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EXPERIMENTAL INVESTIGATION OF FOUNDRY SAND AS A FINE AGGREGATE IN CONCRETE

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ABSTRACT –

High-quality natural river sand is presently limited. River sand is commonly employed as a fine aggregate in concrete. The ban on river sand utilization in numerous areas to preserve riverbeds has significantly increased the demand for alternative fine aggregates in the construction sector, as natural river sand takes millions of years to form. To resolve this issue, a material with properties similar to those of Fine Aggregate may be employed as a substitute in Concrete.

The increasing quantities of waste materials and industrial by-products are a major global issue. The handling of industrial by-products poses a substantial challenge due to stringent environmental regulations. Metal foundries employ significant amounts of sand in the metal casting procedure. Foundry sand is a fine aggregate commonly employed in both manual and mechanical molds. Foundry sand often exhibits a sub-granular to rounded morphology after its application in the foundry process.

A 1:1.23:2.19 mixture is employed for both partial and complete replacement of sand with foundry sand. Cubes and cylinders are molded and cured to conduct compressive strength and split tensile tests on control specimens at 7 and 28 days. The remaining replacement combinations will be formulated and evaluated thereafter. The ideal replacement of foundry sand in concrete can be ascertained.

I. INTRODUCTION

India is presently implementing substantial attempts to enhance infrastructure, encompassing express roads, power projects, and industrial facilities, to meet the demands of globalization in construction. Concrete is essential, and a significant quantity is utilized in all construction processes. River sand, an essential element in traditional concrete manufacturing, has become progressively expensive and scarce due to the depletion of riverbeds. As a result, synthetic sand is employed instead of natural sand.

The latest revision of IS 456:2000 highlights the durability aspects of concrete. The use of concrete is essential. Concurrently, the scarcity of aggregates has markedly increased in recent times. The utilization of industrial soil waste or secondary materials in the production of cement and concrete is promoted as it reduces the consumption of natural resources.

For many years, by-products such as fly ash, silica fume, and foundry sand were considered waste items. They have been efficiently employed in the building industry as partial or total replacements for fine and coarse materials. Specific by-products are employed as an alternative to Portland cement.

II. OBJECTIVES

1. To effectively utilize the waste materials from metal industries. (Recycling of wastematerial)
2. To reduce the problem of disposal of industrial waste.
3. To minimize the requirement of natural sand.
4. To reduce the cost of concrete production as well as the cost of disposal of wastematerials
5. To prove that the industrial waste from metal industries can be a replacement for fineaggregate.
6. To study the physical and chemical properties of industrial waste and are the ingredientsin concrete.
7. To replace the fine aggregate by industrial waste in different ratios such as 20%, 40%,60%, 80% and 100% in M30 mix concrete.
8. To determine the compressive strength and lateral deflection, and compare it withconventional concrete member.

III. METHODOLOGY

1. A literature survey to identify the foundry sand, their methods of application, propertiesand important tests for performance evaluation.
2. Collection of required materials for the project.
3. Identification of suitable materials using mix design as per IS code.

4. Replacement of fine aggregates with foundry sand (20%, 40%, 60%, 80% and 100%).
5. Determine the ultimate compressive strength, Split tensile strength of concrete usingreplaced fine aggregate at different percentage.
6. Testing of specimens.
7. Comparison of test results.

IV. MATERIALS

FOUNDRY SAND

Foundry sand primarily consists of clean, uniformly graded, high-quality silica sand or lake sand, employed in the production of molds for ferrous (iron and steel) and nonferrous (copper, aluminum, brass) metal castings. Although initially clean, these sands may harbor ferrous impurities post-casting, with the iron and steel industries accounting for around 95 percent of foundry sand employed in castings. It is a by-product of the ferrous and nonferrous metal casting industries, where sand has been employed for centuries as a molding medium owing to its heat conductivity. Foundry sand can improve the strength and durability properties of concrete.

Green Sand (Clay Sand)

Clay sand is a mixture of natural silica sand, clay, additives, and water. The clay employed to manufacture wet clay sand is bentonite clay. The compressive strength generally varies from 0.05 to 0.1 MPa. The moisture content varies between 3.5% and 5%, while the air permeability surpasses 80. It is commonly employed in machine molding and hand molding.

