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EXPERIMENTAL STUDY ON FLEXURAL BEHAVIOUR AND LOAD CARRYING CAPACITY OF LIGHT WEIGHT SELF-COMPACTING CONCRETE WITH WALNUT SHELL AS COARSE AGGREGATE

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Abstract - *In recent decades, the application of self-compacting concrete (SCC) has arise in construction structures because of its high qualities to improve durability and decrease bleeding with good bonding with rebar. Besides, large amount of aggregates is required for the production of SCC. On the other hand, replacement of natural aggregate in SCC with waste materials can led to introduce ecological building materials. Walnut shell (WS) is one of the natural and agriculture waste materials which can be used as a replacement for aggregate in SCC. In this research, WS was used as a substituent for coarse aggregate and flyash as mineral admixture for constructing SCC by volume fractions of WS is 35%. The optimum percentage of flyash content is considered for the research. Fresh and hardened properties of SCC as well as lightweight self- compacting concrete (LWSCC) were investigated for the test mix and control one. The results showed that all tested properties have similar results of conventional SCC for flyash. However; the LWSCC can get good compressive strength for volume fraction of WS equal or more than 35%. Where, slump flow diameter (SFD), compressive strengths and split tensile strength for flyash were 560 mm, 34 MPa and 3.22 MPa respectively achieved at 35% ratio of WS. Flexural behaviour of reinforced concrete beam using this light weight aggregate is studied and compared with conventional SCC beam. Hence obtained similar results of conventional SCC.*

***Key Words*: Self-compacting concrete, Walnut shell, Coarse aggregate, Mineral admixture, Lightweight self-compacting concrete.**

1.INTRODUCTION

Concrete is a most viable engineering material used for construction. Normal weight aggregates are such as limestone, granite and sandstone are common materials used as coarse aggregates in concrete. There are also other natural light weight aggregates such as: expanded shale, pumice, slate, perlite, bottom ash, expanded clay etc. were successfully used in the production of lightweight concretes (LWCs) over the decades. Normal weight aggregates are one of the major constituents in concrete, be it normal concrete or SCC. Aggregates are about 60% by volume in SCC and hence they are the main contributor to concrete weight. About 20 billion tons of materials were used for production of concrete annually. So, the estimates of raw materials for the consumption of concrete will be in future is huge amount. Meanwhile, numerous contemporary research works have dedicated to replacing normal weight aggregates with lightweight aggregates (LWA). Generally, there are two classifications of Light weight aggregate, which are artificial type and natural type. Naturally sourced aggregates include pumice, diatomite, volcanic cinders, scoria and tuff while those in artificial category are classified into industrial by products and modified natural arising materials. Undeniably, more benefits can be derived from utilising wastes materials to replace aggregates in concrete as it can reduce the environmental impacts with respect to waste reduction, pollution containment as well as less consumption of energy. Giving a thought on this an attempt has been made to utilise natural aggregate for the construction.

The introduction of new materials, which act as structure mass reduction and workable materials such as lightweight concrete (LWC) and self-compacting concrete (SCC) materials are one of the most recent technology in the modern construction industries. Lightweight self-compacting concrete (LWSCC) is predicted to produce high workability while not segregation and high durability with reduced weight of SCC. Light- weight aggregate (LWA) is generally used in the LWC construction and can be manufactured by naturally sourced or artificially constructed from processing by-products of some industrial processes. Lightweight concrete has a low viscosity and large rate of flow which is very important for concrete pumping, particularly in multi-storey buildings. The success to production of high quality LWSCC lies within the use and quality of aggregates.

Walnut shell (WS) is one of the natural and agriculture waste materials which can be used as a substitution of aggregate in SCC. The utilization of walnut shell aggregate with other quality additional cementing materials like fly ash can provide highly workable and durable LWSCC. Use of these aggregates provides property to the sustainable development by protective energy increasing structural properties and increasing the service lifetime of structural lightweight concrete (LWC). Compaction is normally done with the help of vibrator during concreting and it raises concreting cost. In earnest quest for innovation in construction industry self-compacting concrete (SCC) in late 1980 s and is gradually gaining popularity. SCC have a properties to flow under gravity and more compactly fill the complex space of formwork as well as the area congested with reinforcement. LWSCC is capable of filling up the formwork and encapsulate reinforcement by its self-weight without the need for extra compaction or external vibration. It has better segregation resistance, high flowability and passing ability at fresh state as well as better mechanical and durability properties in the hardened state.

