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Sustainable Production of Self Compacting Concrete by using Fly Ash and Granite Waste

Mr. Md. Azam[1] B. Kiran[2], B. Vijayabai[3], G. Kamalakar[4], B. Saikiran[5]
Assistant Professor, Department of Civil Engineering[1]
UG Students, Department of Civil Engineering[2,3,4,5]
Christu Jyothi Institute of Technology and Science, Jangaon, Telangana, India

Abstract*: The development of sustainable concrete has gained plenty of awareness in recent years. Researchers have conducted many experimental investigations for the manufacture of different forms of concrete by usingnumerous low carbon footprint materials, such as granite waste and fly ash. The using of low carbon footprint materials in construction industry will minimize the exploitation of natural raw materials and promote sustainability in construction industry. This research thus aimed to investigate the influence of granite waste (GW) and fly ash on the production of self-compacting concrete (SCC). The preliminary investigation was carried out for finding the maximum adding percentage of GW and fly ash in the successful production of SCC. The GW was used in the proportion of 10,20 and 30% as an alternative to fine aggregate (i.e. sand) by weight, while, fly ash was substituted with cement in the proportion of 10,20 and 30% by weight. The fresh characteristics (slump flow, V-funnel, and L-box), mechanical characteristics (compressive strength) were evaluated. The findings revealed that the combined use of GW (up to 30%) and fly ash (up to 30%) in SCC has the potential to considerably enhance the fresh and water absorption properties (without adversely affecting strength characteristics*

Keywords: Slump flow, V-Funnel, L-box Compressive strength

I. INTRODUCTION

Self-compacting concrete (SCC) is one of the major revolutions in the construction industry since its development in the later years of the 1980s. SCC is the advanced form of normally compacted concrete (NCC)that can effortlessly flow and spread in the thinner and densely reinforced section without any additional vibration. SCC technology can be termed as ‘‘smart concreting construction” which demands less energy and low operatives and supports in faster casting with lower maintenance. It has various benefits over NCC, for instance, reduces labour cost and construction time, provides flexibility in designing, and produces a homogeneous concrete matrix without honeycombing. Further, SCC exhibits superior mechanical performanceas compared to that of NCC due to the betterrefined microstructure contributed by the presence of higher finecontent in SCC.

Granite Industry Scenario

- The use of stone industry waste in the construction industry has gained a lot of interest worldwide. India holds varieties of stones, like, marble, granite, sandstone, limestone, and slate.
- Granite industry is one of the primary stone industries in India. Granite stone is a kind of igneous rock that is formulated through the gradual crystallization of magma existing beneath the earth.
- Granite has been exploited as a building or decorative stone throughout human history due to its inherent hardness and strong characteristic (Mendoza et al., 2014). According to the World Natural Stone Association report, in 2014, worldwide granite stone production accounted for approximately 349 million sqm/year, and India was the third-largest producer nation of granite stone in the world after China and Brazil (WNSA, 2014). As of 1st April 2015, India had a total of 46,320 million cum granite resources (IBM, 2018).
- Unfortunately, more than 30% is currently produced as granite waste (GW) during cutting and polishing of ornamental granite blocks in granite industries (Singh et al., 2017).

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- This residue initially produced in wet slurry form, which is being thrown away inappropriately on the nearby dumping sites as

1) as a waste product.

- It then converts into dry form after some time due to the evaporation of water that becomes airborne, eventually causing health problems and affects the surrounding ecosystem (Ghannam et al., 2016).

Applications of GW

- Soil stabilization
- Ceramic industry
- Tile and bricks manufacturing
- Indoor and outdoor cladding and paving   Desulfurization process
- Thermoset resin composites   Road embankments
- Asphalt Masonry
- Paving blocks
- Cement-based products (mortar, NCC, and SCC)   Polymer-based composite materials

Benefits of utilizing GW in construction

- It decreases the cost of construction products on using GW instead of cement and sand.   It declines the heat of hydration on using GW instead of cement.
- It increases the resistance to external agents on using GW instead of cement and sand.   It enhances strength.
- It minimizes emission of greenhouse gases like CO_2 and NOx etc. in the production of cement clinker on using GW as a replacement of cement.
- It protects the environment by preserving the significant amount of natural mined materials.   It reduces waste disposal cost, which is continuously rising because of landfill tax.
- It opens a new recycling business.

II. METHODOLOGY

The physical and chemical characteristics of different ingredients in the formulation of SCC mixtures have been discussed in this section. Cement, fly ash, fine aggregate, coarse aggregate, granite waste (GW), water and superplasticizer have been used in the formulation of different SCC mixtures. The SCC mixture details and their mixing procedure have been discussed in this section.

- The testing procedures for fresh, mechanical, characteristics have also been discussed in this section.
- Ordinary Portland cement (OPC; Ultratech brand) of 53 grades were used conforming to BIS: 8112 (1989), and its chemical composition and physical properties are presented.