The generated sand can be employed for casting liquid metal without drying, providing advantages of minimal production expenses and a short producing duration. Wet clay sand employed in sand casting production comprises around 60%. The elevated moisture content in wet sand yields diminished strength and air permeability, resulting in casting defects such as porosity, coarse texture, stickiness, and sand expansion. Hand molding has limited dimensional precision, rendering it appropriate only for the fabrication of small to medium-sized castings in iron and non-ferrous alloys. Conversely, mechanical modeling attains superior dimensional precision, making it suitable for high-volume casting manufacturing.

The clay employed for manufacturing dry sand clay is conventional clay, distinguished by its elevated moisture content. The sand should be desiccated at a temperature ranging from 250 to 400 °C prior to amalgamation for casting, and it is predominantly employed for steel castings. Dry sand is being rapidly phased out due to excessive energy consumption, extended manufacturing cycles, and insufficient dimensional accuracy.

Water Glass Sand (Sodium Silicate Sand)

Sodium silicate sand is a foundry sand that employs sodium silicate, an aqueous solution, as the binding agent. Sodium silicate accounts for 6% to 8% of the sand's quality.

Water glass hardening is crucial before pouring to augment strength. The hardening methods encompass chemical hardening utilizing CO2 gas and drying the heated surface. The hardening ingredient may be integrated into the sand, leading to self-hardening. The incorporation of sodium silicate sand markedly optimized the sand molding process by removing or greatly reducing the drying phase.

However, because to its insufficient collapsibility and difficulties related to falling sand, sand cleaning, and sand recycling, it adheres excessively in iron casting, making it inappropriate for this application; it is predominantly employed in steel casting manufacturing.

Resin Sand (Phenolic, Furan)

Resin sand is a foundry sand that employs synthetic resin, such as phenolic or furan resin, as the binding agent. The integrated resin comprises roughly 3% to 6% of the sand quality. Resin sand may quickly solidify when exposed to heat for 1 to 2 minutes, demonstrating significant dry strength, which produces precisely sized castings with a smooth surface and remarkable collapsibility.

The modeling process is more conducive to mechanization and automation owing to its rapid drying and self-hardening characteristics. Resin sand is a novel modeling substance primarily employed in the fabrication of complex sand cores.

Considering that different sands offer unique benefits, it is essential in metal casting to choose the suitable type to meet various needs.

CEMENT

Cement broadly refers to sticky compounds, but more specifically, it denotes the binding materials employed in construction and civil engineering. It is a material that autonomously cures and solidifies, capable of adhering other substances together. The volcanic ash and crushed brick components used with burnt lime to create a hydraulic binder were thereafter referred to as cementum and cement. Cements employed in construction are categorized as hydraulic or non-hydraulic. The principal use of cement is in the production of mortar and concrete, which bind natural or artificial aggregates to form a durable construction material that withstands standard environmental conditions. The primary type of cement employed is Ordinary Portland Cement. Portland cement is the essential constituent of concrete, mortar, and most non-specialty grout.

The Bureau of Indian Standards (BIS) has classified Ordinary Portland Cement (OPC) into three specific grades: 33 Grade, 43 Grade, and 53 Grade. The grades indicate the compressive strength of cement concrete following 28 days of curing.

FINE AGGREGATE

Fine aggregate is the natural material that fills the voids between coarse aggregate. River sand, with a fraction passing through a 4.75 mm sieve and retained on a 600 µm screen, was employed and evaluated in line with IS:2386. . Fine aggregate is included into concrete to improve workability and maintain consistency in the composition. Fine aggregates must be free of coagulated clumps.

