AN EXPERIMENTAL INVESTIGATION ON PROPERTIES OF HIGH STRENGTH

SELF- COMPACTING CONCRETE MIXES

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ABSTRACT
Concrete is widely used material in various construction works, due to its excellent performance by means of durability, low cost, easily mould into any shape and size etc. to fulfill the increasing requirements in the construction industries. Self - Compacting Concrete (SCC) has the property to place and compact under its own self weight without any vibration and segregation. SCC gives better compaction, effectively covers reinforcement, reduces the cost on machinery and formwork by this it is extensively minimizing the noise pollution. The method of preparing high strength concrete is a flourishing technology in construction industry especially in precast construction. In India, industries discharge large quantities of waste materials during the production of various products. The safe disposal of these waste materials from industry need more land area and simultaneously it is affecting the environment. Such type of waste materials from the industries can be effectively used in making concrete. In the earlier research, industrial waste materials as by products are utilized to form mineral admixtures in replacement of the cement in various applications of concrete structures. In present days, there is a greatest shortage for getting natural river sand to meet out the construction needs. It has made a novel attempt to replace the fine aggregate by using mineral admixtures. The literature evidences that the SCC is made by adding various mineral admixtures as a substitute for cement and also maintain low water cement ratio for getting early strength.

KEYWORDS: Cement, GGBS, Silica fume and Made Sand Compressive Strength, Split Tensile Strength and Flexural Strength.

1. INTRODUCTION

Concrete is widely used material in various construction works, due to its excellent performance by means of durability, low cost, easily mould into any shape and size etc. to fulfill the increasing requirements in the construction industries. Self - Compacting Concrete (SCC) has the property to place and compact under its own self weight without any vibration and segregation. SCC gives better compaction, effectively covers reinforcement, reduces the cost on machinery and formwork by this it is extensively minimizing the noise pollution. The method of preparing high strength concrete is a flourishing technology in construction industry especially in precast construction. In India, industries discharge large quantities of waste materials during the production of various products. The safe disposal of these waste materials from industry need more land area and simultaneously it is affecting the environment. Such type of waste materials from the industries can be effectively used in making concrete. In the earlier research, industrial waste materials as by products are utilized to form mineral admixtures in replacement of the cement in various applications of concrete structures. In present days, there is a greatest shortage for getting natural river sand to meet out the construction needs. It has made a novel attempt to replace the fine aggregate by using mineral admixtures. The literature evidences that the SCC is made by adding various mineral admixtures as a substitute for cement and also maintain low water cement ratio for getting early strength.

2. Role of fly ash (FA), Ground Granular Blast

Furnace Slag (GGBS) and Silica Fume (SF)

In Concrete Fly ash is an ash obtained from the combustion of coal in thermal power plants. It consists of the very fine particles and it is collected from electrostatic precipitator when the ash rises upward. The ash which settles down at the bottom is called as pond ash. Fly ash and pond ash together is referred as coal ash. Fly ash is generally of two major types class C and class F. In the past, fly ash was released into the atmosphere directly, but in the recent days various measures are taken to control flue emission before it is been released into the atmosphere. The applications of fly ash are to reduce crack problems, permeability, bleeding and heat of hydration, produce lower water/cement ratio for similar slumps and also to reduce CO_2 emissions.

GGBS is an inorganic pozzolanic material that has emerged as a new engineering material to replace the conventional Portland Cement (PC). It is an eco friendly material and it promotes sustainable construction and it also reduces the environmental pollution problems. The presence of GGBS in the concrete mix will improve workability property and makes the mix more mobile and cohesive in nature. This is mainly because of the dispersing property and surface characteristics of GGBS particles. The greater fineness of GGBS reduces bleeding of concrete. The mix containing GGBS has very low penetrability, excellent resistance to chloride penetration and it also reduces the freeze and thaw effect.

Silica fume is a pozzolanic material which is obtained from the ferro silicon industry. The specific gravity of silica fume is generally lower than the specific gravity of OPC. The particles of silica fume are spherical in shape and the particle size is ultrafine in nature, usually having diameter in the range of 0.03µm to 0.3µm. For such very fine particles specific surface area cannot be found by using the Blaine method. Nitrogen adsorption method can be used to find the specific surface area of very finer materials. Specific surface area is approximately 20 times much higher when compared to specific surface area of other materials.

