Experimental Investigation on Ternary Concrete Containing of Granulated Blast furnace slag as a partial replacement to Fine aggregate.

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**Abstract.** Concrete is a combination of cement, fine aggregate, coarse aggregate, water and admixtures. According to world coal association survey over 4.1 billion tons of Ordinary Portland cement (OPC) was used across globally in 2020 and also use of OPC emits CO\(_2\) to the atmosphere. In order to overcome the problem, a search for alternative materials is the need of the hour and apart from cement, fine aggregate is also important additive to concrete. Due to the speedy construction rate deficiency of materials occurs reduction in natural aggregates causes problems like dredging of sand in large scale which creates environmental imbalance. The solution is utilisation of Fly ash, silica fume, Ground granulated blast furnace slag (GGBS) which are comes under Industrial by-products. The disposal of Industrial by-products should done properly, else it will cause land pollution. In this present study silica fume, fly ashes are replaced in OPC and fine aggregate with Granulated blast furnace slag (GBFS). The experimental work execute in order to determine mechanical properties such as compression, split tensile and flexural strength of concrete with age 3, 7 and 28 days at various combinations of cement with fly ash varies 20\%, 30\%, 40\% and constant 8\% of silica fume and fine aggregate replaces with Granulated blast furnace slag of 30\%, 40\% and 50\% in M40 grade concrete with water-cement ratio 0.38. As per experimental results conclusions were drawn. As per the experimental results it is recommended that OPC is replaced with 8\% of silica fume, 20\% of fly ash and fine aggregate replaced with 40\% of GBFS achieved optimum strength.

**Key words:** Concrete, Granulated Blast furnace slag, Industrial by-products, Mechanical properties, partial replacement.

1. **Introduction:**

Concrete is an established material for the purpose of construction. Utilization of large amount of OPC leads emission of CO\(_2\), and also extraction of high amount of natural aggregates leads to cause environmental imbalance. To overcome this type of problems need of substituent materials are required like Industrial by-products. In this present study constant 8\% of silica fume, fly ash varies 20\%, 30\%, 40\% as replacement of OPC and 30\%, 40\%, 50\% of GBFS in fine aggregate were used for the purpose of finding the mechanical properties of M40 grade concrete. Concrete takes place second
the world in terms of using materials after the water. The high rate of manufacturing cement leads to emission of CO\(_2\). According to some estimation by experts manufacturing of 1 ton of OPC leads to 1 ton of CO\(_2\) to atmosphere. To reduce CO\(_2\) content in atmosphere need to go with the supplementary materials. Fly ash, micro silica, GGBS are some of cementitious materials which can use partial replacement of OPC [1]. On the other hand, fine aggregate are important ingredient in concretelike river sand and Manufacturing sand. Utilization of large amount of natural aggregates, problems can be occurred such as soil erosion, effect of aquatic life, CO\(_2\) emission and the extracted industrial by-product should disposal properly, and else it may lead to environmental hazards. To overcome this problems the author tried an aim to investigate the optimum percentage of application of industrial by-product such as Granulated Blast furnace slag as fine aggregate [2]. Fly ash and GGBS are partially replaced in PSC and PPC along with M-sand replaces in fine aggregate it gives high strength in the range of 15-35% and 30-50% [3]. Steel slag is replaced 0-50% in fine aggregate and finally study concluded that 30% of steel slag gives optimum compressive strength [4]. OPC is replaced with micro silica and GGBS with water-cement ratio 0.55. The study recommends that 10% micro silica and 30% of GGBS is required to get economical and durable [5]. In M30 grade of concrete 25% of steel slag gives higher mechanical properties [6]. 10% of alccofine, 20% of bottom ash replaced in OPC and 30% of slag replaced in fine aggregate gives maximum strength in triple blended concrete [7]. In M20 grade of concrete showed higher compressive strength when 40% of slag replaced in fine aggregate and 30% of slag replaced in coarse aggregate [8]. An experiment conducted on triple blended concrete getting higher strength when OPC replaces with 4% of fly ash and 16% of GGBS [9].

The objectives of present work is to dictate the fresh and hardened properties of concrete on ternary concrete consisting of silica fume and fly ash as a partial substitution of OPC, to determine the hardened concrete properties of ternary concrete consisting Granulated Blast furnace slag as a partial replacement of fine aggregate, to determine the optimum percentage utilization of Industrial-by-products in partial substitution of OPC and fine aggregate, to establish the application of industrial-by-products for the sake to reduce the CO\(_2\) emission and conserving the natural resources.

2. Materials

2.1 Cement:
OPC 53 grade having specific gravity 3.13, consistency of 32% conforming to IS:269-2015 is used in this study. The brand of cement is DECCAN CEMENTS.

