OPTIMUM REPLACEMENT OF COARSE AGGREGATE BY STEEL SLAG AND FINE AGGREGATE BY WASTE GLASS POWDER

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Abstract - *Glass is one of the world's oldest and most commonly used materials. Glass has a fairly short shelf life in its current condition. Reusing this waste in construction materials is one alternative for safe environmental and economic disposal. The waste glass will be used to substitute fine aggregate in the following proportions: 0%, 10%, 20%, 25%, 30%, 40%, and 50%. This study will go over properties such as compressive strength. Another attempt was made to replace coarse aggregate with steel slag because there is a growing interest in using waste materials as alternative aggregate materials and significant research is being conducted on the use of many different materials as aggregate substitutes such as coal ash, blast furnace slag, and steel slag aggregate. By altering the quantity of steel slag, different concrete mixtures were created Steel slag is to be substituted for coarse aggregate in the following proportions: 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90%. Compressive strength of concrete to be reviewed, as well as another attempt at combined replacement by replacing both fine aggregate and coarse aggregate with waste glass powder and steel slag, while maintaining the optimum replacement of glass powder constant and varying the percentage replacement of steel slag with coarse aggregate in proportions of 0%,10%,20% up to 80%, and thus finding the combined optimum replacement of coarse and fine aggregates with steel slag and waste glass powder in terms of compressive strength of concrete.*

Key Words: Steel slag, Waste glass powder, compressive strength, Super plastisizer, Partial replacement, Combined replacement.

1. INTRODUCTION.

Today, concrete is the most often utilised construction material. In all fields of modern construction, concrete has risen to the rank of a key building material. It's difficult to think of another construction material that is as versatile as concrete. When strength, durability, impermeability, fire resistance, and absorption resistance are necessary, concrete is the ideal material to use.

Concrete is made from a combination of cement, sand, coarse material, and water. Today, global warming and environmental destruction have become obvious problems in recent years, and concern about environmental concerns, as well as a transition from the past's mass-waste, mass-consumption, and mass-production culture to a zero-emanation society, is regarded as crucial. Glass does not normally affect the environment since it does not emit pollutants, but it can hurt humans and animals if not handled safely, and it is less environmentally beneficial because it is non-biodegradable. As a result, the development of new technologies was necessary. Glass encompasses a wide range of chemical variations, including soda-lime silicate glass, alkali-silicate glass, and borosilicate glass. Steel slag might also be utilised as a partial substitute for coarse aggregate. By effectively using these by-products, which would otherwise be discarded, good environmental conditions will be achieved. Because of its mechanical strength, stiffness, porosity, wear resistance, and water absorption capacity, steel slag particles are already employed as aggregates in asphalt paving road mixtures. The feasibility of using steel slag as a replacement for traditional concrete is being researched. When compared to ordinary concrete, the test findings for workability levels and strength are also the same.

1.1 Literature Review

Waste glass powder

One of the oldest man-made materials is glass. It is made in a variety of forms, including packaging or container glass, flat glass, and bulb glass, all of which have a limited life in their manufactured forms and must be recycled to be reused in order to prevent environmental concerns caused by stockpiling or disposal in landfills. The building sector has demonstrated outstanding forms such as package or container glass, flat glass, and bulb glass, all of which have benefited from the recycling of industrial by-products and garbage, including waste glass resources. Quantities of waste glass have increased rapidly in recent decades due to rapid industrialization and significant improvements in living standards; however, the majority of these waste quantities are not recycled but rather abandoned, causing serious problems such as waste of natural resources and environmental pollution.

Steel slag

Aggregates account for around 70-75 percent of the overall volume of concrete. To fulfil the worldwide need for concrete in the future, an alternative material in construction that may fully or partially replace natural aggregate without altering the properties of fresh and hardened concrete is required. The properties of aggregate have an impact on the durability and performance of concrete.