SELF - COMPACTING CONCRETE

- Self Compacting Concrete is the ability to compact by itself under the action of gravitational force or by its own self weight without vibration and without bleeding and segregation.Useful for low cost housing and partition wall.
- SCC will take up the shape of any complicated formwork without any pores and it will permit entry of air and it also effectively covers the reinforcement.
- The utilization of binder, which is an inorganic binder, emerged as a new engineering material to replace the conventional fine aggregate.
- Water proofing in rooftops, sunken toilets etc.
- Interior works and decorative works etc.
- Producing economic concrete by reducing the cost of material.

3. SCOPE AND OBJECTIVE

The main objective of the present work is to develop structural concrete using silica fume (SF), flyash(FA) as coarse aggregate, manufactured sand (M-sand) as fine aggregate, and ground granulated blast furnace slag (GGBFS) as pozzolan.

4. SCOPE OF PROPOSAL WORK

- Numerous studies were carried out to assess the suitability of using mineral admixtures as replacement for cement in SCC. Only limited research conducted in the utilization of fly ash, silica fume and GGBS as a replacement for fine aggregate in HSSCC to improve its properties.
- To evaluate the flexure, shear, and compressive behavior of reinforced CSC.
- To find the bond strength between CSC and steel.
- To assess the durability properties like water absorption, the volume of permeable pores, sorptivity, and temperature resistance of CSC.

5. METHODOLOGY

- Tested the material properties as per IS code procedures.
- Mix design for concrete proportion was arrived at as per IS- 10262- 1982.
- The properties of fresh concrete were determined as per IS- 1199- 1959.
- The concrete specimens were casted and cured as per IS procedures.
- Tests were conducted on hardened concrete to determine various strength parameters.
- Various durability tests were conducted as per standard codes.
- Finally results were compared with conventional concrete and partial replacement concrete mixed with ground granular blast furnace slag and other materials and conclusions were arrived at.

6. LITERATURE REVIEW

Self -Compacting Concrete (SCC) is concrete which flows and can compact under its own weight. The highly fluid behaviour of SCC makes it suitable for placing under challenging conditions and in the section with congested reinforcement. Usage of SCC provides benefits in improving the construction efficiency and minimizing overall cost including man, material and equipment's etc.It is utilized when there is a lack of labour, and also helps in achieving the better surface finish and compaction. Such innovative concrete requires high slump which can be produced by the addition of chemical admixture like super plasticizers. To avoid segregation, the fine aggregate content is increased by 4% to 5% and for the flow ability property volume of cement content is also increased which leads to improving in cost, besides resulting in undesirable temperature rise.

Nadine Hani et al. (2018) carried out the study of effect of increasing water/binder ratio on the raw and hardened properties of SCC containing nano-silica with different dosages, focusing on the mixes with high w/b ratios that are produced in the field in places with hot weather with three different water/binder (w/b) ratios of 0.41, 0.45 and 0.5 and 0%, 0.25%, 0.5% and 0.75% (by weight) replacement of cement by nano-silica.Self compacting concrete was examined concerning fresh state properties and hardened stateand also with Scanning Electron Microscope (SEM) examinations. It was reported that the effect of a nano-silica dosage on compressive strength of concrete with high w/b is greater than that on concrete with low water-binder ratio.

Elias Molaei Raisi *et al.* (2018) carried out an experimental investigation on Mechanical performance of SCC incorporating rice husk ash. The behavior of SCC was studied in hardened state with the partial replacement of cement with RHA (0%, 5%, 10%, 15% and 20%), concrete aged (3, 7, 28, 90, 180, and 270 days), and water to binder ratio (0.38, 0.44,0.50, 0.56, 0.62 and 0.68). Fresh concrete properties were measured by V-funnel flow time, L-box, and slump flow diameter and time tests. Mechanical properties were determined in terms of compressive strength, modulus of elasticity, splitting tensile strength, and compressive stress-strain relationship tests. From the test results, it showed that the workability of SCC containing RHA is decreased by increasing the RHA replacement ratio.

