International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.8, pp 605-622, 2017

# Experimental analysis of waste foundry sand in partial replacement of fine aggregate in concrete

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**Abstract :** Casting industries produce millions of tons of by-product throughout the world. In India, millions of tons of waste foundry sand is produced yearly. WFS are major by-product of casting industry and create land pollution. The river fine aggregate will be replaced with waste foundry sand (0%, 5%, 10%, and 15%) in the concrete. So that the land pollution can be reduced and the demand for the river sand can be reduced. Research has being carried out to know the exact percentage of waste foundry sand (WFS) should be replaced for fine aggregate in concrete.

This experimental investigation was done and found out that with the increase in the WFS ratio. Natural sand was replaced with five percentage (0%, 5%, 10%, 15%, and 20%) of WFS by weight. The sum of five concrete mix proportions (M-1, M-2, M-3, M-4 and M-5) with and without WFS were casted and found out how to reduce the slump and to increase workability of fresh concrete. Compression test has been done to find out the compressive strength of concrete at the age of 7, 14, 21 and 28 days. Test result indicates in increasing compressive strength of plain concrete by inclusion of WFS as a partial replacement of fine aggregate. The results also satisfy the acceptable limits set by the American Concrete Institute (ACI).
**Keywords:** foundry sand, fine aggregate, Concrete.

## 1.0 Introduction

In foundry industry during the casting process a large amount of by-product material is produced. The metals which usually cast in foundry industry are cast iron, steel, aluminium, copper, brass and bronze. Over two third of the total by-product material consists of silica and the one third of the total by-product material consists of metals which is casted on the sand. In foundry industry they use high quality silica sand for moulding the metals and also for casting purposes. The sand which they commonly used in the foundry industry should be easily available, it should possess very high resistance to heat, and it should be cost effective. In the foundry industry the same sand will be used for many castings until it loses its original properties fully or until if it is used again it will affect the casting materials by changing its physical as well as chemical properties. The sand which cannot be reused again in the foundry industry for casting purposes then it is termed as waste foundry sand. The disposal of waste foundry sand becomes major issues and creates land pollution. The colour of the foundry sand will be blackish, grey and also brownish in colour based on the material which is casted on it, the number of times it is used for the casting purposes, and the method used in the casting purposes. The by-product of waste foundry sand will have some of the properties of the material which is casted on it. Due to this when it is used as a partial replacement for fine aggregate in concrete the compressive strength of the concrete can be increased, land pollution due to waste foundry sand can also be reduced to a greater extent, and the demand for the fine aggregate can also be reduced.

Classifications of foundry sand mainly depend upon the binding properties of metals used for casting. Usually all sand cast moulds for ferrous castings are of the clay-bonded sand type. Clay-bonded (Green) sand is usually composed of naturally occurring materials, such as high-quality silica sand (84–94%), clay (3.5–9.5%), additives of various properties (3–11%) to improve the casting. It is black in colour due to carbon content. Most of the foundries use clay bonded sand due their higher resistance to heat, and the binding properties can be increased when it becomes wet. Due to addition of carbonaceous material which prevents the burning of fusing of sand on the casting surface. The chemical traces mostly found on clay-bonded sand are MgO, $K_2$ O, and $TiO_2$. The other common type of sand used is chemically bonded sand and it is used only when very high temperature of moulds is to be casted. Chemically bonded sand is usually composed of silica 93-98% and chemical binder 1-3%. The colour of chemically bonded sand will be light brown.

Chemically bonded sand is used as a Gas Catalyzed system, a family of binder is used where the catalyst is not added to the sand mixture. Gas or vapour is used as a catalyst that is added to the sand and resin components to ensure the mixture remains uncured until it becomes in contact with the catalyst agent. At this stage the sand resin mixture is blown into a core box. The core box serves to compact the sand and the catalyst reacts with the resin components, the sand mixture hardens almost instantly. There are many Gas Catalysed processes including furan / SO2, acrylic / SO2, sodium silicate / CO2, and phenolic urethane / amine vapour.

## 2.0 Literature review

Several researchers have investigated the utilization of WFS in concrete and construction materials such as fly ash (Shi and Qian, 2003) [1]; sewage sludge ash (Cyr et al., 2007) [2]; crushed stone dust (Sahu et al., 2003) [3]; silica fume (Scott and Singh, 2011) [4] and WFS (Santurde et al., 2011) [5]. Shi C and Qian J (2003) [6] studied chemical activation of reactivity of fly ash is an effective method to increase the use of fly ash in concrete. Cyr et al. (2007) [7] showed that sewage sludge ash (SSA) is composed of irregular grains with high specific surface area and thus lead to a significantly high water demand.

**Sahu et al. (2003)**[8] studied the properties of crushed stone dust as fine aggregate for concrete. Two common mixes (M20 and M30 grade concrete) were taken for natural sand. Results said that concrete made with the replacement attains the same compressive strength, tensile strength with lower degree of shrinkage limit when compared to normal concrete.

**Khatib (2005)** [9] studied the properties of concrete which contains fine recycled aggregate. The recycled aggregate consists of crushed concrete (CC) or crushed brick (CB) with particles size less than 5 mm in diameter. The fine aggregate in concrete was replaced with 0%, 25%, 50% and 100% CC or CB. Results said that concrete made with the replacement attains up to 50% CB shows the same 19 long-term strength. Even at 100% replacement of fine aggregate with CB, the reduction in strength was only 10%. After 28 days of curing, the amount of strength development in concrete containing is either CC or CB was higher than that of the conventional concrete. There are several types of waste material / by-products, which can be used in concrete as a partial replacement of fine aggregate. Some of the materials which can be used are recycled fine aggregate, coal bottom ash, stone dust and glass cullet, sewage sludge ash, and waste foundry sand, etc.

