# EXPERIMENTAL STUDY ON FLEXURAL BEHAVIOUR OF LIGHT WEIGHT SELF-COMPACTING CONCRETE WITH WALNUT SHELL AND GGBFS AS MINERAL ADMIXTURE

**Anjana Pradeep[1], Anima P.[2]**

[1]*P.G. Student, Structural Engineering, Universal Engineering college, Thrissur, Kerala*
[2]*Associate Professor, Civil Department, Universal Engineering college, Thrissur, Kerala*

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**Abstract -** *In recent decades, the application of self-compacting concrete (SCC) has emerging in construction structures because of its good abilities 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, replacing natural aggregate in SCC with waste materials can led to discover ecological building materials. Walnut shell (WS) is one of the natural and agriculture waste materials which can be used as a substitution of aggregate in SCC. In this research, WS was used as a replacement of coarse aggregate and ground granular blast furnace slag (GGBFS) as mineral admixture for constructing SCC by employing volume fractions of WS is 35%. The optimum percentage of GGBFS content is considered for the research. Fresh and hardened properties of SCC and lightweight self- compacting concrete (LWSCC) were investigated for the mix and control one. The results showed that all tested properties have satisfactory results of conventional SCC. However; the LWSCC can get at fraction volume of WS equal and or more than 35%. Where, slump flow diameter (SFD), compressive strengths and split tensile strength for flyash were 550 mm, 28 MPa and 2.4 MPa respectively achieved at 35% ratio of WS.*

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

## 1.INTRODUCTION

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 GGBFS 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 property 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 Ground Granular Blast Furnace Slag (GGBFS)

GGBS is mainly used as a partial substituent for cement in concrete. When added as an admixture to concrete, its performances as a stabilizing agent and enhance the quality of concrete. In the production of ready-mixed concrete, a portion of the Portland cement component is replaced by GGBS, generally about 60-70%. It is resistant to sulfate attacks, chloride -related corrosion and alkali-silica reaction. It is one of the greenest construction materials that does not manufactures any waste and its water demand lower by 3-5% compared to OPC.

**Table -1:** Chemical Composition of GGBFS [4]

| Sl.No. | Chemical composition | Percentage Content |
|---|---|---|
| 1 | Silica ($SiO_2$) | 36.41 |
| 2 | Iron Oxide ($Fe_2O_3$) | 0.69 |

| | | |
|---|---|---|
| 3 | Alumina ($Al_2O_3$) | 10.39 |
| 4 | Calcium Oxide (CaO) | 34.12 |
| 5 | Magnesium Oxide(MgO) | 8 |
| 6 | Total Sulphur ($SO_3$) | - |
| 7 | Pottassium Oxide ($K_2O$) | 0.97 |

**Table -2:** Physical Property of GGBFS [4]

| 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 construction, manufactured sand (M-Sand) is an alternative for river sand. M-sand is a product made from hard granite stone that were crushed. M-Sand is less than 4.75mm in size. 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 more than 4.75 mm, but typically between 10 and 40 mm in size is considered as coarse aggregate. Concrete benefits from coarse aggregate's strength, toughness, andhardness 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** |
|---|---|---|
| SpecificGravity | 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 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-6:** Properties of Walnut Shell [13]

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

### 2.5 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 dry surface. 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 can be deleterious to bricks, stones, concrete or steel.

### 2.6 Admixture

"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" is the definition for admixture. Chemical admixtures are used to upgrade the quality of concrete during mixing, transporting, placement and curing. MASTERRHEOBUILD 1126ND has a different chemical structure from the traditional super plasticisers. It consists of a naphthalene formaldehyde polymer with long side chains. With this process, flowable concrete with reduced water content is obtained.

**Table-7:** Performance Data

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

## 3. SPECIMEN DETAILS

Cubes of size 150 mm x 150 mm x 150 mm was used for the study. A total of 6 cubes and 3-cylinder specimen were casted. The specimen was tested by the optimum content of GGBFS 45% with optimum content of walnut shell 35% in self-compacting concrete. And 6 cubes and 3-cylinder specimen were casted of conventional SCC. The mix were designed 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 readied by applying oil in all contact surfaces. 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.

## 4.TEST METHODS

### 4.1 Tests on Fresh SCC

Many different test methods have been introduced in attempts to characterise the properties of SCC. Similarly, there is no single method has been found which characterises all the relevant workability aspects so each mix design should be tested by more than one test method for the different workability parameters. For the initial mix design of SCC all three workability parameters need to be evaluate to make sure that all aspects are fulfilled.

Two test methods are generally sufficient to monitor the quality control in site for production quality. Typical the test conducted are Slump-flow and V-funnel or Slump-flow and J-ring.