Chinmaya Kumar Mahapatra *et al.* (2018) investigated on the utilization of fly ash and colloidal nano silica in Hybrid fiber reinforced SCC. The study investigated on the properties of Hybrid Fiber Reinforced Self Compacting Concrete (HyFRSCC) with Crimped Steel Fibers (CSF) and Polypropylene Fibers (PPF) along with class F Fly Ash (FA) and Colloidal Nano Silica (CNS). The combination of 10% FA, 0.4% CNS, 1.25% CSF and 0.167% PPF found to be optimal recommendation. Multiple linear regression analysis predicts equations of tensile strength as the function of cylinder compressive strength, for combination of FA, CNS, CSF and PPF. A good correlation between tested and predicted values is obtained.

Alireza Habibi*et al.* (2018) made investigation in the development of an optimum mix design method for self compacting concrete based on experimental results. The focus of manufacturing costs of concrete, the total cost of one cubic meter of SCC is assigned as the objective function in the optimization problem, which must be minimized. To verify the proposed method, the mix design problem is solved for several case studies and then the final optimal mix designs are made in laboratory and mechanical properties of specimens are determined. The results showed that the proposed method satisfies the mechanical characteristics of the self compacting concrete and also it minimizes the cost of the concrete.

Anhad Singh Gill *et al.* (2017) studied on the Strength and micro- structural properties of SCC containing Metakaolin and rice husk ash as a mineral admixture was studied experimentally with weight fractions of 5, 10 and 15% by Metakaolin and fine aggregates were replaced by Rice husk ash in percentage of 10, 20 and 30.The fresh and mechanical properties are found up to 365 days. They concluded that, experimental results it is observed that SCC mixes produced with Metakaolin, Rice husk ash and in combo of MK & RHA fulfill the guidelines of EFNARC. The compressive and cylinder split tensile strength results were also found to be positive.

Stefania Manzi et al. (2017) investigated on the SCC with recycled concrete aggregate and also to study its long-term properties. From the results, it is inferred that self compacting characteristics are maintained when recycled aggregates are utilized and their good quality promotes high mechanical properties. The creep and pores size distributions are more affected by the content and assortment of recycled aggregates, although their effect is more limited compared to what occurs in conventional concrete with recycled aggregates.

Dinesh *et al.* (2017) conducted an experimental study on SCC where the cement is partially replaced with fly-ash and silica fume. In the SCC mix, Ordinary Portland Cement was replaced with 5%, 10%, 15%, 20% and 25% of fly-ash and 2.5%, 5%, 7.5%, 10% and 12.5% of silica fume. From the experimental investigations, it was concluded that there was tremendous increase in the fresh properties and hardened properties of the SCC mix for replacement of silica fume and also pointed out minimizing the environmental hazards. It was concluded that there was a reduction in strength due to the use of fly ash as it develops later strength and increase in strength is found due to the use of silica fume in concrete.

Vengadesh Marshall Raman *et al.* (2017) carried out research work in the partial Replacement of Cement with GGBS in SCC for sustainable construction. GGBS can be used as a filler and it helps in reducing the total void content in self compacting concrete. Fly ash level is maintained constant for all mix combinations to increase the powder content for achieve theWorkability. From the iterative trial mixes the water/cement ratio (w/c) was fixed as 0.40. SCC mixtures produced, tested and compared in terms of compressive, split tensile strength and flexural strength with the conventional concrete at the age of 7,14 and 28 days and concluded the role of mineral admixtures are improves the mechanical properties.

Saranya (2017) studied on the possibility of utilizing various industrial by-products like Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash (FA) in the preparation of SCC. The experimental study aimed in producing SCC mixes of M30 grade by adopting various mix proportions, using two mineral admixtures as fly Ash and GGBS. It was ete properties had strength is observed to decrease by the inclusion of fly ash and GGBS. It was also found that the split tensile strength increases with the addition of GGBS up to 50% after that it decreases.