1.2 Flyash

Flyash is a fine powder that obtained as the byproduct of burning pulverized coal in electric generation power plants. Flyash is a pozzolanic material, a substance containing aluminous and siliceous material that forms cement in the presence of water. When flyash mixed with lime and water, it forms a compound similar to Portland cement. As per IS 3812: 2003, the generic name of the byproduct due to burning of coal or lignite in the boiler of a thermal power plant is pulverized fuel ash. Fly ash is the pulverized fuel ash gets from the fuel gases by suitable process like cyclone separation or electrostatic precipitation.

According to IS 3812-1981, there are two grades of Flyash

1. Grade I fly ash, which are derived from bituminous coal having fractions $SiO_2+Al_2O_3+Fe_2O_3$ greater than 70 %.
2. Grade II Fly ash, which are derived from lignite coal having fractions $SiO_2+Al_2O_3+Fe_2O_3$ greater than 50 %

Table -1: Chemical Composition of Flyash [17]

Sl.No.	Chemical composition	Percentage Content
1	Silica (SiO_2)	62.50
2	Iron Oxide (Fe_2O_3)	3.50
3	Alumina (Al_2O_3)	23.40
4	Calcium Oxide (CaO)	1.80
5	Magnesium Oxide(MgO)	0.34
6	Total Sulphur (SO_3)	1.20
7	Pottassium Oxide (K_2O)	0.95
8	Sodium Oxide (Na_2O)	0.24

Table -2: Physical Property of Flyash [17]

Sl. No.	Physical Property	Test Results
1	Colour	Grey
2	Specific Gravity	2.3

2. MATERIALS USED

2.1 Cement

Use of Ordinary Portland Cement (OPC) of Grade 53 according to IS specifications is made in this investigation. Table 3 provides cement's characteristics.

Table-3: Properties of OPC 53 Grade Cement

Properties	Test Results	Technical Reference
Specific Gravity	3.12	IS4031(PART 11): 1988
Consistency(%)	30	IS4031(PART 4): 1988
Fineness of Cement (%)	4.7	IS4031(PART 2): 1996
Initial Setting Time (minutes)	78	IS4031(PART 5): 1988

2.2 Fine Aggregate

For building, manufactured sand (M-Sand) is an alternative to river sand. M-sand is a product made from hard granite stone that has been crushed. M-Sand is less than 4.75mm in size. River sand is in short supply, hence artificial sand has been employed as an alternative for construction. M-Sand is also used since it is readily available and costs less to transport. Additionally, it is a dust-free material that pollutes very little. Table 4 lists the fine aggregate's characteristics.

Table-4: Properties of Fine Aggregate [25]

Properties	Test Results
Specific Gravity	2.52
Fineness Modulus	3.84
Free Surface Moisture	Nil

2.3 Coarse Aggregate

Aggregates with a particle size range of more than 4.75 mm, but typically between 10 and 40 mm in size. Concrete benefits from coarse aggregate's strength, toughness, and hardness qualities as well as its resistance to abrasion. The experimental study's coarse aggregate was 12.5mm in size and conformed to IS 383:1970. Table 5 lists the characteristics of coarse aggregate.

Table-5: Properties of Coarse Aggregate

Properties	Test Results	Technical Reference
Specific Gravity	2.69	IS2386(PART 3): Clause 2.4.2
Free Surface Moisture	Nil	IS383(PART 3): 1970
Fineness Modulus	4.25	IS383(PART 3): 1970 table 2

2.4 Water

Water is required to wet the surface of aggregate to develop adhesive quality as the cement paste binds quickly and satisfactorily to the wet surface of the aggregates than drysurface. It is commonly accepted view that any portable water is suitable to be used in concrete making. It should have inorganic solid less than 1000 ppm and should be free from injurious quantities of alkalies, acids, oils, salts, sugars, organic materials, vegetablegrowth or other substance that may be deleterious to bricks, stones, concrete or steel.

