# EXPERIMENTAL STUDY ON SELF COMPACTING CONCRETE USING FLYASH AND GGBS AS PARTIAL REPLACEMENT OF CEMENT ALONG WITH CRD AND GSP AS COMPLETE REPLACEMENT OF SAND USING NANSU METHOD OF MIX DESIGN

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**ABSTRACT:**

Sustainability is a global concern and hence the goal of human kind should be to create a sustainable world. In order to achieve sustainability, methods that are to be employed are effective utilization of currently available resources for a prolonged period of time, minimization of wastage of material and controlling overuse, and ensuring that there are reserves kept for future generations without complete exhaustion. But the man's greed has influenced his own self to over – utilize, pollute and destroy the natural resources around him without giving a thought for future generations or for the existence of other species. Hence, the current focus of construction of industry should be to partially or completely replace natural sand in concrete by waste material that is obtained through recycling, without comprising the quality of the end product.

In the recent years, the construction industries have identified some waste materials like fly ash, blast furnace slag, and crushed rock dust and granite slurry powder for use in traditional concrete. Crushed rock dust is a kind waste material that is generated from the stone crushing industry which is abundantly available to the extent of 200 million tons per annum which has landfill disposal problems and health and environmental hazards. The present study is an attempt to experiment on use of Crushed rock dust and Granite slurry powder to replace sand in concrete.

An attempt is made to find the solution for the above using the industrial waste materials like of fly ash, ground granulated blast-furnace slag for the replacement of cement as binders and Fillers can be of Crushed rock dust, granite slurry powder for the replacement to fine aggregate materials. Design of M40 with replacement of fine aggregate with 0%, 20%, 40%, 60% 80% & 100% with filler materials. Mechanical Properties such as compressive strength, tensile strength, flexural strength etc. should be known from the laboratory tests. The results are to be compared with the mix of self-compacting concrete having 100% Sand as fine aggregate.

## I. INTRODUCTION

Self-Compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it for placing in difficult conditions and in sections with congested reinforcement, without vibration. In principle, a self-consolidating concrete must

- ➢ Have a fluidity that allows Self-Compaction without external energy
- ➢ Remain homogeneous in a form during and after the placing process and
- ➢ Flow easily through reinforcement

Self-Consolidating concrete has recently been used in the precast industry and in some commercial applications, however the relatively high material cost still hinders the wide spread use of specialty concrete in various segments of the construction industry, including commercial and residential construction.

Compared with conventional concrete of similar mechanical properties, the material cost of SCC is more due to the relatively high demand of cementation materials chemical admixtures including high-range water reducing admixtures (HRWRA) and viscosity enhancing admixtures (VEA).

As with any new technology, there was clearly a learning curve to overcome, and refinement of the materials and mix proportions used took care to finally achieve optimum performance. In Japan, Self-Compacting concretes are divided into three types according to the composition of the mortar:

- ❖ Powder type
- ❖ Viscosity-modifying agent (stabilizer) type
- ❖ Combination type

For the powder type, a high proportion of fineness produce the necessary mortar volume, while in the stabilizer type, fineness content can be in the range admissible for vibrated concrete. The viscosity required to inhibit segregation will then be adjusted by using a stabilizer. The combination type is created by adding a small amount of stabilizer to the powder type to balance the moisture fluctuations in the manufacturing process.

**ADVANTAGES OF SCC**

At present self - Compacting concrete (SCC) can be classified as an advanced construction material. The SCC as the name suggests, does not require vibrated achieving full compaction. This offers benefits and advantages over conventional concrete.

- Low noise-level in the plants and construction sites.
- Eliminated problems associated with vibration.
- Less labor involved.
- Faster construction.

**NECESSITY FOR NEW STRUCTURAL DESIGN AND CONSTRUCTION SYSTEMS**

Self - compacting concrete saves the cost of vibrating compaction and ensure the compaction of the concrete in the structure. However, total construction cost cannot always be reduced, except in large – scale constructions. This is because conventional construction systems are essentially designed based on the assumption that vibrating compaction of concrete is necessary.

