DURABILITY OF CONCRETE USING FOUNDRY WASTE SAND

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Accepted by the faculty of the College of Science and Technology, Morehead State University, in partial fulfillment of the requirements for the Master of Science degree.

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Waste foundry sand (WFS) is a by-product of the processing of both ferrous and non-ferrous metal castings. Foundry sand is clear, standard size, and top-quality silica sand.

In this research work, the properties of the foundry waste sand are studied along with its effecting on the concrete strength. The analysis to substitute the varying percentage of foundry sand with standard sand for its concrete cylinder strength, including quality, is analyzed and recommended for use in further construction works. In this study, the foundry sand is replaced with standard sand by 20 percent, 40 percent, 60 percent, and 80 percent, and the relevant properties and strength will be compared. The results show a slight increase in concrete strength and, with a beneficial scheme, a reduced volume of normal sand that is continuously being used and will one day become non-available material. According to this study, the foundry waste sand has been tested with a little positive effect on strength and depicts appropriate and acceptable

strength properties with no harm to the concrete mix. Furthermore, as the results show, the foundry waste sand is highly recommended to be used in construction work.

Accepted by: ________________________________, Chair

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Contents

Detail of Figures

Detail of Tables

CHAPTER I

INTRODUCTION

1.1. INTRODUCTION

Concrete is a crucial component of structural engineering construction practice, which is critical and influences the stability and efficiency of various structures. The compressive strength of the concrete is a test conducted with the aid of a universal test machine or some other compressive strength machines to find the concrete cylinder's strength. The concrete mix specification is the basic quantity/quantity of the various materials used to blend and produce the appropriate concrete properties. The fine and coarse aggregate is the major and prominent ingredients of the concrete, and the properties of concrete change by changing its size, texture, and properties. The quality and strength of the concrete solemnly depending upon the adjustment of the water-cement ratio. The appropriate water-cement ratio is assumed around 0.5~0.70.

Optimal amounts and sizes of the concrete mix product elements are achieved to produce improved post-concrete performance and to enhance the technique. The aggregate size (uniform graded, distance graded, incorrectly graded) must be tested to build the sample for proper examination. This research procedure includes calculating the size of the fine and coarse aggregate sample, specific gravity, and other tests.

Foundry waste sand is collected as a byproduct from industries like iron, metal, etc. These foundry waste may be reused in concrete to reduce the fine aggregate by different acceptable amounts. The study includes the replacement of sand by different percentages, and then further, it can be used in large-scale construction works in more beneficial ways.

1.2.THE PURPOSE OF THE RESEARCH: PROBLEM STATEMENT

Any countries have a variety of issues with the decomposition of by-products from different fields. Foundry sand waste created as a by-product of the steel and metal industry is analyzed by various researchers. It can be used productively in concrete for many construction works. To protect the environment from any harm, these by-products should be used safely for welfare and quality work, where possible. Yeah, it is normal for each industry to decompose by-products safely, and it is more beneficial for each country to reuse waste by-products for this valuable use.

The other significant prospect for research on this topic is the lack of sand sources. As construction work progresses, the supply of sand is diminishing, and broad and detailed studies on the development of foundry sand may replace traditional sand.

In the development of the era and introducing the new concept of Engineering, the foundry waste sand can be used to produce the high strength concrete with higher workability, as cleared and verified from the literature review. As already discussed, the foundry waste sand is produced from industries, and it might vary with its location properties. So, it is necessary to validate the foundry waste sand source; if passed all the criteria according to ASTM rules and regulations, then further can be used in the construction works via used in concrete.

1.3.SIGNIFICANCE & RESEARCH QUESTION

The development of concrete structures starts in ancient times, and many researchers are working on getting less costly, more beneficial results, including this more appropriate environmentally safe construction. Based on the significance and research prospective, introducing the waste products element in the concrete can have a good and reliable effect on the concrete mix and further in terms of positive environmental effect in some ways. But the research for this is always required to use the waste substance as the construction industry is progressing with high proportions, which may help to utilize the waste substance in beneficial ways.