1.2 Objective

1. To investigate the compressive properties of a cube after 7 and 28 days of curing.
2. M40 grade concrete mix design with varying proportions of steel slag and waste glass powder replacement
3. To investigate the growth of concrete strength by the percentage replacement of glass powder with waste glass powder and steel slag.
4. To investigate the densities of concrete with varying percentages of glass powder and steel slag replacement.
5. Determine the best dose of glass powder and steel slag.

2. METHODOLOGY

The Basic tests are performed on various materials such as OPC43 grade cement, fine aggregate, coarse aggregate, and steel slag to determine their acceptability for use in the production of concrete. Concrete mix proportions are altered to allow for the use of steel slag as a partial replacement for coarse aggregate and waste glass powder as fine aggregate replacement separately . The cubes were formed by substituting coarse aggregate with 0%, 10%, 20%,30%, 40%, 50%, 60%, 70% and 80% steel slag, respectively. While 0%, 5%, 10%, 20%, 25%, 30%, 40% and 50% for fine aggregates replacement. Specimens are cast in accordance with the mix design, and tests are performed following appropriate curing. The tests are compressive strength of cubes (150mmx150mmx150mm), that are then compared to the conventional concrete.

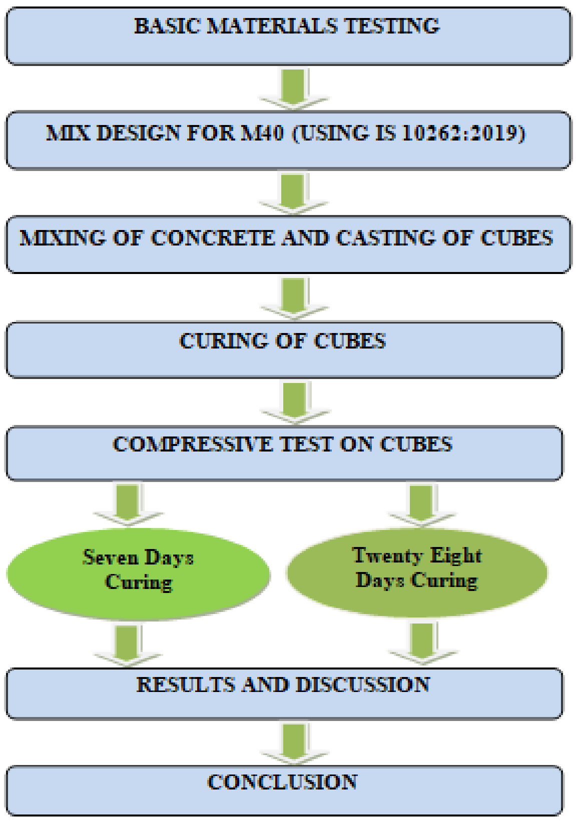


Fig 1: Methodology flow chart

After determining the optimal replacement of coarse and fine aggregate, maintain the fine aggregate optimum replacement constant while altering the coarse aggregate replacement by 10% upto 80%. Following casting of cubes, curing and testing would take place.

3. TESTS ON MATERIALS AND ITS PROPERTIES

The laboratory performed basic tests on cement, coarse aggregate, fine aggregate, and steel slag, and the results will be used in concrete mix design.

3.1 Cement Test Results

Cement Used : ACC OPC 43 Grade

Table 1: Physical Tests on Cement

SN	Test Conducted on cement	Result	IS 8112 Requirement
1	Normal Consistency	34%	-
2	Specific gravity	3.15	
3	Initial setting time	35 Min	Shall not be less than 30 min
4	Final setting time	320 Min	Shall not be greater than 600 min

3.2 Test on fine aggregate

Table 2: Physical Tests on Fine Aggregate

SN	Test Conducted on Fine aggregates	Result	IS Recommendations
1	Fineness Modulus	2.52	Zone II (IS383-1970)
2	Specific gravity	2.68	
3	Water Absorption	1%	Shall not exceed 3% (BS 812-2)

Fine aggregate is defined as aggregate that passes through a 4.75 mm sieve. It is made from locally available river sand that is free of organic impurities. This inquiry makes use of sand that has passed through a 4.75 mm filter and has been kept on a 150 micron IS sieve.