## II LITERATURE REVIEW

- Generally, aggregates occupy 70% to 80% of the volume of concrete and have an natural rock crushed stone, or natural gravels 0 and sands, although, synthetic materials such as slag and expanded clay or shale are used to some extent, mostly in lightweight concretes (Miness et al., 2003).
- In addition to their use as economical filler, aggregates generally provided concrete with better dimensional stability and wear resistance. Although aggregate strength can play sometimes an important role, for example in high strength concretes, for most applications the strength of concrete and mix design are essentially independent of the composition of aggregates. However, in other instances, a certain kind of rock may be required to attain certain concrete properties, ex., high density or low coefficient of thermal expansion (Neville, 1993).
- In order to obtain a good concrete quality, aggregates should be hard and strong, free of undesirable impurities, and chemically stable (Garber and Hoel, 1998). Soft and porous rock can limit strength and wear resistance, and sometimes it may also break down during mixing and adversely affect workability by increasing the amount of fineness.
- Rocks that tend to fracture easily along specific planes can also limit strength and wear resistance (Neville, 1993). Fly ash is one of the most extensively used byproduct materials in the construction field resembling Portland cement (Pfeifer, 1969). It is an inorganic noncombustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace (Halsted, 1986).
- Many class C ashes when exposed to water will hydrate and harden in less than 45 minutes. In concrete, class fly ash is often used at dosages of 15/ to 25% by mass of cementitious material and clss C fly ash is used at dosages of 15% to 40% (Halsted 1986). Dosage varies with the reactivity of the ash and the desired effects on the concrete (Mindless et al., 2003).

## III MATERIALS

**CEMENT**

All types of cement conforming to EN 197 are suitable. Selection of the type of cement will depend on the overall requirements for the concrete, such as strength, durability etc., **$C_3A$** content higher than 10% may cause problems of poor workability retention. The typical content of cement is **350-450 Kg/m$^3$**. More than **500Kg/m$^3$** cement can be dangerous and increase the shrinkage. Less than **350Kg/m$^3$** may only be suitable with the inclusion of other fine filler, such as fly ash pozzolona, etc.,

Ordinary Portland cement of 53 grade from the local market was used and tested for physical and chemical properties as per IS: 4031-1988 and found to be conforming to various specifications as per IS: 12269-1987

**Properties of cement**

**TABLE: TESTS ON CEMENT**

| S.NO. | TEST | RESULTS |
|---|---|---|
| 1 | Normal consistency | 33% |
| 2 | Initial setting time | 39 |
| 3 | Specific gravity | 2.91 |
| 4 | Compressive strength | 53N/ mm$^2$ |

**AGGREGATES**

**FINE AGGREGATE**

All normal concreting sands are suitable for SCC. Either crushed or rounded sand used. Siliceous or calcareous sand used. The amount of fineness less than 0.125 mm is to be considered as powder and is very important for the rheology of the SCC. A minimum amount of fineness (arising from the binders and the sand) must be achieved to avoid segregation.

**TABLE: PHYSICAL PROPERTIES OF CRUSHED ROCK DUST**

| PROPERTY | RESULT |
|---|---|
| Fineness modulus | 2.85 |
| Specific gravity | 2.63 |
| Bulk density (kg/cum) | 1578 |

**COARSE AGGREGATE**

All types of aggregates are suitable. The normal maximum size is generally 10-20 mm. However, particle size up to 20 mm more has been used in SCC. Consistency of grading is of vital importance. Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of the interlocking of the angular particles, whilst rounded aggregates improve the flow because of lower internal friction. Gap graded aggregates are frequently better than those continuously graded, which might experience greater internal friction and give reduced flow.

**FLY ASH**

In the present investigation work, the fly ash used is obtained from RAYALASEEMA THERMAL POWER PLANT, **TADIPATRI**. ANDHRA PRADESH. The specific surface of the fly ash is found to be 4250cm$^2$/gm by blains permeability apparatus and its specific gravity **2.14**.