**Rakshvir and Barai (2006)**[10] studied the various physical as well as mechanical properties of recycled concrete aggregates. Recycled concrete aggregates (RCA) are different from natural aggregates and concrete made from them had different physical as well as chemical properties. The percentage of RCA varies and it was found out that the properties like compressive strength likely to decrease about 10% compared to the conventional concrete. Water absorption of RCA was found to be greater than natural aggregates.

**Aggarwal et al. (2008)** [11] gave an experimental procedure for the design of self-compacting concrete mixes. The test results for self-compacting concrete is 18 as slump flow; V-funnel and L-Box are presented, J-ring. In addition to it compressive strength at the ages of 7, 28, and 90 days was also found to be increasing.

**Raoa et al. (2007)** [12] reviewed an international scenario reducing waste generated, and to reuse the waste in concrete without reducing the strength and other physical properties of concrete. They found the effect of use of recycled aggregate on the fresh and hardened concrete and concluded some of the drawbacks in the use of RA in recycled aggregate concrete (RAC), it also includes lack of awareness between the people, lack of government support, no specific codes for using the RA in new concrete.

**Charkradhara et al. (2011)**[13] found that the influence of different quantity of recycled coarse aggregates (RCC) obtained from a demolished RCC culvert 15 years old on the properties of recycled aggregate concrete (RAC). To analyse the behaviour fresh as well as the hardened concrete, the coarse aggregate replaced by 0%, 25%, 50% and 100% were taken in the concrete mixes. The properties like compressive, tensile strength, water absorption, volume of voids, modulus of elasticity, and density of hardened concrete and depth of chloride penetration were studied. From the experimental results it is clear that the concrete after 7 days curing shows increase in strength than concrete cured completely under water for 28 days for all coarse aggregate replacement ratios. The volume of voids and water absorption of RAC is 2.61 and 1.82% higher than the conventional concrete due to the high water.

**Cachim (2009)**[14] viewed that the workability of fresh concrete, compressive strength, tensile strength, modulus of elasticity and stress–strain behaviour of hardened concrete. The replacement ratios of fine aggregates by 15% and 30% were prepared with a water/cement ratios of 0.45 and 0.5. From the results it is clear that the ceramic residuals can be used as partial replacement for fine aggregates in concrete without changing the properties of conventional concrete for 15% , 20% for 30% replacement.

**Velosa and Cachim (2009)** [15] compared the compositions with different percentages of hydraulic lime and a pozzolanic cement. Concrete specimens were casted and the compressive strength at various ages and a pozzolanic index were found out to calculate the influence of the pozzolanic material on mechanical strength. Schmidt et al. (2011) [16] studied the problems faced due to temperatures change on the performance of polymeric stabilizing agent in fresh cementitious materials.

**Cwirzen A (2010)**[17] found the effect of nano-materials on physical properties of cementations materials. The mechanical properties like compressive and flexural strength can be increased up to 50% by addition of 0.23% of carbon nano-tubes. Carbon nano-tubes and carbon nano-fibres and/or nano-silica. After addition of carbon nano fibres improves the frost resistance, other properties such as autogenous shrinkage decreased significantly. Nano-silica enabled an immense densification of the hydrated binder matrix, which improves the durability and mechanical properties of the concrete.

## 3.0 Moulding material

- A suitable and workable material possessing high refractoriness in nature can be used for mould making. Thus, the mould making material can be metallic or non-metallic.
- For metallic category, the common materials are cast iron, mild steel and alloy steels.
- In the non-metallic group moulding sands, plaster of pairs, graphite, silicon carbide and ceramics are included.

**Out of all, the moulding sand is the most common utilized non-metallic moulding material because of its certain inherent properties namely refractoriness, chemical and thermal stability at higher temperature, high permeability and workability along with good strength. Moreover, it is also highly cheap and easily available.**

## 4.0 Refractory sands

Different types of refractory sands used for moulding purposes are:

1. Silica sand
2. Magnetite
3. Zircon
4. (iv)Silimanite
5. Olivine
6. Graphite/carbon

- Sand used in foundries must be capable of with-standing very high temperatures i.e. 1650°C, and shouldn't collapse under the prevailing load.
- Silica sand can be easily moulded into intricate shapes.
- Silica sand can be used repeatedly for making moulds after addition of some bonding materials.
- Silica sand is cheap and easily available.

- The porosity and permeability in the silica sand will easily allow the gasses formed during the cooling of metals.
- Silica sand is chemically immune to molten metals.

**5.0 Types of Moulding Sand**

Depending upon the purity and other constituents present, sand is classified into

1. Natural sand,
2. Synthetic sand,
3. Loam sand.

(i) **Natural sand**

- Natural sand is directly used for moulding and contains 5-20% of clay as binding material.
- Many natural sands possess a wide working range of moisture and are capable of retaining moisture content for a long time.
- Its main drawback is that it is less refractory as compared to synthetic sand.
- Many natural sands have weak moulding properties.
- These sands are reconditioned by mixing small amounts of binding materials like bentonite to improve their properties and are known as semi-synthetic sand.

(ii) **Synthetic Sands**

- Synthetic sand consists of silica sand with or without clay, binder or moisture.
- It is a formulated sand i.e. sand formed by adding different ingredients. Sand formulations are done to get certain desired properties not possessed by natural sand.
- These sands have better casting properties like permeability and refractoriness and are suitable for casting ferrous and non-ferrous materials.
- Synthetic sands are used for making heavy castings.

