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# Performance of Silica Fume on the Strength Characteristics of Recycled Aggregate Concrete

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**Abstract -** *The various studies related to sustainable concrete construction have encouraged recycled aggregate which is a partial replacement of natural aggregate in concrete mixes. The significance of silica fume (SF) in concrete mix will improve the quality of recycled aggregates in concrete. The Portland cement was replaced with Silica Fume at 0%, 5% and 10%. The coarse aggregate in concrete mix is replaced by 0%, 25%, 50%, 75%, and 100% of recycled coarse aggregates (RCA). The compressive strength and split tensile strength of concrete made with recycled aggregates are evaluated.*
*Manufacturing of recycled aggregate concrete with silica fume consists of different methods to increase the strength of RCA such as surface treatments, three stage mixing and pozzolanic material. In this paper, the method of using pozzolanic material is studied. In this silica fume is used as pozzolanic material.*

***Keywords***: *Recycled aggregate, recycled coarse aggregate concrete, Silica fume, Compressive strength, Split tensile strength.*

## 1.INTRODUCTION

Construction and Infrastructure industries have made a huge difference with regards to development in today's world and we need to mention 'concrete' in our context as a key material for these industries. Concrete is basically a uniform mixture of various materials which glue together to form a hard and durable compound. Cement, Fine aggregates Coarse aggregates and water are basic components required to generate a conventional concrete mix and any other mineral or material added to the mix apart from these components are called admixtures. Discussing about the components here's some data about what actually concrete comprises are cement which is the binder in the mix which is manufactured using lime stone as the raw material, the coarse aggregates are generally quarried from mines and for fine aggregates are quarried and transported from river beds. The quarried rocks are crushed and sieved to desired sizes. The 4/5$^{th}$ part of concrete comprises of the aggregates.

embankments, many types of general bulk fills and fill materials for drainage structures.

**Advantages of recycling of construction materials:-**

- Used for construction of precast & cast in situ gutters &kerb's.
- Cost saving: - There are no detrimental effects on concrete & it is expected that the increase in the cost of cement could be offset by the lower cost of Recycled Concrete Aggregate (RCA).
- Save environment: - There is no excavation of natural resources & less transportation. Also less land is required.
- Save time: - There is no waiting for material availability.

- The project investigates about the effect of replacement of silica fume on fresh and hardened properties of recycled aggregate concrete. Most of the research work done on replacement of coarse aggregate to certain extent only. This study focused on use of 100% recycled aggregate and premium silica fume is used to replace ordinary Portland cement by 5% and 10% to improve the workability and strength of recycled aggregate concrete.

- **OBJECTIVE AND SCOPE:**

- The objective of this paper is to increase the properties of recycled aggregate. The strength of the recycled coarse aggregate will be decreased due to high water absorption. To overcome this there are certain methods such as Surface treatment method, mixing methods, Pozzolanic materials. The best method is by addition of pozzolanic material to improve strength and workability. Here Silica Fume is used as the pozzolanic material. Triple mixing method is used in the concrete mix design. The recycled aggregates are used by replacing the entire aggregate volume which sums to 80% of total concrete quantity.

**CHAPTER 2**
**LITERATURE REVIEW**

**N.Siva kumar et al., (2014) [1]** studied on **"Experimental Studies on High Strength Concrete by using Recycled Coarse Aggregate"**. The scope of this project was to investigate the possibility of using low cost recycled coarse aggregates as an alternative material to coarse aggregate in high strength structural concrete. The

experimental investigation were carried out using detailed strength and durability related tests such as compressive strength.

**N.K.Amudhavalli et al., (2012) [2]** studied on **"Effect of silica fume on strength and durability parameters of concrete"**, the influence of silica fume on concrete and found that 10-15% of silica fume replacement increases.

**Ozgur Cakır et al., (2014) [3]** carried out experiments to find out "**Influence of silica fume on mechanical and physical properties of recycled aggregate concrete**". They studied the effects of incorporating SF (silica fume**properties of concrete containing micro-silica and nano-silica**". Micro-Silica and Nano-Silica are used as partial replacement of cement for the preparation of concrete. In this investigation cement is partially replaced by 5% and 10% of Micro-Silica and 1.5% and 3% of Nano-Silica by weight

## MATERIALS

The experimental program was planned to study and improve the properties of recycle concrete aggregate such as workability and strength, by using pozzolanic material. The pozzolanic material used is Silica Fume.