2.5 Admixture

Admixtures are defined in ACI 116R as "a material other than water, aggregates, hydraulic cement, and fiber reinforcement, used as an ingredient of concrete or mortar, and added to the batch right away before or during its mixing". Chemical admixtures are used to upgrade the quality of concrete during mixing, transporting, placement andcuring.

MASTERRHEOBUILD 1126ND is an admixture of a new generation based on modified naphthalene formaldehyde ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required. MASTERRHEOBUILD 1126ND is free of chloride & low alkali. It is compatible with all types of cements.

MASTERRHEOBUILD 1126ND has a different chemical structure from the traditional super plasticisers. It consists of a naphthalene formaldehyde polymer with long side chains. At the beginning of the mixing process, it initiates the same electrostatic dispersion mechanism as the traditional super plasticisers, but the side chains linked to the polymer backbone generates a steric hindrance which greatly stabilizes the cement particles' ability to separate and disperse. Steric hindrance provides a physical barrier (alongside the electrostatic barrier) between the cement grains. With this process, flowable concrete with greatly reduced water content is obtained.

Table-6: Performance Data

Aspect	Dark Brown Liquid
Relative Density	1.24 ± 0.02 at 25˚ c
pH	≥ 6
Chloride Iron Content	< 0.2 %

2.6 Walnut Shell

Walnut shell has unique properties, it is very dense and takes years and years to decompose or break down. It can be crushed and could be ground into several pieces from extra fine to extra course. Due to the excessive hardness of walnut shell, walnut shell is used as an abrasive that is applied to surface preparation on cementitious surfaces including cast-in-place concrete floors and walls, masonry walls, and shotcrete surfaces. Walnut shell is adequately hard natural material which can be used as coarse aggregate partially for making lightweight concrete. However, its particle size, shape and gradation will affect work-ability and strength of concrete. Moisture content and water absorption properties will influence shrinkage performance.

Fig-1: Walnut Shell and Crushed12.5 mm Walnut Shell

Table-7: Properties of Walnut Shell [13]

Specific Gravity	0.96
Water Absorption	10%
Thickness	0.86 – 1.35
Size Of Aggregate	12.5 mm

3. SPECIMEN DETAILS

Beam of size 150 mm x 200 mm x 1250 mm was used for the study. A total of 2 specimen was casted. The specimen was tested by the optimum content of flyash 25% with optimum content of walnut shell 35% in self-compacting concrete. The beams were designed as balanced section, according to IS 456: 2000 and the details.

3.1 Preparation of Specimen

The required quantities of cement, fine aggregate, coarse aggregate, super plasticisers, mineral admixture and water were taken for control specimens, in addition to this, walnut shell were mixed with the ingredients. Concrete was prepared by machine mixing. Initially cement and fine aggregate were mixed in dry state until it is of even colour throughout and free from streaks followed by the addition of walnut shell and then measured quantity of coarse aggregate was spread out. The whole mass was mixed by machine in an angle of 45%. Three quarter of the total quantity of water was added while the materials were turned in towards the centre with spades. The remaining water was added slowly when the whole mixture was turning over and over again until a uniform colour and consistency was obtained throughout.

The mould was made ready by applying oil in all contact surfaces. The control specimens of normal concrete cover of 25 mm were prepared by placing the reinforcements in the mould with suitable cover blocks. Concrete was spread on the mould and uniformly spread the mix on the mould. The other specimen was cast by adding walnut shell of 35% to the concrete.

Proper surface finishing was provided. The specimen was removed from the mould after 24 hours and kept for curing. After 28 days of curing, specimens were ready for testing.

3.2 Test Set up and Instrumentation

The experimental investigation of this project includes six (6) beams. Three (3) beams cast as control specimens with Fe 415 steel using normal M30 mix and three (3) beams cast as the 35 percentages of walnut shell as volume of coarse aggregate in concrete. All beams have a total length of 1250 mm, width of 150 mm and depth of 200 mm each. The longitudinal reinforcement was calculated using IS 456-2000 to obtain flexural failure and was same for all beams. The main lower reinforcement is 2#8 mm diameter and 8mm diameter stirrups.