Before weighing and strivings, the sample must be brought to an air dry state. This can be accomplished by drying at room temperature or heating at a temperature of 100C to 110C. The air dry sample must be weighted and sieved sequentially on suitable sieves, beginning with the biggest. Before using the sieves, be certain that they are clean.

3.3 Coarse aggregate (CA)

The main component of concrete is coarse aggregate. They provide body to the concrete, minimise shrinkage, and have an economic influence. One of the most critical aspects in generating workable concrete is a suitable gradation of coarse aggregate. In this experiment, the coarse material was crushed aggregate that had been passed through a 20mm IS filter. IS-383-1970 compliant aggregates were used. Crushed aggregate improves strength owing to angular particle interlocking, but spherical aggregate enhances flow because to lower internal friction. Long aggregates are undesirable.

The basics test was conducted on the coarse aggregate in laboratory, the included Specific gravity test, water absorption test, bulk density test, fineness modulus test and etc are conducted before going to design a mix proportion and result shows ion Table 3

Table 3: Physical Tests on Coarse Aggregate

SN	Test Conducted	Results
1	Type	Crushed
2	Specific Gravity	2.73
3	Bulk Density	1813.12 kg/m^3
4	Fineness Modulus	7.208
5	Water absorption	0.5%

3.4 Waste glass powder

Glass powder is made from waste glass collected from Gurugram retailers. Glass waste is a durable material. Glass powder must be pulverised to the right size before being mixed into concrete. Glass powder crushed in a ball for 30 to 60 minutes produced particle sizes smaller than 4.75mm in this study.

3.5 Steel slag

This recipe calls for basic oxygen furnace slag from Jindal Steel Works Pvt. Ltd. in Sandur Village, Bellary District, Karnataka, India. Fluxes (limestone and/or dolomite) are used as fuel in blast furnaces together with coke in the production of iron and steel. Carbon monoxide is created when coke is burnt, converting iron ore to molten iron product. Fluxing agents remove impurities, and slag is generated during the separation of molten steel.

Although almost all steel slag's are air-cooled, contemporary slag manufacturing technology cannot always offer quick cooling, which might affect slag quality. As a result, it is not always appropriate for future use, which is why quality monitoring of steel slag manufacturing is required (Cerjan et al 1995, National Slag Association 1982). Due to their high density, steel slags have long been employed as protective armour stones for rivers, sea and coastal erosion schemes, and different land reclamation projects, yet a certain percentage of generated steel slag is still discharged (National Slag Association 1982). The primary issue with steel slag aggregate is its expansive nature and unfavourable reactivity.

The Characteristics of Steel slags are following.

1. Lighter in weight than the majority of natural aggregates
2. Transport Cost Savings
3. Volume per truckload decreased CO2 emissions > Fewer delivered truckloads
4. Increased Friction Asphalt Blends
5. Increased Stability (Less Rutting)
6. High inertial friction angle
7. Excellent Aggregate Base Because of Stability

Physical test on steel slag

Specific gravity : 3.14

Water absorption : 0.11

3.6Water used

For concreting and curing specimens, portable drinking water with a pH of 7 and according to IS 456-2000 is used.

3.7 Superplastisizer

It is a powerful water reducing agent in concrete agent in concrete. The superplastisizer used to reduced water 20%- 30% hence avoid bleeding in concrete.

4 MIX DESIGN AND IT'S PROPORTION

4.1 General introduction

The recently issued Bureau of Standards (BIS) amended code on "Concrete Mix Proportioning-Guidelines" IS 10262-2019 brings relief to many construction industry stakeholders, notably those involved in concrete manufacturing.