FLY ASH

**TABLE: CHEMICAL COMPOSITION OF FLY ASH**

| S.NO. | CHARACTERISTICS | % |
|---|---|---|
| 1 | Silica, $SiO_2$ | 49-67 |
| 2 | Alumina | 26-28 |
| | | |
| 3 | Iron oxide | 4-10 |
| 4 | Lime | 0.7-3.6 |
| 5 | Magnesia | 0.3-2.6 |
| 6 | Sulfur oxide | 0.1-2.6 |
| 7 | Surface area $m^2/kg$ | 230-600 |

**GROUND GRANULATED BLAST FURNACE SLAG**

Ground granulated furnace slag (confirming to BS9966) is a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form glassy sand like granulated material. The granulated material when further ground to less than 45 µ will have specific surface of about 400 to 600 $m^2$\kg.hte performance of slag largely depends on the chemical compositions, glass content and fineness of grinding.


**TABLE: PHYSICAL PROPERTIES OF GGBS**

| S.NO. | PROPERTIES | RESULT |
|---|---|---|
| 1 | Specific Gravity | 2.89 |
| 2 | Fineness | 330 |
| 3 | Glass content | 92 |
| 4 | Bulk density | 1100 |
| 5 | Color | Dull white |

**TABLE: CHEMICAL COMPOSITION OF GGBS**

| S.NO. | CONSTITUENTS | REQUIREMENTS (BS:6699) | % CONTENTS |
|---|---|---|---|
| 1 | $SiO_2$ | 32-42 | 33.20 |
| 2 | $Al_2O_3$ | 7.16 | 18.1 |
| 3 | CaO | 32-45 | 41.00 |
| 4 | $Fe_2O_3$ | 0.1-1.5 | 1.3 |
| 5 | MgO | 14 Max | 11.0 |
| 6 | $SO_3$ | 2.5 Max | 1.0 |
| 7 | $CaO/SiO_2$ | 1.4 Max | 1.23 |
| 8 | Loss on ignition | 3 Max | 0.5 |

**SUPERPLASTICIZER**

The Super plasticizer used in concrete mix makes it highly workable for more time with much lesser water quantity. It is observant that with the use of large quantities of finer material (fine aggregate +cement +fly ash) the concrete is much stiff and requires more water for required workability hence in the present investigation SP430 is used as water reducing admixture.

**DOSAGE**

The optimum dosage is best determined by site trails with the concrete mix, which enable the effect of workability as a guide, the rate of addition is in the range of 2.5% of powder value.

**WATER**

This is the least expensive but most important ingredient of concrete the water, which is used for the making of concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc. in general, the water, which is fit for drinking, should be used for making concrete.

**WORKABILITY**

The level of fluidity of the SCC is governed chiefly by the dosing of the super plasticizer. However, overdosing may lead to the risk of segregation and blockage. Consequently, the characteristics of the fresh SCC need to be carefully controlled using preferably two of the different types of test.

**MIX PROPORTIONS**

The ingredients for SCC are similar to other plasticized concrete. It consists of cement, coarse aggregate, fine aggregate, water and mineral and chemical admixtures. No standard or all-encapsulating method for determining mixture proportions currently exists for SCC. However, many different proportion limits have been listed in various publications. Multiple guidelines and “rules of thumb” about mixture proportions for SCC were found.

- **INITIAL MIX COMPOSITION**

In designing the mix, it is most useful to consider the relative proportions of the key components by volume rather than by mass.

➢ Water/Powder ratio by volume of 0.80 to 1.10

➢ Total powder content 160 to 240 liters (400 – 600 kg) per cubic meter.

➢ Coarse aggregate content normally 28 to 35 % by volume of the mix.

➢ Water cement ratio is selected based on requirements in EN 206. Typically, water content does not exceed 200 liter/m3.

➢ The sand content balances the volume of the constituents.