(iii) **Loam Sand**

- Loam sand contains many ingredients, like fine sand particles, finely ground refractories, clay, graphite and fibre reinforcements.
- In many cases, the clay content may be of the order of 50% or more.
- When mixed with water, the materials mix to a consistency resembling mortar and become hard after drying.
- Big moulds for casting are made of brick framework lined with loam sand and dried.
- Sweeps etc. are used for making big castings like big bells by using loam sand.

***6.0*Refractory sand grains**

Sand grain size and shape has a marked effect on the properties of moulding sand. The specific surface gives a rough idea of the amount of binder needed for moulding sand.

**Foundry Sand Grain Shape**

The grain shape of foundry sand has a marked influence on its properties like flow ability, cohesiveness and strength. Generally, four types of grains are present in foundry sand given as follows.

***(i)* Rounded Sand Grains**

a. Rounded sand grains give poor bonding strength as compared to angular sand grains.
b. Too many smooth and rounded sand grains result in sand wash, sand crack and sand scales.
c. These sands also possess greater flow ability.

***(ii)* Angular Grains**

a. These grains are produced by breaking of rocks without movement ofparticles.
b. These are also formed by frost and glacial action.
c. Angular grains have greater bonding strength, lesser flow ability and low permeability than round grain sands
d. Angular grains have sharp corners and greater contact surface.

***(iii)* Sub-angular Grains**

a. As compared torounded grains, sub-angular grains possess better strength and lower permeability.
b. In comparison to angular grains, they possess lower strength and better permeability.

***(iv)* Compound Grains**

a. Compound grained sand is formed when two or more sand grains stick together and don't separate either on sawing or washing. These sands are not preferred and used in foundries.

**7.0 Constituents of moulding sand**

The main constituents of moulding sand involve silica sand, binder, moisture content and additives.

**Silica sand**

- Silica sand in form of granular quarts is the main constituent of moulding sand having enough refractoriness which can impart strength, stability and permeability to moulding and core sand.
- Along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities.
- The chemical composition of silica sand gives an idea of the impurities like lime, magnesia, alkalis etc. present.
- The presence of excessive amounts of iron oxide, alkali oxides and lime can lower the fusion point to a considerable extent which is undesirable.
- The silica sand can be specified according to the size (small, medium and large silica sand grain) and the shape (angular, sub-angular and rounded).

**Moisture**

- The amount of moisture content in the moulding sand varies generally between 2 to 8 percent.
- This amount is added to the mixture of clay and silica sand for developing bonds.
- This is the amount of water required to fill the pores between the particles of clay without separating them.
- This amount of water is held rigidly by the clay and is mainly responsible for developing the strength in the sand.
- The effect of clay and water decreases permeability with increasing clay and moisture content.
- The green compressive strength first increases with the increase in clay content, but after a certain value, it starts decreasing.

**Additives**

Additives are the materials generally added to the moulding and core sand mixture to develop some special property in the sand. Some common used additives for enhancing the properties of moulding and core sands are

1. Coal dust
2. Dextrin
3. Pitch
4. Wood flour

## 8.0 Experiential Materials

### a) Properties of moulding sand

The basic properties required in moulding sand and core sand are described as under.

### i) Refractoriness

Refractoriness is defined as the ability of moulding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting. It is a highly important characteristic of moulding sands. Refractoriness can only be increased to a limited extent.

Moulding sand with poor refractoriness may burn on to the casting surface and no smooth casting surface can be obtained. The degree of refractoriness depends on the SiO2 i.e. quartz content, and the shape and grain size of the particle. The higher the SiO2 content and the rougher the grain volumetric composition the higher is the refractoriness of the moulding sand and core sand. Refractoriness is measured by the sinter point of the sand rather than its melting point.

### ii) Permeability

It is also termed as porosity of the moulding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it. All these gaseous generated during pouring and solidification process must escape otherwise the casting becomes defective. Permeability is a function of grain size, grain shape, and moisture and clay contents in the moulding sand. The extent of ramming of the sand directly affects the permeability of the mould. Permeability of mould can be further increased by venting using vent rods

### iii) Cohesiveness

It is property of moulding sand by virtue which the sand grain particles interact and attract each other within the moulding sand. Thus, the binding capability of the moulding sand gets enhanced to increase the green, dry and hot strength property of moulding and core sand.

### iv) Green strength

The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mould. For this, the sand grains must be adhesive, i.e. they must be capable of attaching themselves to another body and. therefore, and sand grains having high adhesiveness will cling to the sides of the moulding box. Also, the sand grains must have the property known as cohesiveness i.e. ability of the sand grains to stick to one another. By virtue of this property, the pattern can be taken out from the mould without breaking the mould and also the erosion of mould wall surfaces does not occur during the flow of molten metal. The green strength also depends upon the grain shape and size, amount and type of clay and the moisture content.

### v) Dry strength

As soon as the molten metal is poured into the mould, the moisture in the sand layer adjacent to the hot metal gets evaporated and this dry sand layer must have sufficient strength to its shape in order to avoid erosion of mould wall during the flow of molten metal.

### vi) Flow ability or plasticity

It is the ability of the sand to get compacted and behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions. Generally sand particles resist moving around corners or projections.

In general, flow ability increases with decrease in green strength, an, decrease in grain size. The flow ability also varies with moisture and clay content.

**vii) Adhesiveness**

It is property of moulding sand to get stick or adhere with foreign material such sticking of moulding sand with inner wall of moulding box.

**viii) Collapsibility**

After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal. In absence of this property the contraction of the metal is hindered by the mould and thus results in tears and cracks in the casting. This property is highly desired in cores.

**ix) Miscellaneous properties**

In addition to above requirements, the moulding sand should not stick to the casting and should not chemically react with the metal. Moulding sand should be cheap and easily available. It should be reusable for economic reasons. Its coefficients of expansion should be sufficiently low.