Previously, the fourth edition of IS 456, published in 2000, was a small stumbling point in the code of practise for "Plain and reinforced concrete." Aligning IS 10262 and IS 456 in terms of concrete producing materials, minimum cement content, minimum water cement ratio, and minimum grade of concrete for various exposure scenarios satisfies the need to align these two standards. The new standard is applicable to ordinary and standard concrete grades (as defined in IS 456- 2000). The code has been updated to suit current water content and coarse aggregate proportioning practices in concrete mixes. The mix mix design were carried out according to specified code book andobtained results obtained given below

Table 4 Mix Ratio proportion

Water	Cement	Fine aggregate	Coarse Aggregate
171 liters	400kg	799kg	1110 kg
0.40	1	2	2.77

CEMENT: SAND: AGGREGATE = 1:2:2.77

4 CASTING, CURING AND TESTING OF CONCRETE

5.1 Casting of cubes

Cubes are cast using moulds measuring 150mm x 150mm x 150mm. The moulds have been cleaned, but the corners have been oiled. All interior surfaces receive one layer of cutting oil

Fig. 2 Casting of cubes

The moulds are filled in three layers, with each layer around one-third the depth of the mould. Every layer is compressed by applying 25 blows with a tamping rod equally throughout the whole cross section for members. The top surface of the moulds is levelled and left for 24 hours after filling and compacting them. The cubes, cylinders, and prism are then taken from the mould and kept for the requisite curing period. The water should be pure and free of impurities. The water should be changed every three days to attain the best benefits.

5.2 Curing of cubes

The cubes were cured in a water container filled with fresh, drinkable water that was devoid of any pollutants. After the curing period is through, all of the specimens should be removed and dried for one day, because optimal results need thorough drying. Before the test, the specimens' surfaces should be cleaned using a compression testing machine (CTM) and a universal testing machine (UTM).

Fig.. 3 Curing of concrete

The compressive strength of concrete is one of its most important characteristics. Concrete is designed to resist compressive stress in most structural applications. The compressive strength of regular concrete cubes and concrete cubes with a fraction of Waste Glass was investigated in this study. The cubes are tested in a 3000 KN compression - testing machine. The weight was applied to the cube in such a way that the cube's two opposing faces were crushed. The force at which the control specimens fracture is recorded. The compressive strength is computed as the average of 3 cubes. Compressive strength is estimated by dividing the load by the area of the specimen.

5.3 Compressive strength test

Among the most important characteristics of concrete is its compressive strength. Concrete is designed to withstand compressive stress in most structural applications. In this study. The compressive strength of ordinary concrete cubes and concrete cubes containing a fraction of Waste Glass was investigated. The cubes are put through their paces on a 3000KN compressive testing machine. The weight was applied to the cube in such a way that the two opposing sides of the cube were crushed. It is documented at what load the control specimens fail.

Fig. 4 Performing the compressive test on cubes in compression testing machine

The average of three cubes is used to calculate compressive strength. The compressive strength of a specimen is estimated by dividing the load by the area of the specimen.

Table 4 Glass replacement compressive strength for Seven days

SN	% of Glass	Load(KN)	Compressive Strength
1	0	593.87	26.39
2	10	665.15	29.56
3	**20**	**723.30**	**32.15**
4	25	669.33	29.74
4	30	605.67	26.91
5	40	548.36	24.37
6	50	449.75	19.98

Table 5 Steel Slag replacement compressive strength for Seven days

SN	% of Steel Slag	Load(KN)	Compressive Strength
1	0	593.87	26.39
2	10	615.40	27.35
3	20	698.07	31.02
4	30	719.00	31.95
5	40	754.00	33.51
6	50	767.33	34.10
7	**60**	**779.00**	**34.62**
8	70	662.66	29.45
9	80	543.00	24.13