Table 1: Physical Properties of Cement & Fly ash

Physical properties	Cement	Fly ash
Consistency (%)	28	-
Specific gravity	3.16	2.2
Soundness (mm)	1	-
Initial setting time (minute)	41	-
Final setting time (minute)	451	-

Table 2: Chemical composition of Cement & fly Ash

Chemical composition (%)		
CaO	45.88	0.9
SiO_2	31.3	58.19
Al_2O_3	3.49	26.93
Fe_2O_3	3.3	4.27

Na2O	0.22	0.07
K2O	0.69	1.1
MgO	5.21	0.69
P2O5	0.05	0.21
LOI	3.97	0.45

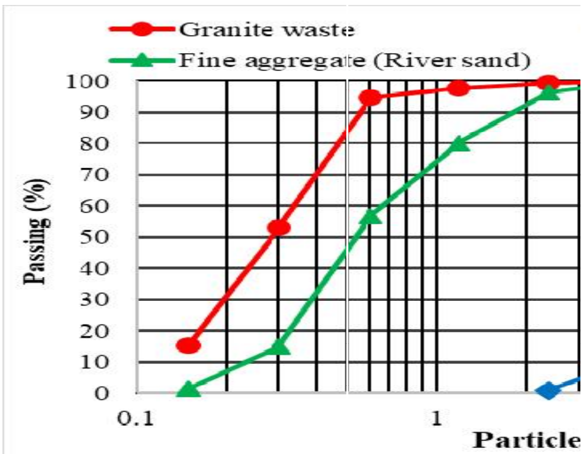

Chart -1: Sieve analysis of aggregates and granite waste

Research plan

The preliminary investigation was carried out for finding the maximum adding percentage of GW and fly ash as a replacement of natural fine aggregate and cement in the successful production of SCC, respectively. For fresh (slump flow, V-funnel time and Lbox), mechanical(compressive strength),characteristics were performed. and the percentage of GW and fly ash was fixed. the comprehensive investigation for fly ash blended SCC (prepared with GW) was carried out by performing fresh, mechanical, characteristics.

Concrete mixture details

For the first phase, three series of SCC mixtures were prepared. SCC mixtures prepared with GW as apartial substitute of fine aggregate in the different percentages of 10,20 and 30%. And fly ash was a partial substitute of cement in the different percentages of 10,20 and 30%. All the SCC mixtures were made by maintaining a fixed binder quantity of 546.79 kg/m^3 and effective water to binder ratio of 0.37. The SP dosagewas adjusted to achieve slump flow in the range of 700 ± 30 mm. Mix design is defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The mix design must consider the environment that the concrete will be in exposure to sea water, trucks, cars, forklifts, foot traffic or extremes of hot and cold. A Mix design was conducted asper IS 10262-2019 to arrive at M 30 mix of SCC.

Testing Procedure

This section addresses the procedure of different tests (fresh, mechanical, durability and microstructure characteristics) which were carried out on SCC mixtures in the fresh and hardened state. Fresh characteristicstests convey the early-age behaviour of concrete mixtures, which is required for proper placement of concretemixtures and ensures its integrity in the fresh state. Whereas, mechanical characteristics tests ensure the performance or integrity of concrete mixture in the hardened state. The procedure of different tests performedon concrete mixtures is discussed below.

Workability

SCC is the advanced type of NCC. The workability of NCC can be determined by performing any oneor two tests like slump, compaction factor, flow table, and vee-bee consistometer, whereas there is no universal test for finding the

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workability of SCC. The SCC must fulfill three characteristics named flowing ability, passing ability, and segregation resistance, for achieving the satisfactory workability of freshly mixed concrete.The aforementioned SCC characteristics can be measured by performing following tests, such as slump flow,V-funnel time, L-box test.

III. RESULTS

Compressive Strength

The compressive strength of the mixes at curing periods of 7 and 28 days, respectively. For all the series and curing durations, the compressive strength initially increased at the 30% replacement level of GW and fly ash the SCC specimens showed comparable strength. The higher or comparable strength up to the 30%replacement level of GW may be attributed to the better filler effect, which was related to the small size and irregular shape of the GW particles.

The smaller size GW particles effectively filled the gaps between the coarser fraction of aggregate particles as well as cement and sand particles.