**Fig. 1. Waste Foundry Sand**

**Table 1. Physical properties of waste foundry sand**

| **Property** | **Value** |
|---|---|
| Specific gravity | 2.66 |
| Water absorption | 1.81% |
| Bulk density | 1440 kg/$m^3$ |
| Voids ratio | 0.60 |
| Porosity | 36.20% |

**Source:** VG alloys industries, Coimbatore

**b) Cement**

Portland Pozzolana Cement (53 grade) conforming to IS: 12269 -1987 and with the specific gravity 3.15 was used for casting all the specimens. Tests conducted on cement are fineness of cement by sieve analysis (using 90 µ sieve), specific gravity using Le-chatlier’s apparatus, initial setting time and final setting time using vicat apparatus.

**Table 2. Properties of cement**

| **Property of Cement** | **Values** |
|---|---|
| Fineness Of Cement | 7.5% |
| Grade Of Cement | 53 |
| Specific Gravity | 3.15 |
| Initial Setting time | 28 minutes |
| Final Setting Time | 600 minutes |

**c) Fine aggregate**

Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve and as per IS: 383-1970 was used for all the specimens. Test conducted on fine aggregate are specific gravity using pycnometer, fineness modulus by sieve analysis.

**Table 3. Properties of Fine Aggregate**

| Properties | Values |
|---|---|
| Specific Gravity | 2.64 |
| Fineness Modulus | 2. 25 |

**c) Coarse aggregate**

Crushed granite aggregate with specific gravity of 2.6 and passing through 20 mm sieve and retained on 12.5 mm sieve and as given in IS: 383 - 1970 is used for all the specimens.

**Table 4. Properties of Coarse Aggregate**

| Properties | Values |
|---|---|
| Specific Gravity | 2.60 |
| Size Of Aggregates | 20 mm |
| Fineness Modulus | 5.96 |

**d) Water**

Casting and curing of specimens were done with the potable water as per IS 456:2000.

**Table 5. pH Value Test**

| WATER | pH |
|---|---|
| Sample 1 | 7 |
| Sample 2 | 7 |
| Sample 3 | 7 |

**9.0 Mixture Preparation for Cube Casting**

**Table 6. Mix Proportion ($M_{20}$)**

| Unit of Batch | Water (Litres) | Cement (Kg) | F.A (Kg) | C.A (Kg) |
|---|---|---|---|---|
| Cubic meter content | 44.10 | 88.2 | 132.54 | 265.09 |
| Ratio of ingredients | 0.5 | 1 | 1.50 | 3.0 |

**Table 7. Mix Proportions of Concrete**

| WFS Type | Untreated WFS | | | | |
|---|---|---|---|---|---|
| WFS (%) | 5 | 15 | 25 | 35 | 50 |
| Cement (kg/m3) | 44.1 | 44.1 | 44.1 | 44.1 | 44.1 |
| FA (kg/m3) | 12.59 | 11.26 | 9.94 | 8.61 | 6.63 |

| | | | | | |
|---|---|---|---|---|---|
| **CA (kg/m3)** | 132.54 | 132.54 | 132.54 | 132.54 | 132.54 |
| **Water (kg/m3)** | 22.05 | 22.05 | 22.05 | 22.05 | 22.05 |
| **WFS (kg/m3)** | 0.66 | 1.98 | 3.32 | 4.64 | 6.63 |

**10.0 Experimental methodology**

**i) Casting of Cubes**

Cubes were made (Fig. 3.9.2) using concrete mixture without WFS and concrete mixture Containing WFS as partial replacement of fine aggregate with various percentages (5%, 15%, 25%, 35%, and 50%).

**Fig. 2. Casting of Concrete Cubes (M20)**

**ii) Curing of Concrete Cubes and Beams**

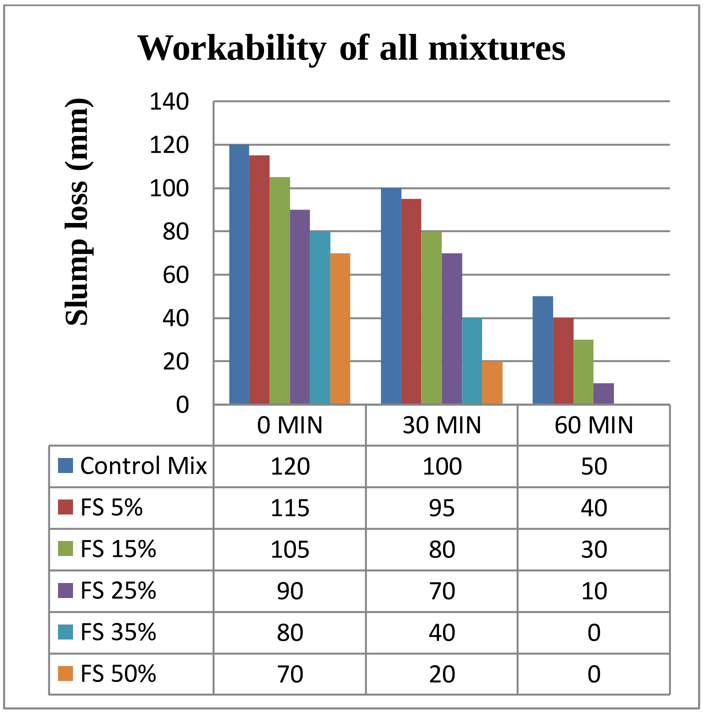
After casting, all the test specimens were stored at room temperature in the casting room. They were de-moulded after 24 hours, and were put into a water-curing tank for 28 days at room temperature.