Table 6 Combined Replacement cubes compressive strength for Seven Days

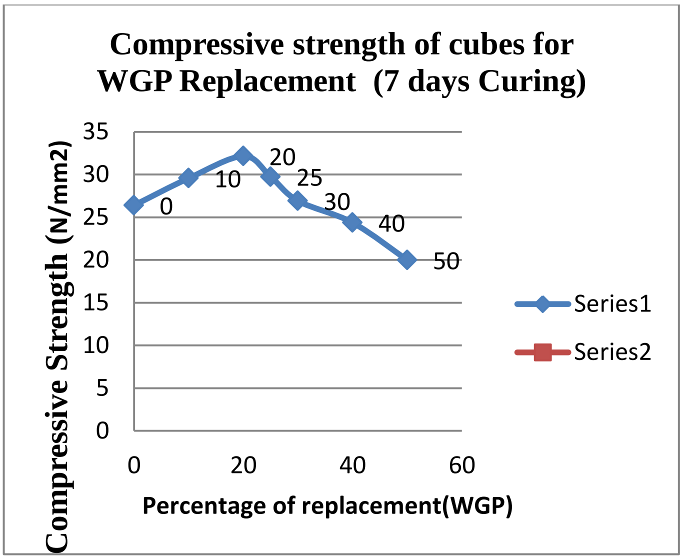
SN	% of Slag	% of Glass	Load(KN)	C/S
1	0	20	732	32.54
2	10	20	746	33.17
3	20	20	758	33.70
4	30	20	779	34.63
5	40	20	793	35.26
6	**50**	**20**	**807**	**35.85**
7	60	20	747	33.23
8	70	20	700	31.14
9	80	20	607	26.98

Table 7 Combined Replacement cubes compressive strength for 28 Days

SN	% of Slag	% of Glass	Load(KN)	Compressive strength
1	0	20	920	40.91
2	10	20	959	42.63
3	20	20	988	43.92
4	30	20	1002	44.54
5	40	20	1010	44.91
6	**50**	**20**	**1025**	**45.57**
7	60	20	960	42.69
8	70	20	905	40.23
9	80	20	785	34.91

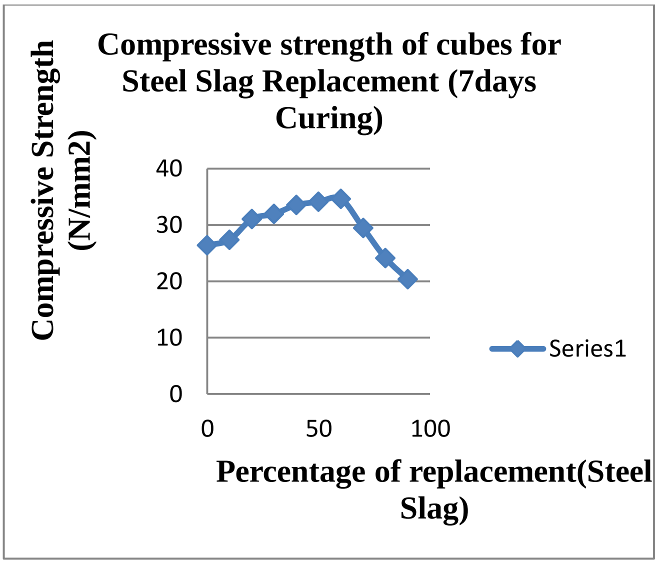
6 RESULTS AND DISCUSSION

6.1 Graph representation of Compressive Strength of cubes



Graph 1 Seven days compressive strength for Waste glass powder

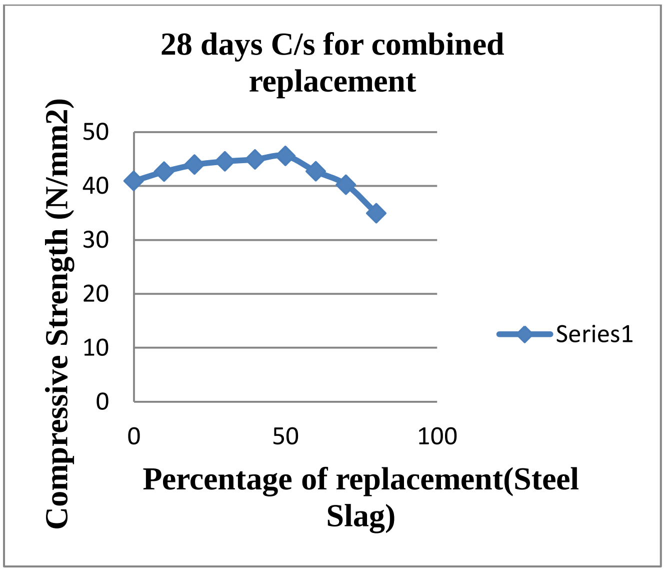
Graph 1 show the effect of replacing fine particles with waste glass powder on hardened concrete properties such as compressive strength. It is found that the compressive strength of seven days cubes improves initially up to 20% replacement, but as we increase the replacement by glass powder after 20%, the compressive strength decreases. As a result, we discovered that the ideal proportion of glass waste powder replacement with fine particles in concrete mix is 20%.



