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# Experimental Investigation of Partial Replacement of Fine and Coarse Aggregates by the Components of Zari Along with the Steel Slag

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**Abstract- This paper presents the results of Design and investigations carried out to evaluate the effects of replacing fine and coarse aggregate with Steel slag along with the components of Zari on various concrete properties. The main purpose of utilizing the Zari in this project is to minimize the environmental pollution and wastage of valuable metals like Gold and Silver. The basic objective of this study is to identify the alternative source of good quality aggregates which is depleting very fast due to the fast pace of construction activities in India. Use of zari, a waste industrial byproduct of weaving industry provides great opportunity to utilize it as an alternative to normally available aggregates. In this study, Concrete of M30 grade is considered for a W/C ratio of 0.45 for the replacements of 0%, 5%, 10% and 15% of both fine and coarse aggregates by zari slag. Whole study was done in two phases, i.e. replacement of normal crushed coarse aggregate with melted and crystallized zari slag and replacement of natural fine aggregate with melted and granular zari slag. This project shows that replacing of natural aggregates by steel slag aggregates along with the components of zari causes a negligible degradation in strength. It also shows that, as the amount of zari slag is increased beyond 75%, the workability of the concrete mixture became an important issue which eventually requires larger amounts of water reducing admixtures to achieve a minimum slump.**

**Keywords:- Experimental investigations, partial replacements, fine and coarse aggregates, Zari components, Steel slag.**

## I. INTRODUCTION

Concrete is the most widely used material on earth after water for the process of construction. Many aspects of our daily life depend directly or indirectly on concrete. Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete is unique among major construction materials in the civil engineering projects.

Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues those together. Almost three quarters of the volume of concrete is composed ofaggregates.To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete. Natural aggregates are obtained from natural rocks.

They are inert, filler materials and depending upon their size they can be separated into coarse aggregates and fine aggregates. The coarse aggregate fraction is that retained on 4.75 mm (No 4) sieve, while the fine aggregates fraction is that

passing the same sieve. During the past 25 years, the production of crushed stone has increased at an average annual rate of about 3.3 percent.

Production of sand and gravel has increased at an annual rate of less than 1 percent. Based on these numbers, by 2020 U.S. production of crushed stone, which is expected to increase by more than 20 percent, will be about 1.6 billion metric tons, while production of sand and gravel will be just under 1.1 billion metric tons, an increase of 14 percent.

In essence the amount of crushed stone to be produced in the next 20 years will equal the quantity of all stone produced during the previous century i.e. about 36.5 billion metric tons. Therefore the use of alternative sources for natural aggregatesis be coming increasingly important. Whereas, Indian silk industry is one of the premier industries producing silk and next to China.

One among the product using silk is Zari yarn. The zari is a value added yarn manufactured using silk and metal. This material is comprised of three components consisting of Silver, Gold and Silk in the core position. This yarn is manufactured using the wrap spinning technique in which the flattened silver wire is wrapped on to the silk yarn and then coated with gold.

The zari is mostly used in the saree border.During the process of weaving the sarees, nearly 30% to 40% of the zari is removed from the sarees because of their useless placements in the design. And hence, the aim of this project is to use this wastage zari in various forms in the concrete mix in order to increase its strength along with the properties of its raw materials like silver, gold and other metals.

The use of zari waste in concrete by replacing natural aggregates is a most promising concept.

Zari concrete can be used due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity.

In northern parts of Karnataka and some other parts of Gujarat and Andhra Pradesh, the construction companies are using the impure form of Gold and Silver mixedwith concrete for construction of some mega structures like bridges and dams, etc. The only potential problem with wasted zari is its expansive characteristics and undesirable reactions between slag and components of concrete.