### 1 Cement

Cement can be defined as a bonding material that has cohesive & adhesive properties which makes it capable to unite with different construction materials in forming a compacted material. An OPC 53 grade of KCP cement is used in this investigation.

### Fine Aggregate

Fine aggregate used in this investigations is clean river sand was purchased from a nearby dealer in Gudivada, which are typically the same materials used in normal concrete mixture.

### Coarse Aggregate

In this investigation, locally available crushed stone aggregate of size 20mm and down in Gudivada are used and various test are carried out on coarse aggregate as per IS 2386- 1963 (part 3). For this study, two types of coarse aggregates were used for the preparation of concrete i.e. Natural coarse aggregate (NCA) and Recycled coarse aggregate (RCA).

### Recycled Coarse Aggregate (RCA)

Recycled coarse aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. Recycled concrete aggregates mainly differ from natural aggregates in that they are composed of two different materials:

1. Natural aggregate and
2. Cement mortar attached.

Recycled coarse aggregate are obtained from concrete waste. Recycled aggregates contains high absorption, rough texture and angular than natural aggregates that affect the concrete mix proportion. The environmental benefits increase by using these recycled coarse aggregates in the preparation

### The Use of Recycled Aggregate in Concrete

The use of crushed aggregate from either demolition concrete or from hardened leftover concrete can be regarded as an alternative coarse aggregate, typically blended with natural coarse aggregate for use in new concrete. The use of 100% recycled coarse aggregate in concrete, unless carefully managed and controlled, is likely to have a negative influence on most concrete properties-compressive strength, modulus of elasticity, shrinkage and creep, particularly for higher strength concrete. Also the use of fine recycled aggregate below 2 mm is uncommon in recycled aggregate concrete because of the high water demand of the fine material smaller than 150μm, which lowers the strength and increases the concrete shrinkage significantly. Many overseas guidelines or specifications limit the percentage replacement of natural aggregate by recycled aggregate. In general leftover concrete aggregate can be used at higher replacement rates than demolition concrete aggregate. With leftover concrete aggregate, information will generally be known about the parent concrete.

### 5 Water

In this study portable water is used confirming to IS:456-2007. The water used for the study was free of acids, organic matter, suspended solids, alkalis and impurities which when present may have adverse effect on the strength of concrete

### 6 Silica Fume

Silica fume, also known as micro silica, is a by-product material that is used as a pozzolan. Electric arc furnaces used in the manufacture of ferrosilicon or silicon metal release silica fume as a by-product. The fume, which has a

high content of very fine spherical particles of silicon dioxide, is collected by filtering the gases escaping from the furnaces. Silica fume rises as an oxidized vapour from the 2000°C furnaces. When it cools it condenses and is collected in huge cloth bags.

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**3 MIXING PROCEDURE**

Mixing of ingredients is done in pan mixer of capacity 50 liters. The cementations materials are thoroughly blended and then the aggregate is added and mixed followed by gradual addition of water and mixing. Wet mixing is done until a mixture of uniform colour and consistency are achieved which is then ready for casting. Before casting the specimens, workability of the mixes was found by slump cone test.

There are 3 types of mixing methods

a) Normal mixing method
b) Double mixing method
c) Triple mixing method

**CASTING SPECIMENS**

The cast iron moulds are cleaned of dust particles with mineral oil on all sides before concrete is poured in to the moulds. The moulds are and applied placed on a level platform. The well mixed concrete is filled in to the moulds and kept on vibration table. Excess concrete was removed with trowel and top surface is finished level and smooth as per IS 516-1969.

**CURING OF SPECIMENS**

The specimens are left in the moulds undisturbed at room temperature for about 24 hours after casting. The specimens are then removed from the moulds and immediately transferred to the curing tank i.e. cubes are cured in fresh water

**6 TESTING OF SPECIMENS**

A time schedule for testing of specimens is maintained to ensure their proper testing on the due date and time. The cast specimens are tested as per standard procedures, immediately after they are removed from curing tanks or curing tubs and wiped off the surface water, as per IS: 516-1959. A compressive strength testing machine of 2000KN capacity is used

**WORKABILITY:**

The property of concrete which determines the amount of useful internal work necessary to produce full compaction is known as workability. Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding or Segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs or pockets may also be visible in finished concrete. The workability was measured using slump cone apparatus for different percentage replacement of natural coarse aggregate with recycled aggregate.