7. MATERIALS USED AND THEIR PROPERTIES

Various materials used for the experimental study are the following:

GGBS:

Ground granulated blast furnace slag (GGBS) is a by-product of the blast furnaces used to make iron. Blast-furnaces are fed with a controlled mixture of iron-ore, coke, and limestone, and operated at a temperature of about 1,500°C. When iron-ore, coke, and limestone melt in the blast furnace, two products are produced-molten iron and molten slag. The molten slag is lighter and floats on the top of the molten iron. The molten slag comprises mostly silicates and alumina from the original iron ore, combined with some oxides from the limestone. The process of granulating the slag involves cooling molten slag through high-pressure water jets. This rapidly quenches the slag and forms granular particles generally not bigger than 5 mm. The rapid cooling prevents the formation of larger crystals, and the resulting granular material comprises around 95% non-crystalline calcium-aluminosilicates. The granulated slag is further processed by drying and then grinding in a rotating ball mill to a very fine powder, which is GGBS.

Fig-1 GGBS

SILICA FUME :

Silica fume was obtained from Elkem (Mumbai, Maharashtra, India) was used in this investigation. The sample of the silica fume is the procured silica fume conforms to ASTM-1240 standard. The physical properties of silica fume.

Fig 2 SILICA FUME

Table: 1 Physical propertice of Silica Fume

S.	Test	Unit	Results
1	Particle size	µ	2
2	Specific gravity	-	2
3	Specific Area	$m^2/$	2

Table: 2 Chemical composition of Silica Fume

S. No.	Chemical composition	Result Obtained
1	Silicon di oxide (SiO_2)	9.34
2	Aluminium Oxide (Al_2O_3)	5.0
3	Ferric oxide (Fe_2O_3)	3.0
4	Calcium Oxide (CaO)	0.7
5	Sodium oxide (Na_2O)	0.5
6	Potassium oxide (K_2O)	0.9

CEMENT*:*

Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of silicates and aluminates oflime obtained from limestone and clay. There are different types of cement, out of that I have used two types i.e.

- Ordinary Portland cement
- Portland slag cement

Ordinary port land cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is of three types, 33 grades, 43 grade, 53 grade. One of the important benefits is the faster rate of development of strength. Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens.

The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates. The Basic composition of cement is provided in table. In the present work 53 grade cement was used for casting cubes and cylinders. The cement was uniform color i.e. grey with a light greenish shade and was free from any hard lumps.

Table: 2 Composition limits of Portland cement

Ingredient	Percentage Content
CaO (Lime)	60 – 67
SiO_2 (Silica)	17 – 25
Al_2O_3(Alumina)	3- 8
Fe_2O_3 (Iron Oxide)	0.5 – 6
MgO (Magnesia)	0.1 – 4
Alkalies	0.4 - 1.3
Sulphur	1 – 3

(Reference: Book concrete technology M.S Shetty)

AGGREGATES:

Aggregate properties greatly influence the behavior of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as

Fine aggregates

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge. Usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as a fine aggregate. The sand used for the experimental works was locally procured and conformed to grading zone III. Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS383-1970 and results are provided in Table .The sand was first sieved through 4.75mm sieve to remove any particle greater than 4.75 mm sieve and then was washed to remove the dust. According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV.

Coarse aggregates

The materials which are retained on a 4.75mm sieve are called coarse aggregate. Coarse aggregate forms the main matrix of the concrete. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20 mm was used in the present work.

Sieve analysis of coarse aggregates used was carried out and results are provided in table.

WATER:

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Potable water is generally considered satisfactory. In the present investigation, tap water was used for both mixing and curing purposes.

MATERIAL PROPERTIES

Cement :

Ordinary Portland Cement of Ultra tech brand of 60 grade confirming to IS: 12269-1987 was used in the present study. The properties of cement are shown below:

Table: 3 Physical properties of cement

Properties	Values
Specific gravity	3.14
Normal consistency	29%
Initial setting	40 mins
Fineness	5%

Fine Aggregate:

M sand as per IS: 383-1987 was used. The properties are:

Table: 4 Physical properties of fine aggregates

Characteristics	Value
Type	River sand
Specific gravity	2.56
Fineness modulus	2.96
Grading zone	II

Coarse Aggregate:

Crushed aggregate confirming to IS: 383-1987 was used.