**Table- 8:** List of Test Methods for Workability Propertiesof SCC [28]

| Sl. No. | Method | Property |
|---|---|---|
| 1 | Slump-flow by Abram's cone | Filling ability |
| 2 | T50cm slump flow | Filling ability |
| 3 | J-ring | Passing ability |
| 4 | V-funnel | Filling ability |
| 5 | V-funnel at T5 minutes | Segregation resistance |
| 6 | L-box | Passing ability |

| | | |
|---|---|---|
| 7 | U-box | Passing ability |
| 8 | Fill-box | Passing ability |
| 9 | GTM screen stability test | Segregation resistance |
| 10 | Orimet | Filling ability |

### 4.2 Workability Criteria for the Fresh SCC

The requirements are to be satisfied at the time of placing which means it in fresh state. Likely changes in workability during transport of mix should be taken into account in production. EFNARC specifications provides typical acceptance criteria for Self-compacting concrete with a maximum aggregate size up to 20 mm are shown in Table 9.

**Table-9:** Acceptance Criteria for Self-Compacting Concrete [28]

| Test Method | Unit | Typical Range of Value | |
|---|---|---|---|
| | | Minimum | Maximum |
| Slump-flow byAbram's cone | mm | 650.0 | 800 |
| T50cm slump flow | sec | 20.0 | 5 |
| J-ring | mm | 6.0 | 10 |
| V-funnel | sec | 0.0 | 12 |
| V-funnel at T5minutes | sec | 0.8 | ±3 |
| L-box | h2/h1 | 0.0 | 1 |
| U-box | h2-h1 (mm) | 90.0 | 30 |
| Fill-box | % | 0.0 | 100 |
| GTM screenstability test | Sec | 0.0 | 15 |
| Orimet | Sec | - | 5 |

These typical requirements shown against each test method are based on modern knowledge and practice. Special care should be taken to ensure no segregation for the mix.

**Table-10** Test Results on Fresh Concrete

| Trial Mix | Slump (mm) | T50 cm (Sec) | L - box |
|---|---|---|---|
| SCC 1 | 480 | 37.00 | 0.4 |
| SCC 2 | 580 | 18.00 | 0.8 |
| SCC 3 | 600 | 6.18 | 0.9 |

### 5 .TEST METHODS ON HARDENED CONCRETE

The properties of hardened concrete, such as compressive strength and split tensile strength of concrete mixes were determined by casting 150 x 150 x 150 mm cube specimens, 150 x 300 mm cylinder specimens as per IS specifications.

### 5.1 Compressive Strength Test

The compressive strength of concrete represents one of the most important features used in the design rules of the concrete structures, and many of other mechanical characteristics and physical properties of concrete. The results are tabulated for conventional SCC in Table 11.

Figure 2 Compressive Strength Test of SCC Mix with GGBFS

**Table-11:** Test Results on Conventional SCC Hardened Concrete

| Sample Number | Compressive Strength of Cube (N/mm²) | Split Tensile Strength (N/mm²) |
|---|---|---|
| 1 | 37.77 | 3.324 |
| 2 | 37.11 | 3.254 |
| 3 | 36.88 | 3.324 |
| Average | 37.25 | 3.333 |

**Table-11:** Test Results on Compressive Strength of LWSCC Cubes with GGBFS

| No. of Days | Load (kN) | Compressive Strength (N/mm²) | Average Compressive Strength (N/mm²) |
|---|---|---|---|
| 7 | 415 | 18.44 | 18.29 |
| | 450 | 20.00 | |
| | 370 | 16.44 | |
| 28 | 680 | 30.22 | 29.09 |
| | 650 | 28.88 | |
| | 634 | 28.17 | |

### 5.2 Split Tensile Strength Test

The concrete is weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when it is subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may produce crack. Tensile strength of concrete is much lower to its compressive strength. It is approximate that the tensile strength of concrete equals roughly about 10 % of compressive strength.

**Table-11:** Test Results on Split Tensile Strength of LWSCC Cubes with GGBFS

| No. of Days | Load(kN) | Split Tensile Strength (N/mm²) | Average Split Tensile Strength (N/mm²) |
|---|---|---|---|
| 28 | 180 | 2.544 | 2.470 |
| | 172 | 2.433 | |
| | 172 | 2.433 | |

Figure 3 Split Tensile Strength Testing of LWSCC Mix with GGBFS

## 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:

- The compressive strength test and split tensile strength obtained from the experimental test were not satisfied.
- 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 but strength obtained was 28 MPa.
- From the obtained results 35% gives the effective replacement of coarse aggregate with walnut shell gives similar strength of self-compacting concrete.

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