COARSE AGGREGATE

It improves the concrete's integrity, reduces shrinkage, and fosters cost efficiency. The aggregate comprises 70-80% of the concrete's volume. It must be resilient, compact, enduring, immaculate, and free from clay or loamy combinations, quarry waste, or organic substances. The aggregate components must be either cubical or spherical, featuring granular, crystalline, or smooth (but not glossy) non-powdery surfaces. Aggregates must be properly screened and, if necessary, meticulously cleansed before use. The categorization of coarse aggregates must comply with the stipulations specified in IS-383. Aggregate retained after passing through a 4.75mm sieve is termed coarse aggregate. Gravel, cobbles, and boulders are included in this category. The maximum size of the utilized aggregate may depend on specific circumstances. Generally, 40mm aggregate is used for standard strength concrete, whereas 20mm aggregate is utilized for high strength concrete. The designated size range for various coarse aggregates is outlined below.

V. MIX DESIGN

At present there are numerous scientific methods of proportioning the materials for a desired concrete strength. It is extremely difficult to select a better method because every method completes by a little trial at the end. The aim of designing a mix is to reduce the quantity of cement to the maximum extent possible without sacrificing strength characteristics.

The grade of concrete to be adopted for this project work has to be similar to M30. Since comparison is to be made with the standard M30 mix.

- Tests are done with constant strength for conventional Mix of strength = 30 Mpa N/mm^2
- Mix design calculation was done as per IS 10262 : 2009
- Based on the % of foundry sand, the strength and density of conventional concretemix will get vary.
- % of foundry sand added = 0%, 10%, 20%, 30%, 40%,50%, 60%,70%,80%
- ,90%,100%.

Water	Cement	Fine Aggregate	Coarse Aggregate
191.6 (L)	504.21 Kg	622.3 Kg	1106.41 Kg
0.38	1	1.23	2.19

VI. FRESH CONCRETE PROPERTIES

SLUMP CONE TEST

The slump cone test is the primary technique for evaluating consistency. It fails to evaluate all factors affecting workability. It functions as a control test and signifies the uniformity of batches.

Concrete is considered workable if it can be easily mixed, placed, compacted, and finished. A functional concrete mixture must demonstrate no segregation or bleeding. Segregation transpires when coarse aggregate disassociates from finer material, leading to a localized accumulation of coarse aggregate. This results in considerable voids, decreased durability, and weakened strength. Concrete bleeding transpires when excess water ascends to the surface of the concrete. This creates small pores within the concrete matrix, which is unfavorable.

Unstable fresh concrete laterally displaces, leading to a decrease in height. This vertical displacement is termed a slump. The slump serves as a measure of the consistency or workability of cement concrete. It indicates the water content necessary for concrete used in diverse applications. To determine the slump value, fresh concrete is placed into a mold of specific shape and size, and the resulting slump is measured after the mold is removed. The collapse exacerbates as water content rises. Diverse tasks have specified unique slump values. The following table demonstrates the relationship between workability degree and slump value.

COMPACTION FACTOR TEST

This test is employed to evaluate the workability of concrete when the nominal aggregate size does not exceed 40 mm. Workability is characterized as the property of concrete that determines the effort required for complete compaction. The test primarily entails exerting a certain amount of labor on a defined volume of concrete and assessing the resulting compaction. The compaction factor is the ratio of the weight of partially compacted concrete to that of completely compacted concrete. It must be presented to two decimal places.

The compaction factor test is more sensitive and precise than the slump test, rendering it particularly beneficial for concrete mixtures with extremely poor workability. This concrete may demonstrate a slump rating between zero and minimal. The compaction factor (C.F.) test can indicate slight variations in workability throughout a wide range. The compaction factor test indicates that an increase in coarse aggregate size leads to a reduction in workability. Nevertheless, the compaction factor test has particular limitations. When the maximum aggregate size substantially surpasses the mean particle size, deposition in the bottom container will cause segregation, resulting in an inaccurate comparison with other mixtures that have lesser maximum aggregate sizes. Moreover, the procedure of pouring concrete into molds is distinct from the more common practices of placing and compacting high concrete.

