Assessment of strength and durability parameters for concrete with partial replacement of coarse aggregates by iron slag and glass powder as an additive

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Abstract. Global warming and environmental destruction have become the major issue in recent years. Use of more and more environmentally friendly materials in any industry in general and construction industry, is of more importance. Preventing the depletion of natural resources and enhancing the usage of waste materials has become a challenge to scientists and engineers. Waste glass in one material when grounded to a very fine powder shows pozzolanic properties which can be used as additives, Iron slag rendered as scrap is used as partial replacement of aggregate in concrete. Iron slag is an industrial waste by-product of steel industry. The present investigation deals with the usage of Iron slag as a partial replacement of coarse aggregate and addition of glass powder to the concrete. The optimum percentage of iron slag to be replaced is found out by conducting 28 days compressive test on cubes of size 150mm×150mm×150mm with 5%, 10%, 15% replacement of coarse aggregates with iron slag. The glass powder is added with percentage of 5%, 10%. With the overall percentage of iron slag and glass powder the workability of concrete is checked and cubes are casted and tested for its compressive strength and durability parameters like saturated moisture content, effective porosity, sulphate attack and carbonation depth.

1. Introduction

In civil engineering, concrete structures such as raft foundation, retaining walls and massive dam which are almost built by this material are very popular structural type. Such structures usually require large volumes of concrete. In the volume of concrete, the share of aggregates is typical in 70% and 80% which forms a major part of nearly 3 tons of concrete delivered each year for every human on the plant, making it the most manmade product in the world. The aggregates greatly influence different properties of concrete for example workability, dimensional, stability, strength, and durability.

It is the usual practice to use river and sand as fine aggregate and crushed granite, gravel and limestone of different sizes and shapes as coarse aggregate in the preparation of concrete. These materials are quarried from natural sources. Excessive utilization of such materials will result in depletion of natural resources as well as environmental degradation. Hence it is all more essential to search for alternatives to these materials. Towards this goal it is better to consider the wastes like iron slag and glass powder in the concrete mix. Iron slag is a byproduct of steel industry and glass powder is generated as a by-product of the glass industry.
slag, bottom ash, copper slag etc., generated by human activities. Use of such wastes as aggregates will to some extent will solve the problem of shortage aggregates in concrete making at several construction sites, and minimize the problem associated with aggregate mining and waste disposal. Even though some progress has been made in this direction, still, deeper research is required to evaluate the waste materials as aggregate in concrete. With this view in mind one of the wastes, namely iron slag scrap, was utilized as coarse aggregate in preparation of concrete.

The recycling and reuse of the waste has become the best other options and their removal issues of waste. The reuse of such waste will diminish the nature impact and is more economical. The energy required to reuse the recyclable material is not as much as that of virgin materials. The utilization of these waste products in construction industry is best option due to large numbers of construction site all over the world. Ordinarily glass does not hurt nature in any capacity since it doesn’t emit contaminations, yet it can hurt just as creatures, if not managed cautiously and it is less benevolent to condition since it is non-biodegradable. Thus, the improvement of new advances has been required. The term glass contains several chemical diversities including soda- lime silicates glass, alkali-silicate glass, and borosilicate glass. Until this point, these kinds of glasses, glass powder have been generally utilized in cement and aggregate mixture as pozzolana for civil works. Presently the waste glass in and around the small shops is packed as a waste and arranged as landfill. Squander glass contain high silica (SiO2)i.e., 72% waste glass when ground to fine powder reacts with alkalis in cement and cementitious product that help contribute to the strength development.

Khalid Raza et.al [1] in his study investigates that the compressive strength and flexural strength of M40 grade concrete with 0.45 water/cement ratio were investigated with coarse aggregate partially substituted with iron slag aggregate (ISA) at different proportions of 0 %, 10 %, 20 %, 30 %, 40 % and 50 % to evaluate and verify the compressive strength, flexural strength, and split tensile strength. J. Premalatha [8] et.al made the investigation on concrete properties with various % of glass powder varying from 0%, 5%, 10%, 15% and 20% were done on fresh and hardened concrete. Standard tests were used to examine the maximum stress-strain behaviour, mechanical strength, and toughness properties of concrete with partial replacement of natural river sand by glass powder. The optimum glass powder content was obtained by determining specimens produced with various concrete grades M20, M30, M40, M50, and M60.