The workability of fresh concrete depends mainly on the material, mix proportion and environmental conditions. Fresh concrete containing silica fume is more cohesive and less prone to segregation than concrete without silica fume. As the silica fume content is increased, the concrete may appear to become sticky.

**Factors affecting workability**:

1. Method and duration of transportation
2. Quantity and characteristics of materials.
3. Aggregate grading, shape and surface texture
4. Quantity and characteristics of chemical admixtures
5. Amount of water
6. Amount of entrained air

**COMPRESSIVE STRENGTH:**

Compressive Strength is determined by loading properly prepared and cured cubic, cylindrical or prismatic specimens under compression. The compressive strength of concrete specimens is calculated by using the compressive testing machine (CTM) which is having capacity of 2000KN. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed to the nearest $N/mm^2$.

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Among many test applied to the concrete, this is given utmost important which has an idea view about all the characteristics of concrete. The test values obtained with this process one can predict whether the concrete is properly casted or not.

The cubes of size 150×150×150mm were casted. After 24 hours, the specimens are removed from the moulds and subjected to curing for 7 days and 28 days in portable water. After curing, the specimens are tested for compressive strength using compression testing machine of 2000 KN capacity (IS: 516 – 1959). The maximum load at failure is taken. The average compressive strength of concrete specimens is calculated by using the following equation. The average compressive strength of concrete specimens is calculated.

$$\text{Compressive strength of concrete} = \frac{\text{Ultimate compressive loa}}{\text{Area of cross section (mm s}}$$

contribution of silica fume to strength development after 28 days is minimal.

### 5.4 SPLIT TENSILE STRENGTH:

It is well known that the concrete is weak in tension. Tensile strength is one of the basic important properties of the concrete. The tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking takes place is a form of tension failure. The usefulness of the splitting cube test in assessing the tensile strength of concrete is widely accepted in the laboratory.

The cylinders are of size 150 mm diameter and 300mm length is casted. After 24 hours, the specimens are removed from the moulds and subjected to curing for 7 days and 28 days in portable water. After curing, the specimens are tested for split tensile strength using compression testing machine of 2000 KN capacity (IS: 516 – 1959). The maximum load at failure is taken