**11. Test on fresh concrete**

**i) Slump Cone test results**

**Table 8. Workability of all mixtures**

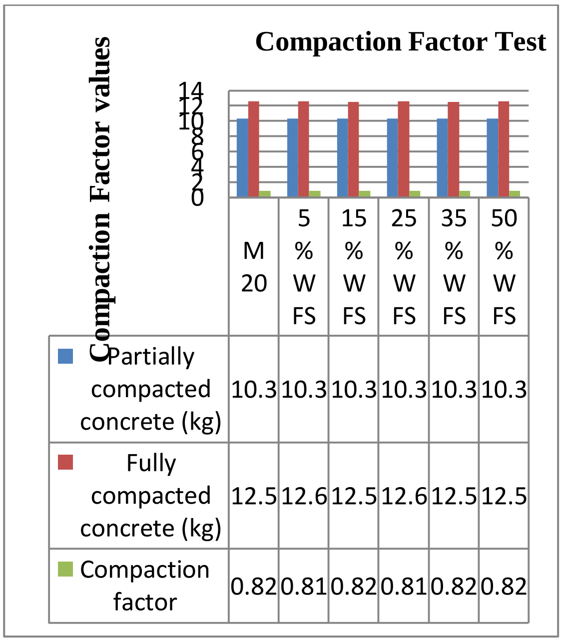
| DURATION | Control Mix | FS 5% | FS 15 % | FS 25% | FS 35 % | FS 50% |
|---|---|---|---|---|---|---|
| 0 MIN | 120 | 115 | 105 | 90 | 80 | 70 |
| 30 MIN | 100 | 95 | 80 | 70 | 40 | 20 |
| 60 MIN | 50 | 40 | 30 | 10 | 0 | 0 |




**ii) Compaction factor test results**

**Table 9. Compaction Factor Test (WFS)**

| Concrete mix | Partially compacted concrete (kg) | Fully compacted concrete (kg) | Compaction factor |
|---|---|---|---|
| M20 | 10.28 | 12.54 | 0.819 |
| 5% WFS | 10.28 | 12.62 | 0.814 |
| 15% WFS | 10.28 | 12.5 | 0.82 |
| 25%WFS | 10.28 | 12.62 | 0.814 |
| 35% WFS | 10.28 | 12.5 | 0.82 |
| 50% WFS | 10.28 | 12.54 | 0.819 |

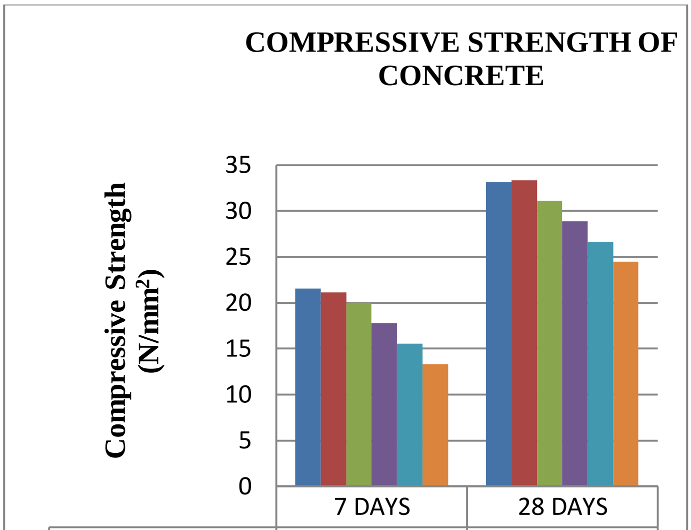


## 12. Tests on Harden Concrete

### i) Compressive strength test

**Table 10. Compressive Strength Test in (WFS)**

| Concrete | Description | 7 days | 28 days |
|---|---|---|---|
| Conventional concrete | Compression strength ($N/mm^2$) | 21.54 | 33.14 |
| 5% replacement by WFS | Compression strength ($N/mm^2$) | 21.16 | 33.33 |
| 15% replacement by WFS | Compression strength ($N/mm^2$) | 20.01 | 31.11 |
| 25% replacement by WFS | Compression strength ($N/mm^2$) | 17.78 | 28.88 |
| 35% replacement by WFS | Compression strength ($N/mm^2$) | 15.56 | 26.67 |
| 50% replacement by WFS | Compression strength ($N/mm^2$) | 13.33 | 24.44 |




| | 7 DAYS | 28 DAYS |
|---|---|---|
| Conventional concrete | 21.54 | 33.14 |
| 5% replacement by WFS | 21.16 | 33.33 |
| 15% replacement by WFS | 20.01 | 31.11 |
| 25% replacement by WFS | 17.78 | 28.88 |
| 35% replacement by WFS | 15.56 | 26.67 |
| 50% replacement by WFS | 13.33 | 24.44 |

ii) **Water Absorption, Voids, Porosity test**

**Table 11. Water Absorption, Voids, Porosity test**

| WFS (%) | Water absorption % | Porosity (%) | Void ratio (%) |
|---|---|---|---|
| Conventional Concrete | 2.5 | 3.7 | 5.9 |
| 5% WFS | 2.45 | 3.4 | 5.8 |
| 15% WFS | 2.40 | 2.6 | 5.6 |
| 25% WFS | 2.35 | 2.0 | 5.4 |
| 35% WFS | 2.30 | 1.4 | 5.2 |
| 50% WFS | 2.25 | 0.6 | 5.0 |