2. Research Significance

The primary objective of this section is to assess the outcomes of distinct kinds and percentage of Iron Slag and Glass Powder proportioning on the mechanical properties of concrete such as Compressive and Flexural strength of reinforced concrete cube samples with M20 grade mix. According the Compressive strength of concrete of M20 Grade with water-binder ratio as 0.45 and mix proportion of 1:1.5:3. This study enhances to reduce the usage of natural resources like Coarse Aggregate by replacing it with alternately available materials or waste materials like Iron Slag. and to reduce the expense of construction and the material utilized for making concrete. It is also used for improving the the compressive strength of concrete by replacing Coarse Aggregate with Iron Slag and Glass Powder as an added substance to Concrete.

The main objectives of this present study to decide the ideal estimation of replacement of Iron Slag waste in ordinary concrete instead of aggregate to get the estimated workability and to decide the compressive strength of concrete at ideal replacement of waste Iron Slag and Extra Addition of Glass Powder as an added substance in ordinary concrete. Comparative investigation of workability and compressive strength of conventional concrete with concrete replaced with Iron Slag and Glass powder as an added substance.

3. Materials and Mix Proportioning

Materials utilized in this undertaking were OPC 53 Grade cement affirming to IS 8112, fine aggregate and coarse aggregates affirming to IS 383-1970. Designed concrete mix of M-20 grade having mix proportion 1:1.5:3 is taken with water cement ratio 0.5. Considering the above proportion the coarse aggregate is partially replaced by Iron slag and Glass powder is added to the concrete at various proportions (state Iron slag, Glass powder) 0%-0%, 5%-5%, 10%-5%, 15%-5%, 5%-10%, 15%-10%.
10%-10%, 15%-10% were utilized in concrete. The concrete predominantly comprises of cement, coarse aggregate, and fine aggregate. In any case, as indicated by our project coarse aggregate is partially replaced by Iron slag and Glass powder is added to the concrete mix.

This study was conducted out using the Materials and Proportioning of M20 Mix with Portland Cement, widely available in India for concrete production, siliceous river sand with a fine aggregate having fineness modules of 2.6 and a proportional maximum size of 20 mm. In accordance with the Indian Standard IS 2386-1963, the coarse aggregate ingested cooperates with the Indian Standard IS 383-1970 code and is measured for its physical characteristics, its special gravity 2.75 as just an angular coarse aggregate. The free-state bulk density is 1554 kg/m³ and the compressed state is 1594 kg/m³. Potable water have been used in the investigations for mixing of specimens.

**Calculation of Materials Proportioning of M20 Mix design**

Volume of the concrete = 1 m³

Volume of cement = \( \frac{\text{Mass of the cement}}{\text{Specific gravity of the cement}} \times \frac{1}{1000} \) = \( \frac{320}{3.12} \times \frac{1}{1000} = 0.102 \text{m}^3 \)

Volume of water = \( \frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000} \) = \( \frac{197.16}{1000} = 0.197 \text{m}^3 \)

Volume of all aggregates = 1 - [0.102 + 0.197] = 0.701 m³

Mass of coarse aggregate = \( \text{Abs. Volume} \times \text{Vol. of CA} \times \text{Sp. gravity of CA} \times 1000 \) = 0.701 x 0.56 x 2.65 x 1000 = 1040.28 kg

Mass of fine aggregate = \( \text{Total Volume} \times \text{Vol. of FA} \times \text{Sp. gravity of FA} \times 1000 \) = 0.701 x 0.44 x 2.65 x 1000 = 817.36 kg

For M20 grade of Concrete = 1:1.5:3

Volume of cement = \( \frac{1}{1+1.5+3} \times 0.0243 = 4.418 \times 10^{-3} \text{m}^3 \)

Volume of fine aggregate (FA) = \( \frac{1.5}{1+1.5+3} \times 0.0243 = 6.63 \times 10^{-3} \text{m}^3 \)

Volume of coarse aggregate (CA) = \( \frac{3}{1+1.5+3} \times 0.0243 = 0.013 \text{m}^3 \)

Mass of cement = density of cement x volume = 1440 x 4.418 x 10^{-3} = 6.36 kg

Mass of FA = density of fine aggregate x volume = 1680 x 6.63 x 10^{-3} = 11.53 kg