Table: 5 Properties of coarse aggregates

Characteristics	Value
Type	Crushed
Specific gravity	2.60
Maximum size	20mm
Fineness modulus	6.69
Crushing value (%)	34
Gradation	Well

GGBS:

Table : 7 Physical properties of GGBS

Properties	Values
Specific gravity	2.85
Partical size	0 to 100 mm
Specific area	625

SUPER PLASTICIZER:

In this investigation, a locally available super plasticizer conplast SP430 was used, which is Sulphonated Naphthalene based. The properties of Super plasticizer.

Table : 7 Properties of Super Plastizer

S.No	Test Particulars	Remarks
1	Type	Sulphonated naphthalene based
2	Specific gravity	1.220 to 1.300 at 30°
3	Recommended Dosage	0.60 – 1.5 lit per 100 kg of cement
4	Solid Content	40%
5	Workability	High Workability
6	Cohesion	Minimizing Segregation
7	Durability	Increase in density and impermeability

8. EXPERIMENTAL PROGRAMMES

Mix design

The mix design calculations are dependent on the properties of the constituent materials.The first objective is to achieve the stipulated minimum strength.The second objective is to make the concrete in the most economical Manner. Cost wise all concrete's depends primarily on two factors, namely cost of material and cost of labor. Labor cost, by way of formwork, batching, mixing, transporting and curing is namely same for good concrete. It is defined as the process of selecting suitable ingredients of concrete and determining of concrete and determining their relative propositions with the object of producing concrete of certain minimum strength and durability as economically as possible.

MIX PROPORTION FOR M25 GRADE CONCRETE

There is no standard method of designing concrete mixes incorporating. Hence the method of mix design proposed by IS 10262 – 1982 was employed to design the conventional concrete and coconut shell concrete to obtain the mixes. The purpose of mix propositioning is to produce the required properties in both plastic and hardened concrete.

Water	Cement	Fine aggregate	Coarse aggregate
193.44 Kg/m^3	387 Kg/m^3	831 Kg/m^3	1089 Kg/m^3
0.50	1	2.21	2.67

Table 8: Mix proportion for M25

TESTS ON FRESH CONCRETE

- Compaction Factor Test
- Sump cone test

TESTS ON HARDENED CONCRETE:

- Compressive strength
- Split tensile strength
- Flexural strength test

9. TESTS RESULTS AND DISCUSSIONS

TESTS ON HARDENED CONCRETE

Compressive strength results:

The compressive strength of concrete is one of the most important and useful properties of concrete. At least three cubes of 150mm x 150mm x 150mm are casted for each age 7,14&28 days.

Table: 9 Compressive strength of cubes at 7 days

Sl. No.	Mix % of FA+SF+ GGBS	Days	Area of Cube (N/mm^2)	Load KN	Compressive Strength (N/mm^2)
1	5 %	7 days	150mmx150mm (22500 mm^2)	455.00	20.22
2	10 %			465.00	20.67
3	15 %			477.50	21.20
4	20 %			495.00	22.00

Table: 10 Compressive strength of cubes at 14 days

Sl. No.	Mix % of FA+SF+ GGBS	Days	Area of Cube (N/mm^2)	Load KN	Compressive Strength (N/mm^2)
1	5 %	14 Days	150mmx150mm (22500 mm^2)	555.00	24.67
2	10 %			587.50	26.11
3	15 %			611.25	27.17
4	20 %			640.00	28.44

Table: 11 Compressive strength of cubes at 28 days

Sl. No.	Mix % of FA+SF+ GGBS	Days	Area of Cube (N/mm^2)	Load KN	Compressive Strength (N/mm^2)
1	5 %	28 Days	150mmx150mm (22500 mm^2)	715.00	31.77
2	10 %			725.00	32.22
3	15 %			747.50	33.22
4	20 %			755.00	33.55