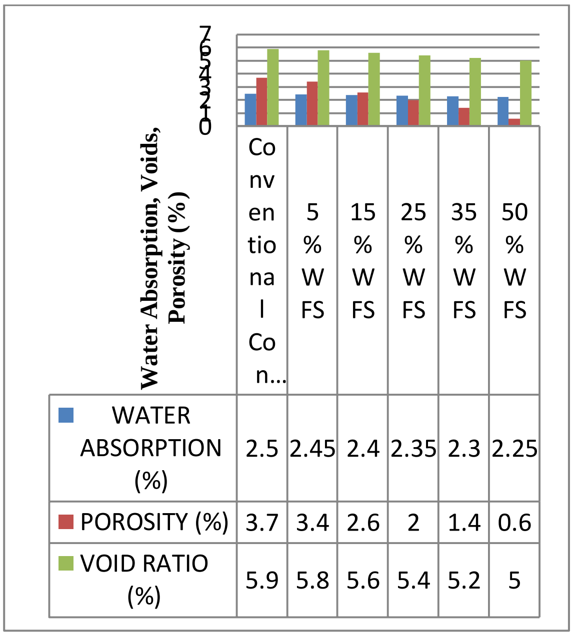


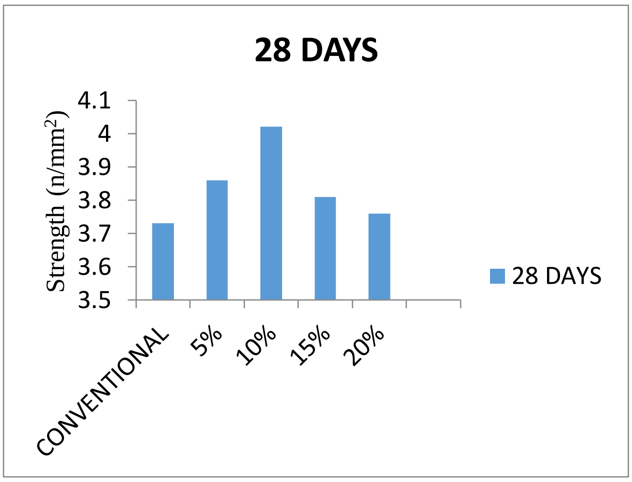

**Table11. Flexural Strength of Normal Concrete and WFS Concrete – 28 days**

| Sl.No | Load ( N) | Deflection at mid span (mm) | Specimen Observation |
|---|---|---|---|
| 1 | 0 | 0 | |
| 2 | 1.4 | 0.1 | |
| 3 | 5.1 | 0.4 | |
| 4 | 12.7 | 1.16 | |
| 5 | 16.5 | 2.03 | |
| 6 | 18.3 | 2.51 | INITIAL CRACK |
| 7 | 21.0 | 3.35 | |
| 8 | 24.2 | 4.18 | |
| 9 | 28.5 | 5.22 | |
| 10 | 31 | 5.83 | |
| 11 | 35.8 | 6.8 | |
| 12 | 38.5 | 7.5 | |
| 13 | 42 | 8.15 | ULTIMATE LOAD |
| 14 | 40 | 9.05 | |

**iii) Structural flexural behaviour of WFSC beams**

**Table 12. Conventional Beam Test Results–$M_{20}$**

| S.NO | NAME OF THE SPECIMEN | % REPLACEMENT WFS | FLEXURAL STRENGTH ($N/mm^2$) |
|---|---|---|---|
| | | | 28Days |
| 1. | M1 | 0% | 3.73 |
| 2. | M2 | 5% | 3.86 |
| 3. | M3 | 10% | 4.08 |
| 4. | M4 | 15% | 3.81 |
| 5. | M4 | 20% | 3.76 |




**Load - Deflection behaviour of beam:**

- The first crack appeared at the load of 18.3 kN
- The ultimate strength of beam was 42kN
- At the ultimate load, deflection was 8.15mm

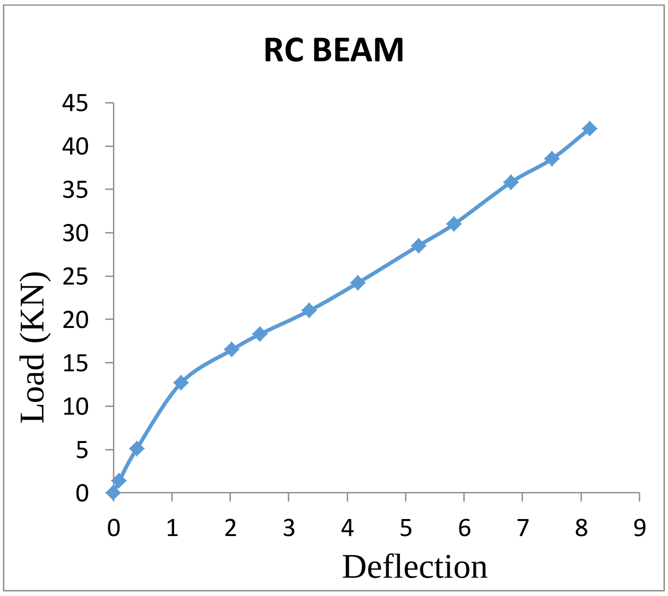
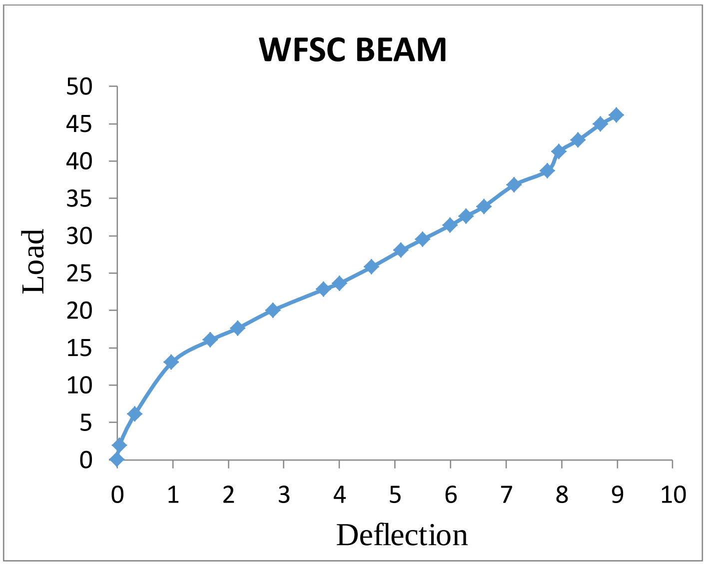