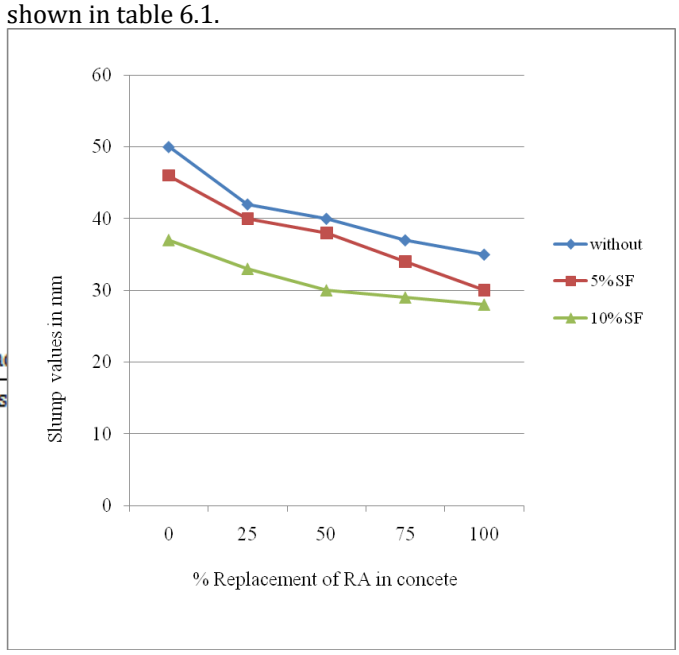
## RESULTS AND DISCUSSIONS

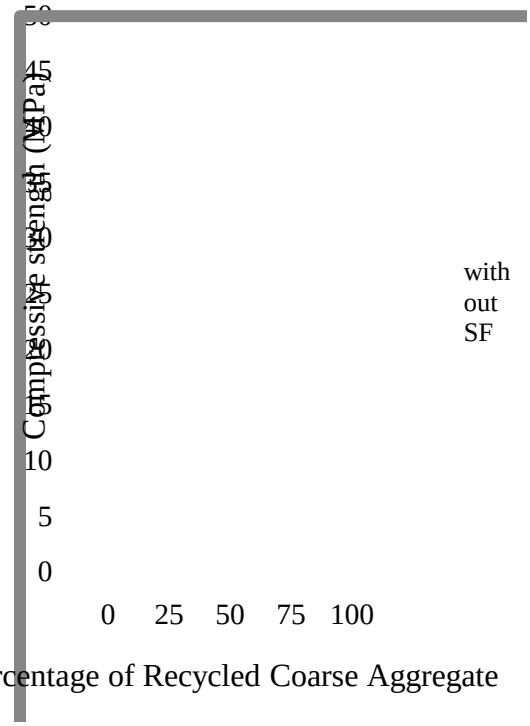
### 6.1 INTRODUCTION

Three Mixes of concrete cubes of size 150×150×150mm are prepared. These three are prepared with different percentage replacement of recycle coarse aggregate i.e. 25%, 50%, 75%, and 100%. Mix 1 is prepared with 0.43 w/c ratio without any cement replacement and Mix 2 is prepared by replacing 5% cement with silica fume with 0.42 w/c ratio and Mix 3 is prepared by replacing 5% cement with silica fume with 0.42 w/c ratio. Super plasticizer (SP 430) is also added (i.e., 0.9% of cement used) for the three mixes to improve the workability. The pozzolanic material Silica fume is used in recycled aggregate to improve proper bonding between the cement paste and aggregate. For the three sets workability, compressive strength and split tensile strength are tested.

### 6.2 SLUMP RESULTS

Workability of the three mixes Mix 1, Mix 2 and Mix 3 is gradually decreased with increase in percentage of recycled aggregates. The set with 5% and 10% silica fume has less workability compared to without silica fume. Workability with different % of RCA (in slump value) is shown in table 6.1.

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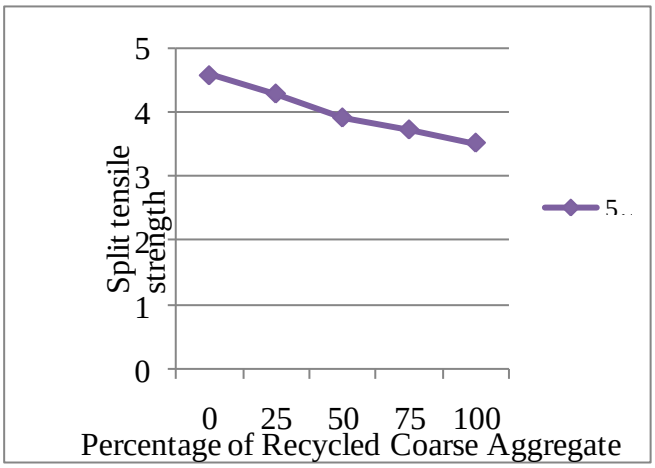


**SPLIT TENSILE STRENGTH RESULTS**

The split tensile strength results obtained after the curing of 7 days and 28 days are shown in the table 6.3. Figures 6.10, 6.11, 6.13 represent the split tensile strength for 28 days without silica fume and with 5% and 10% silica fume. Figures 6.14, 6.15 represent the combined values of split tensile strength for mixes without silica fume and with 5% and 10% silica fume. The split tensile strength of the three sets is also decreased with the increase in percentage of recycled aggregates. The split tensile strength also shows the similar pattern of results as the compressive strength results.

**CONCLUSIONS**

The following conclusions are made from the study:

1. The reduction in compressive strength of recycled concrete is observed when the natural aggregates are replaced with recycled coarse aggregate by 25, 50, 75 and 100% respectively. This may be because of the loose mortar around the recycle aggregate which do not allow the proper bonding between the cement paste and aggregate.
2. The strength (30 MPa) is generally used for a wide range of structural uses. From the present study it is concluded that without decreasing the water-cement ratio, the target mean strength of above mentioned grade of concrete can be achieved through recycled aggregates and Silica fume.
3. For 5% replacement of silica fume in cement the strength value increases when compared to 10% of silica fume.
4. At 28 days 100% replacement of RCA with addition of silica fume achieves strength of 32.63 MPa. In a long period of time this strength can be achieved to the strength of natural aggregate concrete.

The 100% Recycled Aggregate Concrete attained strengths equal to that of specimens casted with 100% normal aggregates when the cement is replaced with 10% silica fume

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