Mass of CA = density of coarse aggregate x volume = 1750 x 0.013 = 22.75 kg

Similarly Quantities for proportion when the coarse aggregate is partially replaced by Iron slag and Glass powder is added to the concrete at various proportions (state Iron slag, Glass powder) 0%-0%, 5%-5%, 10%-5%, 15%-5%, 5%-10%, 10%-10%, 15%-10%.

| Table 1 : Quantities of Materials required for various Replacement Proportions |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Proportions (Iron slag, Glass powder) | Wt. of Cement (kg) | Wt. of FA (kg) | Wt. of CA (kg) | Wt. of Iron Slag (kg) | Wt. of Glass Powder (kg) | Volume of Water (Litres) |
| Conventional | 6.36 | 11.53 | 22.75 | 0 | 0 | 3.82 |
| 5%,5% | 6.36 | 11.53 | 21.61 | 1.13 | 0.58 | 3.82 |
| 10%,5% | 6.36 | 11.53 | 20.47 | 2.27 | 0.58 | 3.82 |
| 15%,5% | 6.36 | 11.53 | 19.33 | 3.41 | 0.58 | 3.82 |
| 5%,10% | 6.36 | 11.53 | 21.61 | 1.13 | 1.15 | 3.82 |
| 10%,10% | 6.36 | 11.53 | 20.47 | 2.27 | 1.15 | 3.82 |
| 15%,10% | 6.36 | 11.53 | 19.33 | 3.41 | 1.15 | 3.82 |

According to weights of the cement, fine aggregate and coarse aggregate are gauged. These materials are regularly blended in with the assistance of trowel in a tray, the mixture is moved to the pan mixer and permitted to blend for few moments. As per the w/c ratio the determined volume of water is added to the mixture and permitted to blend for few minutes to accomplish the consistency. At that point, the concrete mix is taken out in a tray and equitably blended in with the assistance of trowel.
Before casting the mould, oil is applied to the moulds, then the moulds are filled with concrete in 3 layers by giving 25 blows for each layer. Then the moulds are placed on the tabular vibrator for 5-10 minutes to keep away from voids or air bubbles. Then the concrete moulds are dried at room temperature 299K for 24hrs. After 24hrs moulds are demoulded and the concrete cubes are kept in restoring tank for 7days, 14days, 28days. For testing the cubes, the cubes are taken out from the restoring tank and left out for sun dry. At the point when the cubes are totally dried the cubes are prepared for testing.

| Table 2 : Compressive strength for various Replacement Proportions |
|---------------------------------------------------------------|
| **Proportions for Iron Slag and Glass powder**                |
| **Compressive Strength (N/mm$^2$)**                           |
| **Target strength (N/mm$^2$)**                                |
| **7 Days** | **14 Days** | **28 Days** | **7 Days** | **14 Days** | **28 Days** |
| --- | --- | --- | --- | --- | --- |
| S1 | S2 | Average | S1 | S2 | Average | S1 | S2 | Average |
| Conventional | 16.67 | 16.44 | 16.56 | 22.89 | 23.78 | 23.34 | 30.22 | 35.56 | 32.89 |
| 5%,5% | 15.33 | 12.22 | 13.78 | 24.76 | 22.78 | 23.77 | 32.14 | 31.45 | 31.79 |
| 10%,5% | 10.44 | 17.55 | 14.00 | 23.78 | 23.12 | 23.45 | 34.56 | 34.24 | 34.31 |
| 15%,5% | 13.33 | 11.44 | 12.39 | 22.67 | 22.14 | 22.41 | 28.89 | 32.09 | 30.45 |
| 5%,10% | 15.76 | 11.67 | 13.72 | 23.33 | 21.45 | 22.39 | 26.11 | 31.54 | 28.85 |
| 10%,10% | 16.67 | 14.44 | 15.56 | 20.56 | 20.45 | 20.51 | 25.33 | 28.39 | 26.86 |
| 15%,10% | 10.44 | 12.67 | 11.56 | 21.22 | 22.12 | 21.67 | 25.56 | 26.78 | 26.17 |
| 58 | 53 |

The outcomes got from the tests completed on 7, 14 and 28 days of curing were compared with the conventional concrete to decide the compressive strength. The strength characteristics of concrete mixtures have been figured by taking different percentages of Iron Slag as partial substitution of coarse aggregate and Glass powder as addition, and the partial replacement include 5%,10%,15% of coarse aggregate by Iron Slag and addition of Glass powder by 5%,10% respectively. Hence the following proportions are taken they are (5%, 5%), (10%, 5%), (15%, 5%), (5%, 10%), (10%, 10%), (15%, 10%).