**NANSU MIX DESIGN METHOD FOR SELF COMPACTING CONCRETE**

**MIX DESIGN FOR M40:**

Maximum size of aggregate = 12.5mm
Specific gravity of coarse aggregate= 2.66
Bulk density of coarse aggregate = 1410kg/cum
Specific gravity of fine aggregate = 2.63
Bulk density of fine aggregate = 1578kg/cum
Specific gravity of cement = 2.91
Specific gravity of fly ash = 2.14
Specific gravity of GGBS = 2.89
Super plasticizers = VMA & CONPLAST – SP430
Specific gravity of super plasticizer = 1.1

Air content = 1.5
Packing factor = 1.12

**MIX PROPORTIONS ADOPTED FOR M40 GRADE CONCRETE**

1 Coarse aggregate : 710.64 Kg/$m^3$
2 Fine aggregate : 972.04 Kg/$m^3$
3 Cement content : 348 Kg/$m^3$
4 Total water : 171.449 Kg/$m^3$
5 Fly ash : 89.348 Kg/$m^3$
6 GGBS : 38.292 Kg/$m^3$
7 SP dosage : 8.0 Kg/$m^3$

The mix proportion then becomes

**REPLACEMENT OF FINE AGGREGATE BY CRUSHED ROCK DUST WASTE:**

If 10% of fine aggregate replaced, then weight of CRD = 0.1(30.132) =3.01 kg
If 40% of fine aggregate replacement occurred, then weight of CRD =12.04 kg
If 60% of fine aggregate replacement is done, then weight of CRD = 18.06 kg

**MIXING OF CONCRETE**

In the process of mixing, the materials are weighed with their proportion exactly and then the materials are stacked on a watertight platform the materials are thoroughly mixed in their dry conditions before water is added. The prepared mix was immediately use for testing the work ability of fresh mix.

**CASTING OF TESTING OF SPECIMENS**

After achieving self-compact ability, with the same mix proportions cubes were casted. When tested for their day's strength is achieved is good. Hence, the same proportions cubes, cylinders, beams of standard size were cast and cured for 90 days.

**CURING OF TEST SPECIMEN**

After casting, the moulded specimens are stored in a laboratory at a room temperature for 24 hours. After this period, the specimens are removed from the moulds and immediately submerged in clean, fresh water, of curing water tank. The specimens are cured for 90 days in present investigation work.

**CASTING AND CURING**

Casting is done 9 specimens of cubes and 9 specimens of cylinders.
Curing had been done for 90 days.

**CURING OF CONCRETE CUBES & CYLINDERS**

**STUDY OF HARDENED CONCRETE**

The principles properties of concrete which are of practical importance are those concreting its strength, stress –strain characteristics, shrinkage and creep, deformations, permeability and durability of these strength of the concrete assumes a greater significance because the strength is related to the structure of hardened cement paste and gives an overall picture of the quality of the concrete.

## V EXPERIMENTAL RESULTS

### TESTS CONDUCTED ON SCC SPECIMENS

**COMPRESSIVE STRENGTH OF CONCRETE**

Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen. (Ex 100 mm cube according to ISI), divided by the areas of cross-section in uniaxial compressive under a given rate of loading. The test of compressive strength should be made on 150 mm size cubes.

Place the cube in the compression-testing machine. The green button is pressed to start the electric motor. When the load is applying gradually, the piston is lifted up along with the lower plate and thus the specimen application o the load should be 300 KN per minute and can be controlled by load rate control knob. Ultimate load is noted for each specimen. The release valve is operated and the piston is allowed to go down. The values are tabulated and calculations are done.

**FIG: TESTING OF COMPRESSIVE STRENGTH OF CONCRETE (CTM)**

**TENSILE STRENGTH OF CONCRETE**

**SPLIT TENSILE STRENGTH**

A concrete cylinder of size 150 mm diameter x 300 mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner. The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress.