## II. PROPERTIES

**1. Properties of Gold:**

- Density (g/cc) :19.3
- Melting Point (°K) :1337.58
- Boiling Point (°K) : 3080
- Appearance : soft, malleable, yellow metal
- Atomic Radius (pm) :146
- Atomic Volume (cc/mol) :10.2 Covalent Radius (pm) 134
- Ionic Radius : 85 (+3e) 137 (+1e)
- Specific Heat (@20°C J/g mol) : 0.129
- Fusion Heat (kJ/mol) : 12.68
- Evaporation Heat (kJ/mol) : ~340
- Debye Temperature (°K) : 170.00
- Pauling Negativity Number : 2.54
- First Ionizing Energy (kJ/mol) : 889.3
- Oxidation States : 3,1
- Lattice Structure :Face-Centered Cubic(FCC)
- Lattice Constant(Å) : 4.080
- Specific Gravity (20°C) : 18.88
- CAS Registry Number :7440-57-5

**2. Properties of Silver:**

- Density(g/cc) :10.5
- Appearance : silvery, ductile, malleablemetal
- Isotopes : There are 38 known isotopes of silver.
- Atomic Radius (pm) :144
- Atomic Volume (cc/mol) : 10.3
- Covalent Radiu (pm) : 134
- Ionic Radius : 89 (+2e) 126 (+1e)
- Specific Heat (@20°C J/g mol) : 0.237
- FusionHeat(kJ/mol) :11.95
- Evaporation Heat (kJ/mol) : 254.1
- Debye Temperature (K) :215.00
- Pauling Negativity Number : 1.93 First Ionizing Energy (kJ/mol):730.5
- Thermal Conductivity : 429 W/m•K@ 300 K
- Oxidation States : +1, +2,+3
- Structure :Face CenteredCubic
- Lattice Constant (Å) : 4.090
- CAS Registry Number :7440-22-4

**3. Properties of Zari with Steel slag**

- Density (kg/cum) :1645
- Specific Gravity :2.80
- Water Absorption :0.40%
- Fineness Modulus :2.64

**4. Properties of Aggregates:**

Table 1. Properties of Aggregates.

| Natural Coarse Aggregate (Physical Properties) | |
|---|---|
| Specific Gravity | 2.82 |
| Water Absorption | 0.55% |
| Dry density | 1322 kg/cum |
| Soundness | 0.55% |
| Fineness modulus | 4.16 |
| Zone | - |
| Abrasion Value% | 22 |
| Impact Value% | 16 |
| Crushing Value % | 23 |

Table 2. Properties of Aggregates.

| Natural Fine Aggregate (Physical Properties) | |
|---|---|
| Specific Gravity | 2.70 |
| Water Absorption | 0.65% |
| Dry density | 1468kg/cum |
| Soundness | 0.90% |
| Fineness modulus | 2.64 |
| Zone | II |
| Abrasion Value% | - |
| Impact Value% | - |
| Crushing Value % | - |

Steel slag aggregates have two main features which are of concern to their use in construction, namely, volume expansion and high particle density. During the making of steel there is a small percentage of calcium and magnesium oxides which is left undissolved in the slag. These changes in volume can occur either in a few weeks after production of slag or may occur many years later if the slag is initially protected from contact with water.

A general method usually used to overcome the expansion problem is to store the slag for aging in stockpiles for some four to six months before using it. Density of steel slag is also an important issue to be considered. Steel slag is a heavier material than natural rock types such as basalt, granite, or limestone. Thus, any given volume would require about 15 to 25% greater tonnage of steel slag than traditional natural aggregates which may create an economic disadvantage for steel slag in some applications where transportation costs are significant.

## III. MIX PROPORTIONS

Mix proportions for fine and coarse aggregate replacement.

Table 3. Mix Proportions.

| % | 0% | 5% | 10% | 15% | w/c ratio |
|---|---|---|---|---|---|
| $M_{30}$ | 1:1.8:3.37 | 1:1.7:1:3.2 | 1:1.62:3.03 | 1:1.53:2.86 | 0.45 |

Size and Number of Specimens used for the replacement of the Zari Slag for Fine and Coarse Aggregate.

Table 4. Size and Number of Specimens.

| Specimen | Size (mm) | No. of Specimen |
|---|---|---|
| Cube | 150 x 150 x 150 | 12 |
| Beam | 100 x 100 x 500 | 12 |
| Cylinder | 150 dia., 300h | 12 |

Then the moulds are casted and cured for conducting the tests.