The compressive strengths of various proportions have been compared with conventional concrete. From Table 3, At (5%, 5%) proportion, there is 26.93% increase after 14days, at (10%, 5%) proportion there is 18.41% increase, at (15%, 5%) proportion there is 10.62% increase, at (5%, 10%) proportion there is 13.43% increase, and at (10%, 10%) proportion there is 6.36% increase. By the test results the compressive strength tends to increase for all proportions. As the percentage of replacement of Iron slag and addition of Glass powder is increased the compressive strength is increased as shown in table 2.

Distinct mechanical properties, such as compressive strength and split tensile strength, must be investigated experimentally in different specimens. Within each mechanical characteristics, the size of the specimens has to be determined and analysed. The specimen descriptions and work scheme are shown in Table 2. The structural properties of the different mineral admixture replacements of specimens, such as 10%, 20%, 30%, 40%, and 50%, were investigated in this study. For 7 days, 14 days and 28 days, the respective samples were cast and examined.

4. Mechanical Behaviour of Alccofine based Self Compacting Concrete

Saturated moisture content, porosity, sulphate attack, carbonation depth, was moisture-curing with each combination after 14 and 28 days have shown in table 3. The Indian Standard mixtures were prepared (by weight) is used in mixes of traditional 1 : 1.5 : 3 after many trials for durability studies. For weight, the water/cement ratio were 0.45.

| Table 3 : Durability parameters for Iron Slag and Glass powder replacements |
|---------------------------------------------------------------------------|
| **Proportions for Iron Slag and Glass powder**                            |
| **Water Absorption (%)** | **Effective Porosity (%)** | **Penetration Depth (mm)** | **Average Loss in weight by Sulphate Attack (%)** |
| **14 days** | **28 days** | **14 days** | **28 days** | **14 days** | **28 days** | **14 days** | **28 days** |
| Conventional | 2.63 | 2.45 | 5.70 | 3.94 | 3.54 | 4.43 | 58 | 53 |
5. Conclusions

Based on the experimental the following conclusion is drawn within the limitation of test result. For different replacement, the fresh and hardened properties observed were good as compared to 5%,5%, 10%,5%, 15%,5%, 5%,10%, 10%,10% and 15%,10% Iron slag and glass powder ratios replacement. In view of results acquired, following conclusions can be drawn:

Based on test examination, it is discovered that Iron slag can be utilized as a partial replacement of coarse aggregate. Water required creating a similar workability stays same with the increase in the percentage of Iron slag and Glass powder. Usage of Iron slag and Glass powder in conventional concrete diminishes the expense of concrete because these are the waste materials from the industries, and they additionally reduce the issues of disposal and end up being environment friendly.

The greater compressive strength is increased up to 27% for 10% of Iron slag and 5% of Glass powder when compared to Conventional concrete. Meanwhile, it is noticed that the compressive strength is increased for all proportions from conventional concrete and Iron slag and glass powder ratios varying from 5%,5%, 10%,5%, 15%,5% 5%,10%, 10%,10% and 15%,10% The target strength is obtained at 14 days for all the proportions for some of the mixes which indicate the compressive strength have enhances by using this Iron slag and glass powder ratios in M20 grade of concrete. Thus, the development of concrete with iron slag and glass powder has given a new dimension in the disposal of waste by a cleaner technology. Also, using such waste reduces the strain in the extraction of natural aggregate from the earth.

Tests which conducted for the saturated moisture content, effective porosity, resistance to sulphate attack, carbonation depth, was moisture-curing with each combination after 14 and 28 days have been done. Due to these variation over the mixing proportioning, it is noticed that water absorption for 15% of Iron slag and 10% of Glass powder lesser when compared to other mixes. Also, while finding out the acid resistance over the concrete, rate of loss in weight may increased in conventional concrete mix over other mixes. Effective porosity and carbonation depth tests for the concrete mixes have increased for 14 days and decreases for 28 days in all mixes, which makes slight variation in the durability parameters.

6. References

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