**Table 13. Test Results WFS Concrete Beam –$M_{20}$**

| Sl.No | Load( kN) | Deflection at mid span (mm) | SpecimenObservation |
|---|---|---|---|
| 1 | 0 | 0 | |
| 2 | 1.9 | 0.04 | |
| 3 | 6.1 | 0.32 | |
| 4 | 13 | 0.98 | |
| 5 | 16 | 1.68 | |
| 6 | 17.6 | 2.17 | |
| 7 | 20 | 2.8 | |
| 8 | 22.8 | 3.72 | initial crack |
| 9 | 23.6 | 4.0 | |
| 10 | 25.8 | 4.58 | |
| 11 | 28 | 5.11 | |
| 12 | 29.5 | 5.5 | |
| 13 | 31.4 | 6.0 | |
| 14 | 32.6 | 6.28 | |
| 15 | 33.9 | 6.6 | |
| 16 | 36.8 | 7.15 | |
| 17 | 38.7 | 7.75 | |
| 18 | 41.2 | 7.95 | |
| 19 | 42.8 | 8.3 | |
| 20 | 44.9 | 8.7 | |
| 21 | 46.1 | 8.99 | ultimate load |
| 22 | 45.2 | 9.3 | |

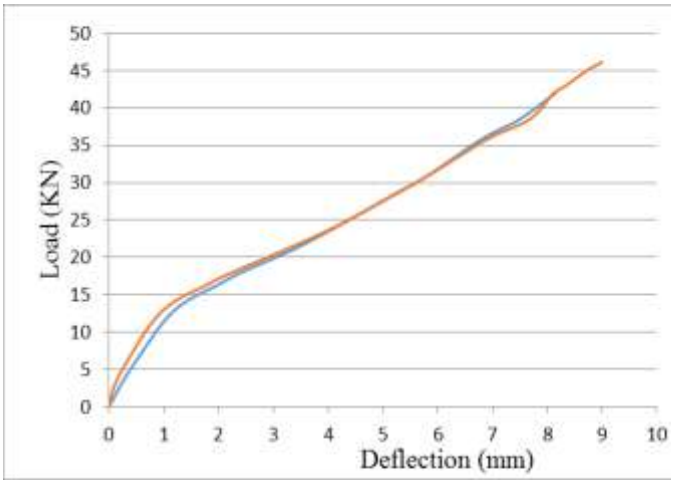
**Load - Deflection behaviour of WFSC beam:**

- The first crack appeared at the load of 22.8 KN
- The ultimate strength of the beam was 46.1KN
- At the ultimate load, deflection was 8.99mm




**Load VS Deflection on behaviour**

The load deflection history for all beams was recorded from the load deflection shown in figure. It was noted that the flexural behaviour as all the beams were good as compared to the reference concrete beam(RCB).The partial replacement of WFS in reinforced concrete combination performed better than all other beams.



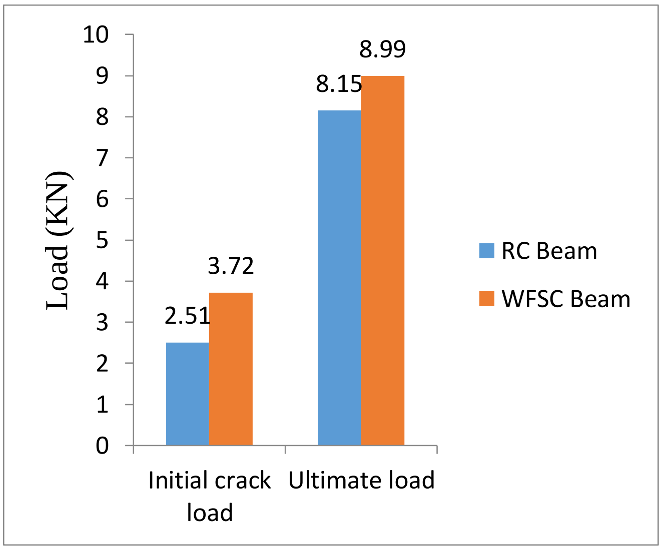

**First crack load and deflection**

The static load was applied to all the beam specimens. The mid –point load deflection was noted using the dial gauge. The figure shows the variation of first crack load and the ultimate load. The WFSC reinforced concrete shows 48% increase in first crack load this is due to the effect of iron content in the WFS which increase the first crack load and also resist their propagation.

The ultimate load carrying capacity of RC Beam and WFSC Beam was 42 and 46.1 kN respectively. There is an increase of ultimate load 10% as compared to the conventional RC Beam. The importance of using WFS reinforced concrete to have a ductile failure rather than brittle failure of the specimen and all the specimens were observed to fail in ductile manner. All the beams were fail in flexural mode, there is any shear failure in the beam.