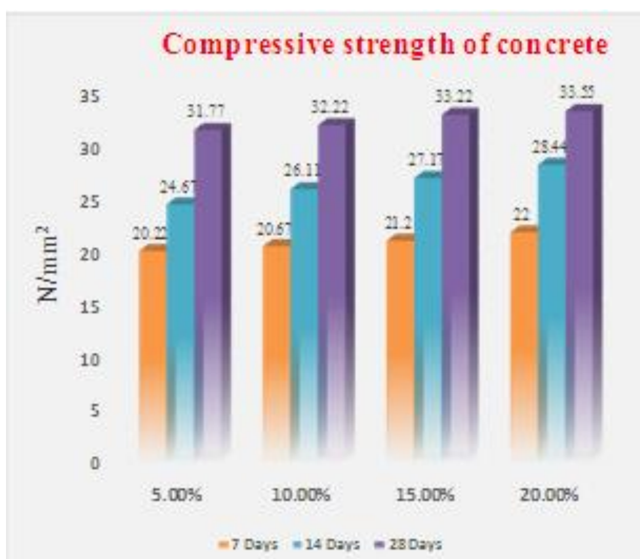

Fig: 3Effect on compressive strength of concrete

Split Tensile Strength results:

(Area of cylinder 150mm x 300mm)

Table: 12 Split tensile Strength at 7 days

Sl. No.	Mix % of FA+SF+ GGBS	Days	πld 1 x 10^3 (mm^2)	Load KN	Split Tensile Strength (N/mm^2)
1	5 %	7 Days	150mmx300mm	147.50	2.09
2	10 %		(141.40 mm^2)	150.00	2.12
3	15 %			155.00	2.19
4	20 %			162.50	2.30

Table: 13 Split tensile Strength at 14 days

Sl. No.	Mix % of FA+SF+ GGBS	Days	πld 1 x 10^3 (mm^2)	Load KN	Split Tensile Strength (N/mm^2)
1	5 %	14 Days	150mmx300mm (141.40 mm^2)	210.00	2.97
2	10 %			226.25	3.20
3	15 %			230.00	3.25
4	20 %			237.50	3.36

Table: 14 Split tensile Strength at 28 days

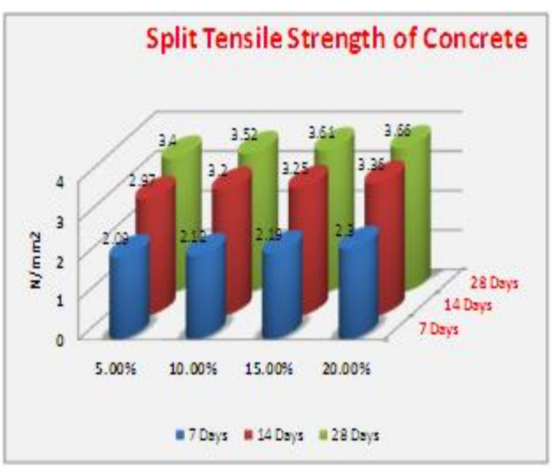

Fig: 4 Effect on Split tensile strength of concrete

Fig 5 Split tensile test

Flexural Strength results:

(Area of flexure 15cm x 15 cm x 70cm)

Table:15 Flexural Strength at 7 days

Sl. No.	Mix % of FA+SF+ GGBS	Days	bd^2 1 x 10^6 (mm^3))	Load KN	Flexural Strength (N/mm^2)
1	5 %	7 Days	15cm x 15cm x 70cm (3.375)	21.25	3.78
2	10 %			23.75	4.22
3	15 %			26.25	4.67
4	20 %			25.00	4.44

Table 16 Flexural strength at 14 days

Sl. No.	Mix % of FA+SF+ GGBS	Days	bd^2 1 x 10^6 (mm^3)	Load KN	Flexural Strength (N/mm^2)
1	5 %	14 Days	15cm x 15cm x 70cm (3.375)	33.00	5.87
2	10 %			35.00	6.22
3	15 %			36.875	6.55
4	20 %			39.375	7.00