Horizontal tensile stress = $2P/\pi DL$

Where,

P = Compressive load on the cylinder
L = Length of the cylinder
D = Diameter of the cylinder

**FIG: TESTING OF SPLIT TENSILE STRENGTH OF CONCRETE**

## V RESULTS

**DIFFERENT TRIAL MIXES FOR NATURAL SAND**

| TRIAL MIX | CEMENT | FLYASH | GGBS | SAND | COMPRESSIVE STRENGTH 90DAYS N/MM² FOR SAND | SPLIT CYLINDER TEST 90 DAYS N/MM² FOR SAND | FLEXURAL TEST 90DAYS N/MM² FOR SAND |
|---|---|---|---|---|---|---|---|
| M1 | 100 | 0 | 0 | 100 | 42.54 | 2.12 | 4.22 |
| M2 | 93 | 5 | 2 | 100 | 44.41 | 2.33 | 4.35 |
| M3 | 86 | 10 | 4 | 100 | 48.64 | 2.48 | 4.82 |
| M4 | 80 | 15 | 5 | 100 | 49.53 | 2.53 | 4.89 |
| M5 | 79 | 15 | 6 | 100 | 49.23 | 2.42 | 4.78 |


**DIFFERENT TRAIL MIXES FOR NATURAL SAND**

**COMPRESSIVE STRENGTH OF CUBES**

**TABLE: COMPRESSIVE STRENGTH OF CUBES OF GSP & CRD FOR 90 DAYS**

The different combinations of granite slurry powder and Crushed rock dust used in SCC test.

| TRIAL MIX | CEMENT (%) | FLY ASH (%) | GGBS (%) | FINE AGGREGATE (%) | | | LOAD (KN) | COMPRESSIVE STRENGTH (N/MM²) | AVERAGE STRENGTH (N/MM²) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | SAND | CRD | GSP | | | |
| M1 | 80 | 15 | 5 | 100 | 0 | 0 | 1110<br>1120 | 49.31<br>49.75 | 49.53 |
| M2 | 80 | 15 | 5 | 0 | 80 | 20 | 960<br>970 | 42.87<br>43.11 | 42.87 |
| M3 | 80 | 15 | 5 | 0 | 60 | 40 | 1100<br>1080 | 48.88<br>48.80 | 48.54 |
| M4 | 80 | 15 | 5 | 0 | 40 | 60 | 920<br>900 | 40.88<br>40.02 | 40.45 |

**SPLIT TENSILE STRENGTH OF CYLINDERS**

**TABLE: SPLIT TENSILE STRENGTH OF CYLINDERS OF GSP & CRD FOR 90 DAYS**

The different combinations of granite slurry powder and Crushed rock dust used in SCC test.

| TRIAL MIX | CEMENT (%) | FLY ASH (%) | GGBS (%) | FINE AGGREGATE (%) | | | SPLIT CYLINDER TEST 90DAYS (N/MM²) |
|---|---|---|---|---|---|---|---|
| | | | | SAND | CRD | GSP | |
| M1 | 80 | 15 | 5 | 100 | 0 | 0 | 2.53 |
| M2 | 80 | 15 | 5 | 0 | 80 | 20 | 1.52 |
| M3 | 80 | 15 | 5 | 0 | 60 | 40 | 2.48 |
| M4 | 80 | 15 | 5 | 0 | 40 | 60 | 1.65 |

**FLEXURAL TEST OF BEAMS**

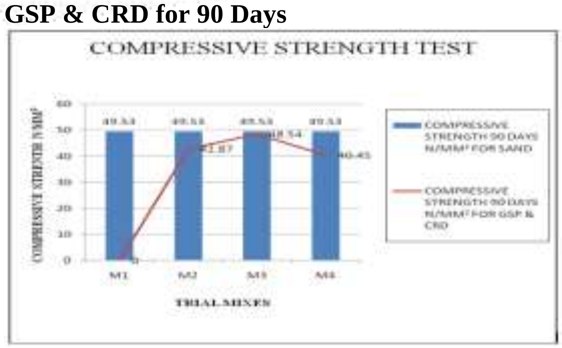
**TABLE: FLEXURAL STRENGTH OF BEAMS OF GSP & CRD FOR 90 DAYS**

The different combinations of granite slurry powder and Crushed rock dust used in SCC test.