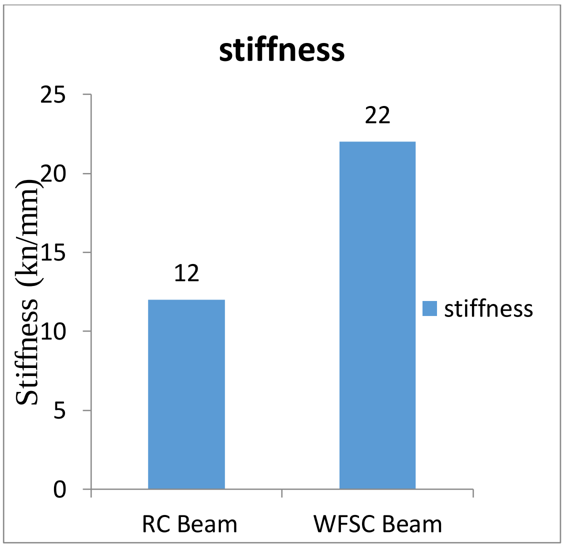
**Table. 14 Load and Deflection results for conventional beam and WFSC Beam**

| Sl.No | Designation | % WFSReplacem entof cement | Load (KN) | Deflection (mm) | Remarks |
|---|---|---|---|---|---|
| 1 | Conventional beam | 0 | 18.3 | 2.51 | First crack load and deflection |
| | | | 42 | 8.15 | Ultimate load and deflection |
| 2 | WFSC Beam | 20% | 22.8 | 3.72 | First crack load and deflection |
| | | | 46.1 | 8.99 | Ultimate load and deflection |



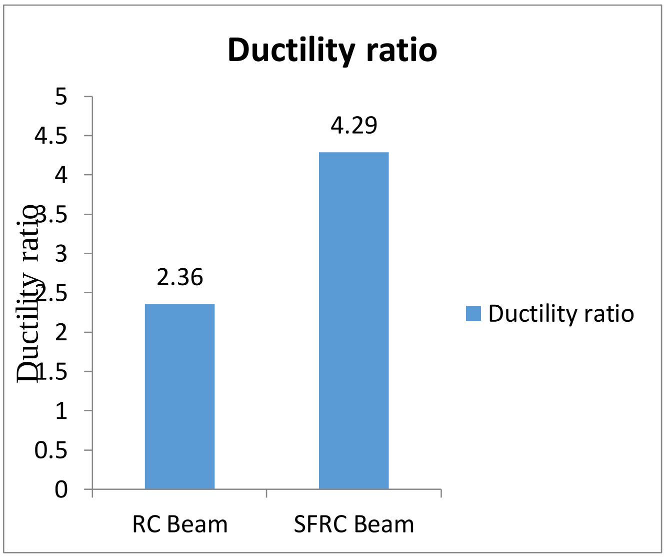

**Stiffness**

Stiffness may be defined as the amount of load required to cause a unit deflection. The stiffness for the beam specimens was calculated by drawing a tangent gives to initial crack load, and the slope of that tangent gives the values of stiffness. The addition of WFS in concrete improves the stiffness as compared to that of RC Beam. The increase in percentage of stiffness for WFSC beam was 83%.



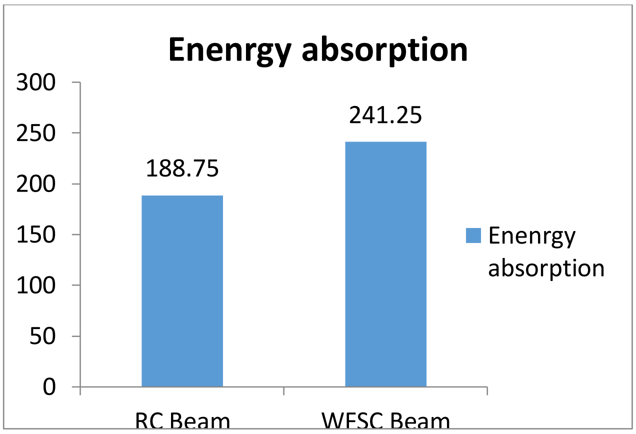

**Ductility factor**

Ductility factor is defined as the ratio between deflections of ultimate load to the deflection at yield. The ductility factors of beam were increased considerably as compared to the conventional RCB. The increase in 82% as compared with the RCB and it also shows that the addition of WFS in concrete increase the ductility of the conventional concrete to a large extent and make the material more ductile rather than a brittle failure of concrete.




**Energy absorption capacity**

The energy absorption capacity is an important parameter as it as indication as how much the energy being absorbed by the beam before it fails .The energy absorption capacity is obtained by calculating the area under the load deflection curve. It is observed that the GGBS and Sisal fibre reinforced concrete shows higher energy absorption with reference to the RC Beam. The increase in percentage of energy absorption of SFRC Beam was 28%.




## 13.0 Conclusions

The present work investigated the physical and chemical properties of waste foundry sand. Concrete properties (compressive strength, water absorption and porosity) were analyzed for untreated WFS and reclaimed WFS as partial replacement of sand (5%, 15%, 25%, 35% and 50%). On the basis of the results from the present study, following conclusions are drawn.

Based on the test carried out on the five mixtures the following conclusion has been made:

- The fineness and high water absorption properties of the WFS and Reclamation of WFS reduce the workability of the concrete, and the workability of the concrete also decreases with an increase in the WFS substitution rate.
- In all ages of concrete, the strength properties of the concrete mixtures containing WFS and Reclamation of WFS up to 20% was relatively close to the strength value of the CM.
- The concrete mixtures of WFS and Reclamation of WFS 25% and 35% showed a decrease in compressive strength of only 1.6% and 5.7%, respectively, at the age of 28 days when compared to the CM.
- Water absorption, voids, porosity decreases with addition of WFS and Reclamation of WFS compared to control mix.

- From the results obtained it is suggested that WFS and Reclamation of WFS with a substitution rate up to 25% can be used effectively as a fine aggregate in good concrete production without affecting the concrete standards.

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