2.2 Fly ash:
Fly ash having specific gravity 2.12 used in this study according to IS:3812. This material data provided by ASTRRA CHEMICALS. The chemical properties of fly ash are mentioned below Table:1.

| Content          | Percentage (%) |
|------------------|----------------|
| SiO\(_2\)+Al2O3+Fe2O3 | 90.5           |
| SiO\(_2\)        | 58             |
| CaO              | 3.6            |
| SO\(_3\)         | 1.8            |
| Na\(_2\)O        | 2              |

2.3 Silica fume:
The use of Silica fume in this study was conforming IS:15388-2003. Table 2 indicates that physical properties of material provided by GEOTECH SERVICES PVT.LTD. (soil&material testing laboratory).

Table 2: Material properties of silica fume
2.4 Fine aggregate:
Fine aggregate having specific gravity 2.35, water absorption 6.38%, drawn ZONE II in sieve analysis conforming IS:383-2016.

2.5 Granulated blast furnace slag (GBFS):
Granulated blast furnace slag having specific gravity is 2.8, water absorption is 2.9% and sieve analysis is ZONE II. Chemical properties of materials provided by JSW CEMENTS LTD as per IS:12089. Table 3 indicates chemical compositions of GBFS.

Table 3: Chemical compositions of GBFS

| Characteristics     | Requirement as per IS:12089 | Test Results |
|---------------------|-----------------------------|--------------|
| SiO2 (%)            | ----                        | 33.04        |
| Al2O3 (%)           | ----                        | 20.66        |
| Fe2O3 (%)           | ----                        | 0.99         |
| CaO (%)             | ----                        | 36.20        |
| MgO(%)              | 17 Max                      | 7.74         |
| Loss in ignition (%)| ----                        | 0.14         |

2.6 Coarse aggregate:
Locally available crushed stones of size 20mm were used in this study as conforming to IS:383-2016. Physical properties of coarse aggregate were water absorption of 1.6%, specific gravity of 2.78 according to IS:2386-1963.

2.7 Super plasticizer:
KVRPCE-100 used as super plasticizer. Specifications of admixture are shown in Table 4 provided by GUJRAT POLYSOL Chemicals Pvt. Ltd.

Table 4: Specifications of super plasticizer

| Characteristics    | Pale yellowish to brown |
|--------------------|-------------------------|
| pH value           | 5.5-6.5                 |
| Solubility         | Readily soluble in water|
| Solid              | 50%                     |
| Specific gravity   | 1.108                   |
| Chloride content   | Below 0.02%             |
Figure1: Materials

The materials like Fly ash, OPC, Silica fume and GBFS are shown in Figure.1.

3. Results and Discussions:
3.1 Mix design:
The mix design for M40 grade tender as per IS:10262-2019. The quantity of concrete making materials furnished in Table 5.

| Material          | OPC  | Fine aggregate | Coarse aggregate | Water | Chemical admixture |
|-------------------|------|----------------|------------------|-------|--------------------|
| Quantity          | 423  | 605            | 1270             | 160   | 3.6                |

In ternary concrete silica fume replaces constant of 8%, fly ash 20%, 30%, 40% in OPC and fine aggregate replaces with GBFS 30%, 40%, 50%. Future the mix id and mix descriptions are mentioned in Table 6.

| Mix ID | Mix descriptions               |
|--------|--------------------------------|
| CC     | Conventional concrete          |
| MIX1   | Silica fume 8%+Fly ash 20%+GBFS 30% |
| MIX2   | Silica fume 8%+Fly ash 20%+GBFS 40% |
| MIX3   | Silica fume 8%+Fly ash 20%+GBFS 50% |
| MIX4   | Silica fume 8%+Fly ash 30%+GBFS 30% |
| MIX5   | Silica fume 8%+Fly ash 30%+GBFS 40% |
| MIX6   | Silica fume 8%+Fly ash 30%+GBFS 50% |
| MIX7   | Silica fume 8%+Fly ash 40%+GBFS 30% |
| MIX8   | Silica fume 8%+Fly ash 40%+GBFS 40% |
| MIX9   | Silica fume 8%+Fly ash 40%+GBFS 50% |