VII. HARDENED CONCRETE PROPERTIES

COMPRESSIVE STRENGTH TEST

The concrete is blended in exact ratios, placed into the mold, and sufficiently compacted to remove any voids. Following a 24-hour period, the molds are extracted, and the test specimens are submerged in water for curing. The upper surface of this specimen must be made homogeneous and polished. This is achieved by applying cement paste and uniformly dispersing it across the whole surface of the specimen. The specimens are subjected to testing with compression testing equipment following a curing period of 3, 7, or 28 days. The load must be progressively increased at a rate of 14 N/mm² per minute until the specimen fails. The failure load divided by the specimen's area determines the compressive strength of concrete. At least three specimens are assessed at each specified age. The specimen's failure is classified as 'hourglass' type failure. This transpires due to the plates providing lateral support to the cubes. The compression testing system produces a complex stress distribution resulting from the end constraints imposed by the steel plates of the compression testing machine (CTM). Under compressive strain, the cube specimen undergoes lateral expansion as a result of the "Poisson's effect." However, the steel platens do not exhibit lateral expansion to the same extent as concrete. Thus, a differential propensity for lateral expansion is present between steel plates and the sidewalls of concrete cubes. This generates tangential forces between the terminal surfaces of the concrete specimen and the adjacent steel plates of the CTM. Thus, in addition to the imposed compressive force, lateral shearing stresses are also considerable in these specimens. The influence of this shear decreases towards the cube's center. The cube displays a nearly vertical fissure in its center, which may occasionally result in complete fragmentation, leaving a relatively unscathed central core.

SPLIT TENSILE STRENGTH TEST

Splitting tensile strength generally surpasses direct tensile strength but is inferior to flexural strength (modulus of rupture). Splitting tensile strength is employed in the design of structural lightweight concrete components to evaluate the shear resistance provided by concrete and to determine the development length of the reinforcement. This testing method entails exerting a diametrical force along the length of a cylindrical concrete specimen at a predetermined rate until failure ensues. This loading induces tensile strains on the plane of application and somewhat significant compressive stresses in the surrounding area of the load. Despite the imposition of a compressive force, tension is induced by the Poisson effect, leading to the specimen's collapse in tension. Tensile failure occurs rather than compressive failure because the load application areas experience triaxial compression, allowing them to withstand far higher compressive loads than indicated by uniaxial compressive strength test results. Slender bearing strips are utilized to uniformly distribute the load applied along the cylinder's length. The maximum load sustained by the specimen is divided by pertinent geometric parameters to ascertain the splitting tensile strength.

VIII. RESULT

SLUMP CONE TEST

Foundry sand (%)	Compaction factor
0	0.97
10	0.97
20	0.97
30	0.96
40	0.96
50	0.95
60	0.95
70	0.95
80	0.94
90	0.94
100	0.94

COMPACTION FACTOR TEST

Foundry sand (%)	Slump in mm
0	58
10	59
20	59
30	58
40	57
50	61
60	61
70	60
80	61
90	62
100	62

HARDENED CONCRETE PROPERTIES

COMPRESSIVE STRENGTH TEST

- Compressive Strength of Concrete cube Specimens is tested after $7^{th}$and 28^{th} days. The test is done using Compression Testing Machine.
- As per IS456:2000 and IS516:1959 the compressive strength value of cubespecimen should not less than 30 N/mm^2

SPLIT TENSILE STRENGTH TEST

- Split Tensile Strength of Concrete Cylinder Specimens is tested after 28^{th} days. Thetest is done using Compression Testing Machine.
- As per IS 456:2000 and IS5816:1999 the split tensile strength of concrete shouldnot less than 1/10 of f_{ck}.

IX. CONCLUSION

Use of foundry sand in concrete can save the ferrous and non-ferrous metal industries disposal, cost and produce a 'greener' concrete for construction. Thus a better measure by an innovative construction material is formed through this research. Based on the experimental study undertaken following conclusions are drawn.

- The properties of materials are found to be good
- Replacement of fine aggregate with WFS showed increase in the compressivestrength and split tensile strength of plain concrete up to 50%
- 50% replacement of fine aggregate with WFS was taken as the optimized mix.
- The value of maximum compressive strength and split tensile strength achieved using50% replacement of fine aggregate with WFS at 28 days is 42.95 N/mm^{2}and 5.78 N/mm^2.
- Using the optimized mix ,the compression member were cast.
- Proved that , the concrete using 50% replacement of fine aggregate with foundry sandcan be use in structural member