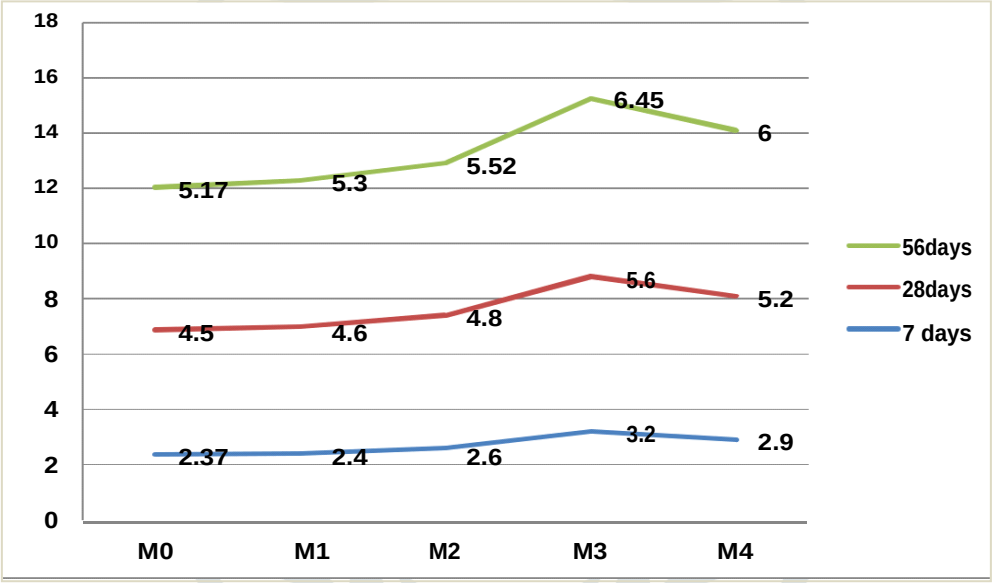

Fig-9:% Replacement Vs. Flexural Strength

Discussions:

The graph is drawn between the percentages of replacement vs. flexural strength of concrete.

- At 7days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the flexural strength increases by 1.26% in the same way, the gradual increase of replacement by 15% of Steel Slag i.e. at 20% Glass Powder and 30% Steel Slag the flexural strength is increased by 9.7%.
- The flexural strength increases by 35.02% for 20% Glass Powder and 30% Steel Slag replacement and flexural strength decreases by 22.36% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 50% Steel Slag we got maximum strength.
- At 28days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the flexural strength increases by 2.22% in the same way, the gradual increase of replacement by 15% of Steel Slag i.e. at 20% Glass Powder and 30% Steel Slag the flexural strength is increased by 6.66%.
- The flexural strength increases by 24.44% for 20% Glass Powder and 30% Steel Slag replacement and flexural strength decreases by 15.55% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 30% Steel Slag we got maximum strength.
- At 75days, for the 20% replacement of Glass Powder with cement and 0% replacement of Steel Slag with Fine Aggregate the flexural strength increases by 2.5% in the same way, the gradual increase of replacement by 15% of Steel Slag i.e. at 20% Glass Powder and 30% Steel Slag the flexural strength is increased by 6.77%.
- The flexural strength increases by 24.8% for 20% Glass Powder and 30% Steel Slag replacement and flexural strength decreases by 16.05% for 20% Glass Powder and 45% Steel Slag replacement. At 20% Glass Powder and 30% Steel Slag we got maximum strength.

Conclusions:

This study was carried out to investigate the combined influence of G.P and S.S replacing cement and F.A, on Hardened Properties of Concrete. Following conclusions were inferred from the test results:

- Compressive Strength, Split Tensile Strength, Flexural Strength increases with the increase in Granular Steel Slag content at constant level of Glass Powder up to 50% of Steel Slag which may be due to the pozzolanic action of Steel Slag Aggregates or difference in hardness of Steel Slag and replaced aggregates.
- The percentage variation of compressive strength is 2.35% at M1, 7.35% at M2, 20.58% at M3, 13.53% at M4 for 7 days and 2.16% at M1, 7.23% at M2, 12.7% at M3, 10.45% at M4 for 28 days and 2.26% at M1, 11.4% at M2,
- 17.96% at M3, 14.73% at M4 for 56days with respect to M0 Mix.
- The maximum increase in Compressive strength is 20.58% at 7days, 12.7% at 28days and 17.96% at 56days for M3 Mix respectively.
- The percentage variation of Split Tensile Strength Test is 2.36% at M1, 6.3% at M2, 28.34% at M3, 11.02% at M4 for 7 days and 2.86% at M1, 6.2% at M2 20.95% at M3, 12.38% at M4 for 28 days and 3.3% at M1, 5.8% at M2, 24% at M3, 12.4% at M4 for 56 days with respect to M0 Mix.
- For Split Tensile Test the maximum increase is 28.34% at 7 days, 20.95% at 28 days and 24% at 56 days for M3 Mix respectively.
- The percentage variation of Flexural Strength Test is 1.26% at M1, 9.7% at M2, 35.02% at M3, 22.36% at M4 for 7 days and 2.22% at M1, 6.66% at M2, 24.5% at M3, 15.55% at M4 for 28 days and 2.5% at M1, 6.77% at M2, 24.8% at M3, 16.05% at M4 for 56days with respect to M0 Mix.
- For Flexural Strength the maximum increase is 35.02% at 7 days, 24.5% at 28 days and 24.8% at 56 days for M3 Mix respectively.

- The waste materials i.e. Glass Powder and Granular Steel Slag may effectively be utilized in construction industry for the production of concrete, offsetting huge quantities of cement and natural aggregates. This may reduce environmental issues and land fill problems in addition to lowering the concrete production cost.
- The developed concrete may be used for residential construction, where moderate compressive strength of concrete is desired. However, durability of concrete need to be investigated to check its performance against acid attack, sulphate attack, freezing and thawing etc. before application.

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