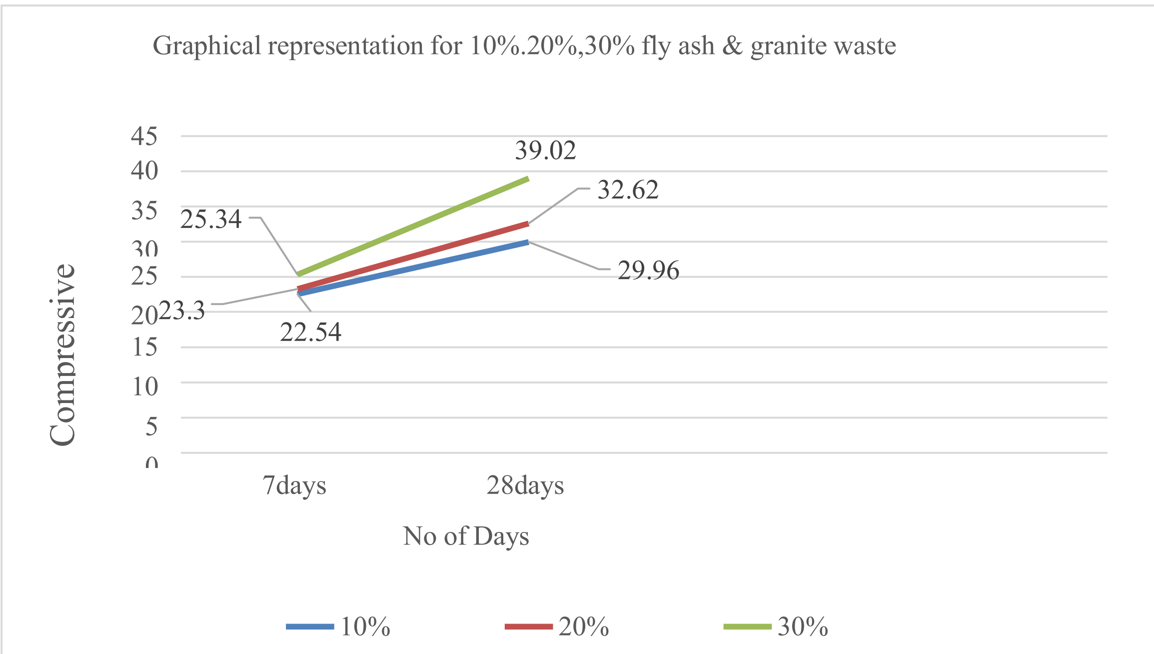

Chart -1: Graphical representation of specimens.

ADVANTAGES OF SCC:

- **Improves Workability**: SCC flows easily and settles into formwork under its own weight without theneed for excessive vibration. This makes it easier to pour and shape, reducing labour and time requirements.
- **Enhanced Finish:** SCC produces a smooth surface finish with fewer imperfections compared to conventional concrete. This is especially beneficial for architectural and decorative applications whereaesthetics is important.
- **Reduced Labor & Equipment Cost**: since SCC doesn't require extensive vibration during pouring, it reduces the need for labour and expensive equipment such as vibrators, which can result in cost savings.
- **Increased Construction Speed:** SCC speeds up construction processes due to its ease of placement and compaction. This can lead to shorter project durations and earlier completion times.

IV. CONCLUSION

This experimental study aimed to explore the feasibility and possibility of partial replacement of cement and fine aggregate by fly ash and granite waste for SCC concrete production. Based on the results of this experimental investigation, following conclusions could be drawn:

Properties of fly ash and granite waste makes it suitable ingredient for replacing in cement and fine aggregate for production of SCC.

- The slump of the concrete increased when the percentage of Fly ash & granite waste increases and decrease as comparison with the conventional concrete. The workability was found to be increasing with increase in the replacement percentage of partial replacement of cement and fine aggregate by fly ash and granite waste for SCC concrete production.
- The average result obtained from 3 various percentage of SCC was 10% for 7 days and 28 days compressive strength values are 22.54 & 29.96 N/mm^2 respectively, 20% for 7 days and 28 days
- compressive strength values are 23.30 & 32.62 N/mm^2 respectively, 30% for 7 days and 28 days compressive strength values are 25.34 &39.02 N/mm^2 respectively.
- The total average compressive strength of 3 various percentage of SCC for 7 days and 28 days are 25.34 &39.02 N/mm^2 respectively.

V. FUTURE SCOPE

- **ENVIRONMENTAL BENEFITS:** Utilizing fly ash and granite waste in SCC production reduces the demand for virgin materials like cement and aggregates, thus conserving natural resources and lowering carbon emissions associated with their extraction and production.
- **WASTE MINIMIZATION:** By incorporating industrial by-products such as fly ash and granite waste into SCC, it helps in reducing the amount of waste sent to landfills, contributing to a more circular economy and sustainable waste management practices.
- **ENHANCED PROPERTIES**: Research and development efforts can focus on optimizing the mix design to improve the mechanical properties, durability, and workability of SCC containing fly ash and granite waste. This can involve experimenting with different proportions, additives, and processing techniques to achieve desired performance standards
- **TECHNOLOGY ADVANCES:** Advances in materials science, nanotechnology, and construction techniques can lead to the development of novel additives, admixtures, and processing methods that enhance the performance and sustainability of SCC containing fly ash and granite waste.

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