3.2 Workability:
The workability of concrete is measured by using slump cone apparatus. This test was carried out as per IS:1199-1959. The targeted slump for M40 design mix was 100mm. For the purpose maintain the targeted slump of 100mm the dosage of admixture (KVRPCE-100) is adjusted. Table 7 shows the Superplasticizer dosages of mix proportions.
Table 7: Superplasticizer Dosage for 1m$^3$ of Concrete

| Mix Id | Superplasticizer Dosage for Conventional mix (ml) | Superplasticizer Dosage for trail mix (ml) | Variation (%) |
|--------|--------------------------------------------------|------------------------------------------|---------------|
| MIX1   | 2817                                             |                                          | 1.03          |
| MIX2   | 2938                                             |                                          | 1.07          |
| MIX3   | 3012                                             |                                          | 1.10          |
| MIX4   | 3112                                             |                                          | 1.13          |
| MIX5   | 2731                                             |                                          | 1.29          |
| MIX6   | 3541                                             |                                          | 1.35          |
| MIX7   | 4215                                             |                                          | 1.54          |
| MIX8   | 4630                                             |                                          | 1.69          |
| MIX9   | 5022                                             |                                          | 1.83          |

From the above table, it is observed that percentage increase in GBFS, the chemical admixture dosages also increases it means the workability was decreasing because of water absorption of GBFS is less than fine aggregate.

3.3 Tests conducted:
Mechanical properties like compressive strength performed in this study as per IS:14858-2000. The mould size is 150mm length, 150mm width and 150mm height. Split tensile strength carried out as per IS:516-2018 mould size is 150mm diameter and 300mm length. Flexural strength of beam size is 100mm width, 100mm height, 500mm length carried out as per IS:516-2018. Testing set up of compression, split tensile and flexural strength are manifest in Fig.2.

![Figure 2: Experimental set up](image)

3.3.1 Compressive strength:
The values of Compressive strength for 3, 7 and 28 days are mentioned in Table:7. From this result observed the compressive strength of Mix-2 which is highest of all mixes with values of 41.54 N/mm$^2$, 42.33N/mm$^2$ and 58.76 N/mm$^2$ respectively and also improvement in early age strength due to adding of silica fume is observed, because the addition of fly ash lateral strength increases. After 28 days the specimen has been tested for compressive strength increased by 25% compared to conventional concrete.
Table 8: Compressive strength of Fresh Concrete and Blended concrete

| Mix ID | Compressive Strength (MPa) Avg. |
|--------|--------------------------------|
|        | 3 Days | 7 Days | 28 Days |
| CC     | 15.36  | 32.88  | 46.02   |
| MIX1   | 23.88  | 39.40  | 52.84   |
| MIX2   | 41.54  | 42.33  | 58.76   |
| MIX3   | 38.89  | 41.23  | 53.57   |
| MIX4   | 31.71  | 36.71  | 47.75   |
| MIX5   | 33.12  | 40.53  | 51.64   |
| MIX6   | 29.61  | 36.55  | 49.72   |
| MIX7   | 28.49  | 38.98  | 46.81   |
| MIX8   | 29.59  | 39.36  | 47.76   |
| MIX9   | 26.56  | 35.57  | 44.03   |

3.3.2 Split tensile strength:

![Split tensile strength graph](image)

**Figure 3:** Split tensile strength for 3, 7 and 28 days.

Figure 3 indicates the split tensile strength of triple blended concrete at 3, 7 and 28 days. It is noticed that from the above graphical representations the optimum strength obtained at MIX2 contains 8% of silica fume, fly ash of 20% in OPC and 40% of GBFS in fine aggregate. Initial age strength increases due to the addition of silica fume, lateral strength is improved because addition of fly ash is observed.
3.3.3 Flexural strength:

![Figure 4: Flexural strength for 3, 7 and 28 days](image)

Figure 4 indicates average flexural strength of M-40 grade concrete with 3, 7 and 28 days. By the above figure it is observed that Mix-2 getting optimum strength compared to other mixes. The optimum containing 8% of silica fume, 20% of fly ash in OPC and 40% GBFS in fine aggregate. Due to the adding of silica fume early age strength increases.

Conclusions:

- The workability is decreased when GBFS percentage increases. The targeted slump of 100mm is carry off by adjusting the super plasticizer quantity.
- The addition of silica fume in concrete shows improvement in early age strength.
- Formed on the above test results the best mix proportion for M40 grade concrete is Mix-2 in which the OPC is substituted with 20% of Fly ash, 8% of Silica fume and fine aggregate is replaced with 40% of GBFS.
- The compressive strength of Mix-2 is 58.76 N/mm² which is highest of all mixes. The same tendency is noticed in split tensile and flexural strengths.
- The OPC can be replaced 20% fly ash, 8% silica fume. The fine aggregate is replaced with 40% of GBFS is recommended.
- By using Industrial by-products, the reduction in CO2 emission and saving in natural resources are established.
- The present study is applicable in all general constructions such as commercial buildings and bridges.

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