The steel cover used was 25 mm. All beams were cast using M30 concrete mix. The beams were cured using jute bags with room temperature for 28 days. The compressive strength of the concrete mix was measured after 28 days using standard cubes. The mean compressive strength for the mix was 35 MPa.

The flexural strength of the specimens was tested using a 30-ton loading frame. A dial gauge was attached at the bottom of the beam to determine the deflection at the centre of the beam. For testing of the specimen, the supports were provided at a distance of 130 mm from the edges of the beam. The effective span of the beam was taken as 990 mm in the case of 1250 mm beam. A proving ring of 500 kN was connected at the top of the beam to determine the load applied.

The flexural strength of the beam was tested as a two-point loading system using a hydraulic jack of 50 ton attached to the loading frame. The behaviour of beam was keenly observed from beginning to the failure. The loading was stopped when the beam was just on the verge of collapse. The first crack propagation and its development were observed carefully. The values of load applied and deflection were noted directly and further the plot of load v/s deflection was performed which was taken as the output. The load in KN was applied with uniformly increasing the value of the load and the deflection under the different applied loads was noted. The applied load was increased up to the breaking point or till the failure of the material.

4 RESULTS

4.1 Load Deflection Behaviour

Due to increase in the load, the beam starts to deflect, up to certain level the load v/s deflection graph will be linear that is load will be directly proportional to deflection. Due to further increase in the load, the load value will not be proportional to deflection, since the deflection values increases as the strength of the materials goes on increasing material loses elasticity and undergoes plastic deformation. The deflection and the corresponding load, of RC beams reinforced with walnut shell as coarse aggregate were compared with normal RC beams of SCC.

The load values and corresponding deflection of control specimens and other specimens are given in table 8. Flexural cracks and shear cracks were formed in the mid-span and quarter span respectively of all the tested beams. No shear failure of the beam was observed till the failure. The maximum load values and maximum vertical deflection at midspan is given in table 8 and observed that the maximum load was carried by the RC beams walnut shell as coarse aggregate.

Figure 2 indicates the load-deflection curves of control beams and RC beams reinforced with walnut shell as coarse aggregate. The test results clearly indicated that RC beams reinforced with walnut shell as coarse aggregate has similar load compared with the control beams.

Table-8 Load – Deflection

Deflection (mm)	Control specimen Load (kN)	Test specimen Load (kN)
0	0	0
0.5	11.26	9.806
1	20.71	24.065
1.5	36.77	36.77
2	53.0333	59.226
2.5	88.0332	88.0332
3	109.484	109.485
3.5	134.74	123.839
4	151.194	136.74
4.5	156.88	151.194
5	162.646	156.88

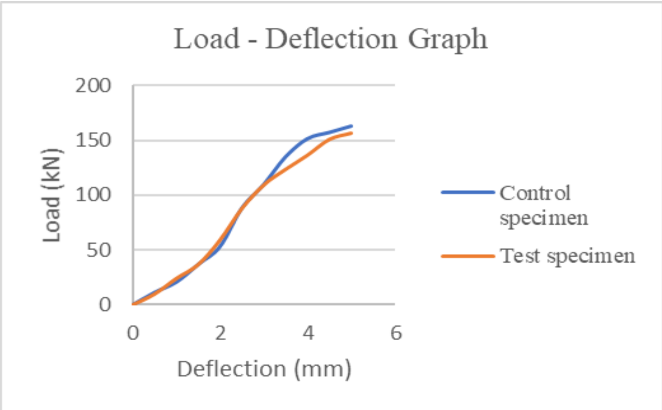

Chart-1: Load - Deflection Graph

5. CONCLUSIONS

The main aim was to study the properties of LWC using walnut shell as coarse aggregate with the conventional self-compacting concrete. From the studies we come to the following conclusions:

- From the study it shows that LWC required density below 2000 kg/m^3 and with the required strength were 38 MPa and we obtained density as per the study and strength obtained was 34 MPa.
- From the obtained results 35% gives the effective replacement of coarse aggregate with walnut shell gives similar strength of self-compacting concrete
- The beam casted using the same mixture carried and found both control beam and test beam shows similar behaviour
- The beam failures flexurally and cracks were formed with an inclination
- Initially number of cracks formed are few in number and also, they are hairline cracks
- Cracks were formed in the tension zone of the beam

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