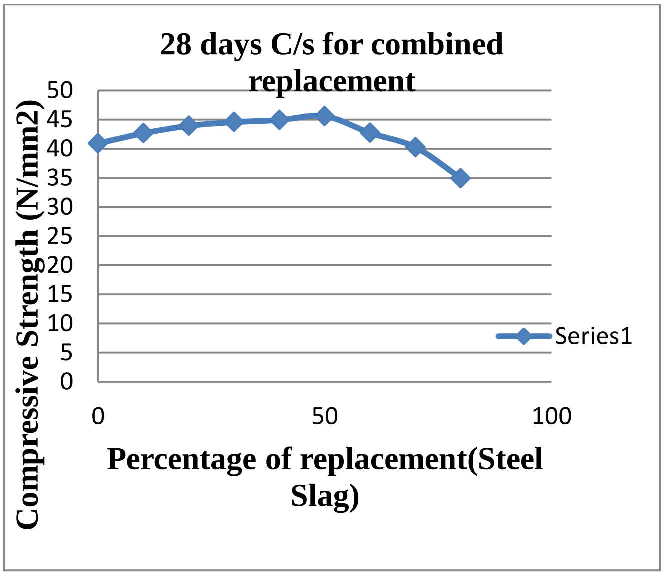
Graph 2. Seven days compressive strength for Steel slag replacement

Above graph 2 shows that the individual replacement of coarse aggregates with steel slag at different replacement i.e. 0% (Convential Concrete), 10%,20%,30%, 40%, 50%, 60%, 70%, and upto 90%. The compressive strength test was carried out on seven days cubes and the results suggest that the strength of concrete initially increasing upto 60% replacement after that strength gets decreases. Based on the results obtained the optimum replacement of coarse aggregates with steel slag in concrete mix is 60%

Hence, We observed that optimum percentage of Steel slag replacement with Coarse aggregates in concrete mix is 60%.



Graph 3 Seven days compressive strength for combined replacement

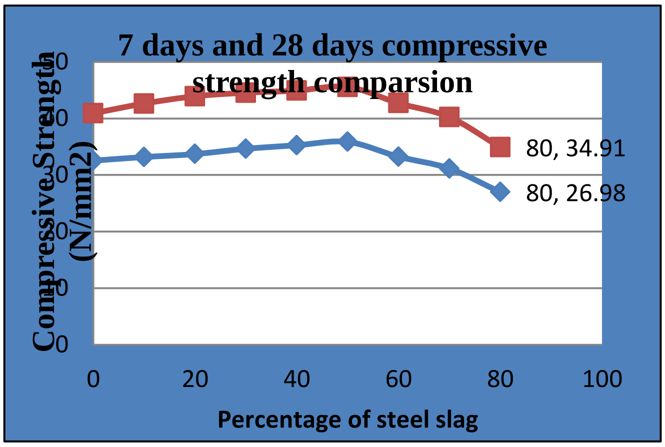


Graph 4 28 days compressive strength for combined replacement

Above Graph 3 & Graph 4 Shows that the optimum percentage of replacement of steel slag in concrete at 7 and 28-days compressive strength is 50% with 20% replacement of glass powder.