Table 17 Flexural strength at 28 days

Sl. No.	Mix % of FA+SF+ GGBS	Days	bd² 1 x 10⁶ (mm³)	Load KN	Flexural Strength (N/mm²)
1	5 %	28 Days	15cm x 15cm x 70cm (3.375)	3.375	6.44
2	10 %			3.375	6.90
3	15 %			3.375	7.33
4	20 %			3.375	7.67

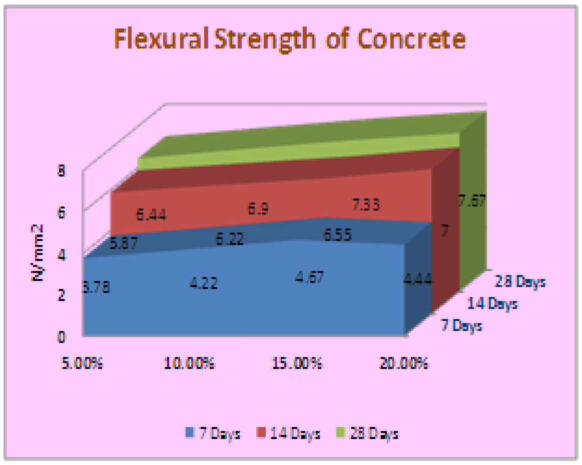

Fig: 6 Effect on Flexural strength of concrete

Fig 7 Flexural strength test

10.NUMERICAL ANALYSIS

ANSYS is a finite element program. We have used ANSYS 2012 in this research to obtain the behavior of the tested beams. A graphical user interface was used for creating models. The different tasks and entries are described here which are used to create the finite element model.

ANSYS RESULTS

Defelection of Various of Beam from Numerical Analyses

10.1 Flexural Strength of Beam with M60 Grade of FA+SF+GGBS 5% Concrete (28 Days) (M1)

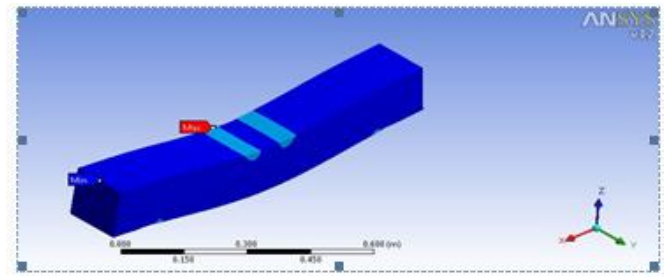

Fig 8 Conventional Concrete Beam Stress (M1)

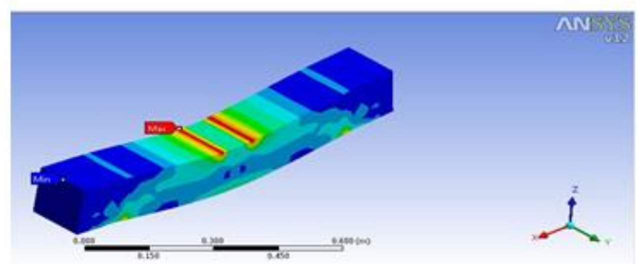

Fig 9 Conventional Concrete Beam Strain (M1)

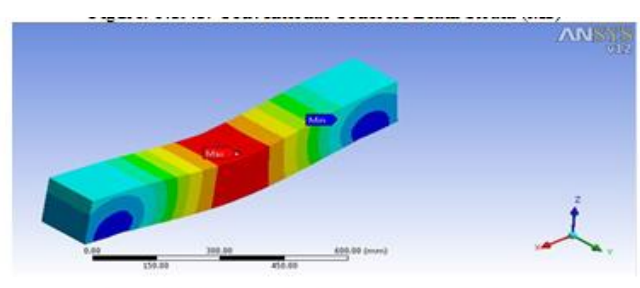

Fig 10 Conventional Concrete Beam Strain (M3)