## IV. TESTING AND ANALYSIS

**1. Compressive Strength Test:**

The cubes of size 150 x 150 x 150 mm are placed in the machine such that load is applied on the opposite side of the cubes as casted. It is aligned carefully and load is applied, till the specimen breaks.The failure load of compressive strength of the cube is calculated by using the formula, Compressive Strength= Total Failure Load/ Area of the Cube

**2. Split Tensile Test:**

The test is carried out by placing cylinder specimen of dimension 150 mm diameter and300 mm length,

horizontally between the loading surface of compression testing machine and the load is applied until failure of the cylinder along the vertical diameter occurs. The failure load of the specimen isnoted.The failure load of tensile strength of the cylinder is calculated by using the formula,

**Tensile Strength = 2P / 3.14 DL**

**3. Flexural Strength Test:**

The test is carried out to find the flexural strength of the beam of dimension 100 x 100 x500 mm. The beam is then placed in the machine in such manner that the load is applied to the uppermost surface as cast in the mould. Two pointsloading adopted on an effective span of 400 mm while testing the prism.

The load is applied until the failure of the beamoccurs.The failure load of flexural strength of the beam is calculated by using the formula,

**Flexural Strength = PL/Bd2**

## V. LITERATURE COLLECTIONS

**P. S. Kothai, et al:** In this research study, the OPC of 53 grades has been used and the fine aggregate has been replaced by steel slag accordingly in the proportion of 0%, 10%, 20%, 30%, 40%, 50% by weight of M20 grade concrete. Concrete mixtures were produced, tested and compared in terms of compressive strength of the conventional concrete at 28 days.

**S. T. Borole, et al:** In this, experimental investigation has been carried out on the test specimens to study the strength properties as a result of replacing coarse aggregate by steel slag in various percentages namely 0%, 25% and 50% of steel slag. The OPC of 53 grade, natural river sand, and crushed granite coarse aggregates, the impure form of gold and steel slag has been used.

**Gozde Inan Sezer, et al:** In this study, the use of steel slag as fine and/or coarse aggregate in concrete is investigated. For this purpose 12 different concrete mixtures with different w/c of 0.40, 0.55 and 0.70 which include steel slag aggregate as fine and/or coarse aggregate are prepared. Compressive strength, split tensile strength, flexural strength, freeze-thaw resistance and water penetration depth of concrete mixtures containing steel slag aggregate are examined in comparison with concrete mixtures prepared by using limestone aggregate.

**Shriver padha, et al:** This study is to evaluate the various properties of a concrete obtained by partial replacement of fine aggregate by steel slag and primitive forms of gold and silver.

Apart from cement, fly ash and meta-kaolin were used as binding material.

**Ansu John, et al:** The steel slag along with silver content from basic oxygen furnace was been used for the study. Compressive strength test were conducted on samples with slag ratio of 0%, 25%, 50%, 75% and 100% and cement content of 200 kg/m3, 300 kg/m3 and 350 kg/m3.

**Mahadev shreemanth, et al:** In this study Ordinary Portland cement of 53 grades has been used. The compressive strength, tensile strength and flexural strength of concrete mixes of M20, M30 and M40 grade of concrete made by 0%, 25%, 50%,75% and 100% replacement of fine aggregate with impure form of gold and silver was tested after 7 and 28 days of curing for w/c ratio of 0.5, 0.45 and 0.40. The result indicated that the compressive strength at 7 days was high.

## VI. TEST RESULT ANALYSIS

Table 5. Compressive Strength Results.

| Sl.No. | % of F.A. | % of Slag for F.A. | % of C.A. | % of Slag for C.A. | Compressive Strength in Mpa (7days) | Compressive Strength in Mpa (14days) | Compressive Strength in Mpa (28days) |
|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 100 | 0 | 19.65 | 27.34 | 34.67 |
| 2 | 95 | 5 | 95 | 5 | 20.06 | 29.57 | 37.46 |
| 3 | 90 | 10 | 90 | 10 | 23.68 | 37.88 | 39.92 |
| 4 | 85 | 15 | 85 | 15 | 21.26 | 35.57 | 38.12 |

Table 6. Split Tensile Strength Results.