The test was performed on (54+51) cubes with varying percentage replacement, and the final output results are shown in Tables 4-7. On behalf of table data graphs have been plotted between percentage of replacement and compressive strength. Its suggest that the initially strength gain and after some replacement it decreases down.

6.2 Comparison



Graph 5 Comparison graph between 7days and 28 days compressive strength

Above 5 shows that comparison between 7 days 28 days compressive strength for combined replacement. Where,

[Graph 8.5 Series 1 7 day C/s, Series 2 – 28 day C/s]

The inclusion of waste glass content in the concrete mix enhances the compressive strength of the mix with 20% waste glass powder, according to the results of the tests. When concrete mixes containing 10%, 20%, 30%, 40%, and 50% waste glass powder are used, the compressive strength increases by 21.82 percent when compared to the standard mix.On 7 days of testing, the optimal replacement of steel slag as coarse aggregate is 60%.

While compressive strength increased by 31.18 percent when compared to the standard mix. Furthermore, the test was conducted on combined replacement while maintaining fine aggregate replacement constant at 20% and altering steel slag as coarse aggregate replacement in the sequence of 0%,20% upto ,80%. Furthermore, the test results indicate that the best percentage for mixed replacement while preserving 20% waste glass powder is 50%, while the optimum percentage for coarse aggregate replacement is 50%.

7 SUMMARY AND CONCLUSION

7.1 Summary

The primary purpose of this study is to look at the effects of waste glass and steel slag content on the properties of concrete mixes when used as a partial substitute for fine and coarse aggregates, respectively. This aim was achieved by determining the effects of adding waste glass powder and steel slag on the fresh characteristics of concrete mixes, as well as researching the effects on the hardened concrete properties. Choosing the best waste glass and steel slag content to employ as a partial replacement within the concrete mix, focusing on concrete mixes with optimal waste glass and steel slag contents by measuring their compressive strength. These goals were met by performing a conventional series of compressive strength tests. The output outcomes of this laboratory programme demonstrated credible data points and future study objectives.

After putting in the effort, obtained the following results: optimal replacement of fine aggregate with waste glass powder, optimal replacement of coarse aggregate with steel slag, and optimal percentage of combined replacement of coarse aggregate and fine aggregate, which were discussed in the conclusion section.

7.2 Conclusion

The research findings may lead to the following conclusions, which are summarised below.

1) There is a 21.82 percent improvement in compressive strength for concrete mixes containing 10%, 20%, 30%, 40%, and 50% waste glass powder as compared to conventional concrete mixes after 7 days of curing.

2) There is a fall in compressive strength in concrete mixtures containing 30%, 40%, and 50% waste glass powder. GP mix concrete for a 7-day curing period.

3) For 7 days curing of concrete, concrete mixes containing 10%, 20%, 30%,... up to 80% steel slag have a 31% improvement in compressive strength when compared to standard concrete mixes.

4) There is a reduction in compressive strength in concrete mixes containing more than 60% steel slag as coarse particles.

5) The combined replacement for steel slag found best at 50 percent while maintaining waste glass powder constant throughout 20 percent and varied steel slag as a coarse aggregates partial replacement.

6) The density of concrete reduces as the proportion of glass powder increases.

7) The use of recyclable waste glass in concrete reduces building costs.

8) This substance can lessen the environmental consequences of trash and the maximum quantity of sand mining.

7.3 Scope for future study

1) Study of mechanical properties of concrete like flexural strength & split tensile strength.

2) In a concrete pavement research, coarse particles were replaced with steel slag.

3) Investigation of the fresh characteristics of concrete after the substitution of glass powder and steel slag.

4) The investigation of the environmental impacts of such waste generated (Glass and Steel slag)

5) Data collection, such as slag waste created by steel plants.

6) Combined replacement of Coarse Aggregate and Fine Aggregate with keeping Coarse aggregate replacement constant.

7) Study of compressive strength with different grade of concrete mix

8) Study of compressive strength with different water cement ratio

9) Use of glass powder as replacement of cement and study of pozzolanic property

10) Glass powder and steel slag replacement to study the fresh concrete properties

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