10.2 Flexural Strength of Beam with M60 Grade of FA+SF+GGBS 20% Concrete (28 Days) (M4)

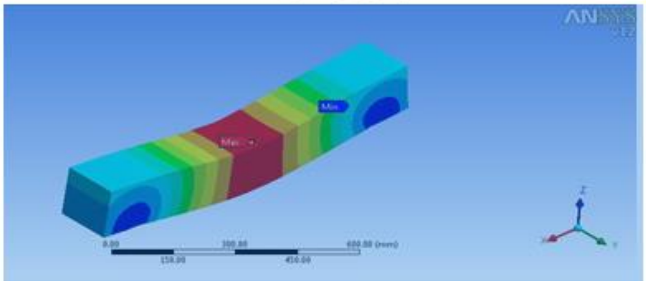

Fig12 Conventional Concrete Beame Deformation Strain (M4)

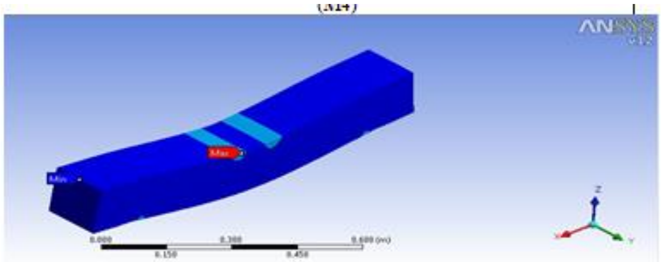

Fig12 Conventional Concrete Beam Stress(M4)

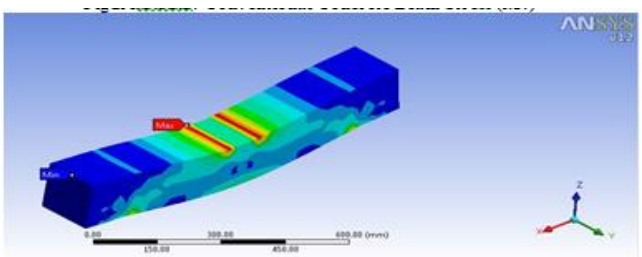

Fig 13 Conventional Concrete Beam Strain(M4)

11. CONCLUSIONS

- Adding FA+SF+GGBS in concrete will increase the ductile behaviour of concrete. So that tensile strength will increase.
- The compressive strength, split tensile strength, flexural strength of concrete will increase by percentage of FA+SF+GGBS adding 5%, 10%, 15% & 20%.
- The experimental investigations on the specimen with 5% FA+SF+GGBS addition give better compressive strength of 1.01% increased, split tensile strength of 1.03% increased, and flexural strength of 1.07%. When compared to conventional concrete.
- The experimental investigations on the specimen with 10% FA+SF+GGBS addition give better compressive strength of 1.04% increased, split tensile strength of 1.06% increased, and flexural strength of 1.14%. When compared to conventional concrete.
- The experimental investigations on the specimen with 20% FA+SF+GGBS addition give better compressive strength of 1.06% increased, split tensile strength of 1.08% increased, and flexural strength of 1.20%. When compared to conventional concrete.`
- The percentage absorption of water in a coconut shell is more as compared to the natural and fine aggregate.
- The slump value of concrete as we increase the percentage of coconut shell firstly decreases up to 10% and then increases up to 15% replacement.
- The slump value decreases as we increase the percentage of m-sand from 10% to 15%
- The various properties of hardened concrete that are compressive strength test, flexural strength test and split tensile strength test decreases as we increase the percentage of FA+SF+GGBS
- Keeping a constant percentage of coconut shell as we increased the percentage of m-sand in the concrete then strength properties increases and reach approximately to value of conventional concrete.
- Up to 15% of aggregate replaced by FA+SF+GGBS is good according to strength and cost-wise.
- An increase in percentage replacements by FA+SF+GGBS reduced the strength and density of concrete.
- It helps in reducing up to15% pollution in the environment.
- It is concluded that the FA+SF+GGBS are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production.
- Trying to replace aggregate with coconut shell partially to make the concrete structure more economic along with good

strength criteria.

- From one cube calculation, the bulk amount of shell replacement can be evaluated & reduces overall construction cost.
- This can be useful for the construction of a low-cost housing society
- Solves problems of disposal of FA+SF+GGBS
- The slump of concrete increases as the percentage of FA+SF+GGBS increases.
- It leads to sustainable development.
- Continuous extraction of aggregate from rocks will lead to its depletion.

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