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| Sl.No. | % of F.A. | % of Slag for F.A. | % of C.A. | % of Slag for C.A. | Split Tensile Strength in MPa (7days) | Split Tensile Strength in MPa (14 days) | Split Tensile Strength in MPa (28days) |
|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 100 | 0 | 2.26 | 2.41 | 2.45 |
| 2 | 95 | 5 | 95 | 5 | 2.75 | 2.89 | 3.28 |
| 3 | 90 | 10 | 90 | 10 | 3.42 | 3.46 | 4.51 |
| 4 | 85 | 15 | 85 | 15 | 3.31 | 3.32 | 3.92 |

Table 7. Flexural Strength Results.

| Sl.No. | % of F.A. | % of Slag for F.A. | % of C.A. | % of Slag for C.A. | Flexural Strength in Mpa (7 days) | Flexural Strength in Mpa (14 days) | Flexural Strength in Mpa (28 days) |
|---|---|---|---|---|---|---|---|
| 1 | 100 | 0 | 100 | 0 | 2.21 | 2.50 | 2.79 |
| 2 | 95 | 5 | 95 | 5 | 2.68 | 2.95 | 3.82 |
| 3 | 90 | 10 | 90 | 10 | 3.41 | 4.13 | 4.95 |
| 4 | 85 | 15 | 85 | 15 | 3.18 | 3.76 | 4.28 |

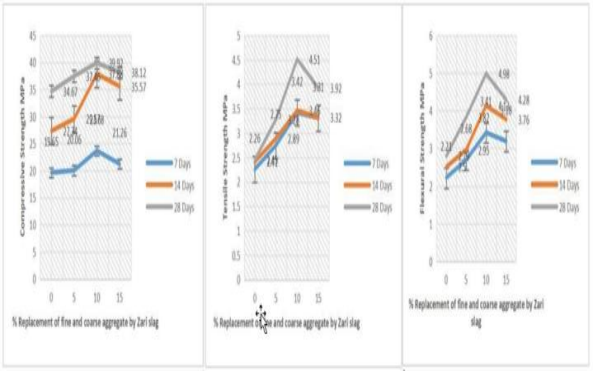

Fig 1. Experimental results.

## VII. CONCLUSION

From the experimental results obtained on the replacement of fine and coarse aggregate partially by the Zari slag on concrete, the following conclusions are drawn,from the result it is appeared that the Zari Slag can be used as a fine and coarse aggregate in concrete mixtures. It is appeared that the partial replacement of the Zari Slag as fine and coarse aggregate is more convenient.

Usage of Zari Slag as a fine and coarse aggregate increases the unit weight of the concrete mixtures. The lowest water penetration depth values were observed in concrete mixtures containing the coarse Zari Slag aggregate. It is found that the replacement of zari with steel slag in concrete gives more effective strength in 10 % optimum replacement.

Due to the presence of several dangerous heavy metals and salts in the zari slag aggregates, some prescribed tests should be carried out to verify its environmental compatibility. The wastage of precious metals like Gold and Silver can be reduced by implementing them in the process of construction. The components along with the silk and steel or coppermat increase their additive property.

## VIII. SUGGESTIONS FOR FUTURE RESEARCH

A much more extensive field study on a concrete structure made with zari slag aggregates used in the mixture should be conducted and changes in durability and mechanical properties should be investigated and correlated to laboratory results.

Further investigation on resistance of concrete with zari slag aggregates to attack by sulfates; alkali silica reactions, carbonation, sea water attack, harmful chemicals and resistance to high temperatures are needed. The behavior of these aggregate concrete under corrosive environments and its fire resistance capacity should also be investigated. The results of such studies would directly benefit the construction industry and broader use of steel slag in concrete would improve overall properties and cost effective solution.

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