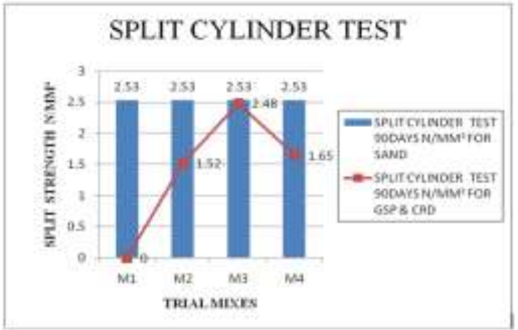
| TRIAL MIX | CEMENT (%) | FLY AS H (%) | GGBS (%) | FINE AGGREGATE (%) | | | FLEXURAL TEST 90DAYS (N/MM²) |
|---|---|---|---|---|---|---|---|
| | | | | SAND | CRD | GSP | |
| M1 | 80 | 15 | 5 | 100 | 0 | 0 | 4.89 |
| M2 | 80 | 15 | 5 | 0 | 80 | 20 | 4.03 |
| M3 | 80 | 15 | 5 | 0 | 60 | 40 | 4.82 |
| M4 | 80 | 15 | 5 | 0 | 40 | 60 | 4.41 |

**GRAPH**

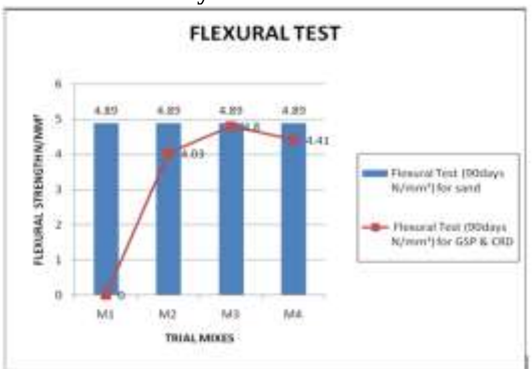
**Compressive strength of SCC for different Combinations of GSP & CRD for 90 Days**




**Split Tensile strength of SCC for different combinations of GSP & CRD for 90 days**




**Flexural strength of SCC for different combinations of GSP & CRD for 90 days**




**CONCLUSION:**

All the experimental data shows that the addition of the industrial waste improves the physical and mechanical properties. These results are of great importance because this kind of innovative concrete (Green concrete) requires large amount of fine particles. Due to its high fines of the granite, powder it provided to be very effective in assuring very good cohesiveness of concrete. From the above study, it is concluded that the crushed rock dust and granite slurry powder may be used as a replacement material for fine aggregate.

- The replacement of fine aggregate with 60% Crushed Rock Dust(CRD) and 40% Granite Slurry Powder (GSP) gives very good result in strength aspect and quality aspect. The result showed that the M3 mix induced higher compressive strength, split tensile strength and flexure strength.
- Increase in GSP more than 40%, the workability affects forming more lumps during the preparation of mix.
- Green concrete induced higher workability and it satisfy the self-compacting concrete performance, which is slump flow, is 680 mm without affecting the strength of concrete. Slump flow increases with increase of GSP content. V-Funnel time decreases with increase of GSP.
- Test results shows that these industrial wastes (Fly Ash, Ground Granulated Blast Furnace Slag, Crushed Rock Dust and Granite Slurry Powder) are capable of improving hardened concrete performance.
- Green concrete enhancing fresh concrete behavior and can be used in architectural concrete mixers containing white cement.
- The combined use of crushed rock dust and granite slurry powder exhibited excellent performance due to efficient micro filling ability and use of fly ash and ground granulated blast furnace slag (GGBS) improved pozzolanic activity.

Therefore, the result of this study provides a strong recommendation for the use of fly ash (15%), GGBS (5%) as replacement for binding material in concrete & also mixture of CRD (60%), GSP (40%) as 100% replacement to fine aggregate in concrete manufacturing.

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