The suggested scale of the gross aggregates would be 38 mm. The size of the gross aggregate depends on the type of concrete, strength, and site-specific characteristics. Literature suggests that concrete compressive power increases as the volume of sand smelting waste increase to a rate of 60%. It is more attractive than unpredictable from the point of view of the minimum space round aggregate. From the point of view of the capacity to bind to the mortar, the round aggregate may be inferior, but in general, the form of the grains may be much less important than their size and hardness.

As the foundry waste, sand has been extensively studied as a constituent material for its deemed characteristics to achieve the desired strength. Its possible application in concrete has not been fully investigated. The findings of using used sand as a partial replacement for regular sand (fine aggregate) in concrete were analyzed in this study.

1.4. RESEARCH OBJECTIVES

The primary objectives of this research are as follow:

- To check the durability of foundry waste sand using experiments.
- To check the usage and accessibility of foundry waste sand.
- Verifying the methodology and mechanical properties of using the foundry waste sand using material testing.
- Finding the optimum percentage of replacement of foundry sand with normal sand and finding the strength-related property with the help of casting the standard cylinder and then testing it. Both the foundry waste cylinders and normal cylinder properties will be compared.

1.5. ASSUMPTIONS AND LIMITATIONS

For the sake of accurate statistics, the reports are often cross-checked. In this study, the traditional casting using fine aggregates and other materials is based on specified ASTM methods. The key point is that the source of the foundry waste sand is satisfactory and can be used for building purposes. It is believed that there is a lot of testing needed to verify the source, and this is performed squarely in large-scale building projects. In this works, we will completely rely upon the industry provider documentation.

Large repositories are available regarding the foundry waste sand. As already discussed, it is a byproduct of several industries. The advantages of using foundry sand as a partial substitute for fine aggregate sand in concrete, particularly regarding the optimal replacement quality or a complete replacement, are discussed in this study.

As mentioned previously, the mix design is prepared as per ACI standards, but it should be kept in mind that the water-cement ratio is the major to a scheme of concrete strength. The minimum water-cement ratio produces more strength as it is workable and cost-effective. On the other hand, cement is the most expensive component in concrete ingredients. The dilemma is easily seen in the schematic graphs of Figure 1.1.

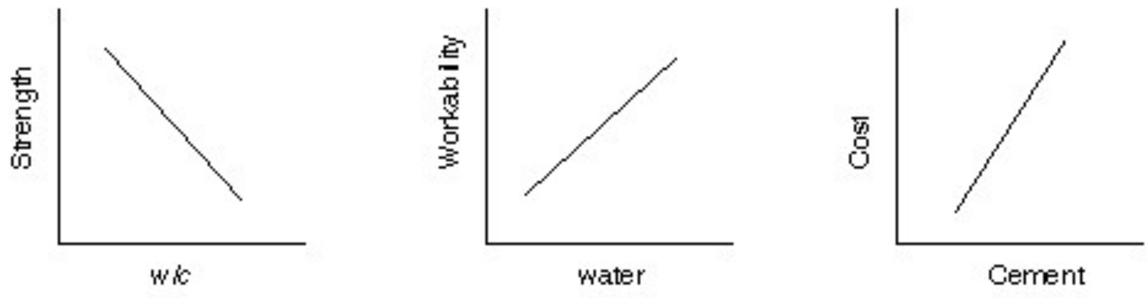

Figure 1. 1: Concrete dilemma and behavior sketches

1.6.DEFINITION OF TERMS

This section includes a list of commonly used words and acronyms, along with their meanings, that will be used in the study. In addition to the basic terms, it also includes descriptions of some of the functionality that will be used in the analysis.

FOUNDRY WASTE SAND

Waste foundry sand (WFS) is a byproduct of the production of both ferrous and nonferrous metal castings. It is high-quality silica sand.

UNIFORMITY AND RELIABILITY

Sand and other ingredient pass all test which is required to use the sand in concrete and further for construction works.

STRENGTH

Strength represents the casted concrete sample strength to with-stand the applied load.

CHAPTER II

REVIEW OF LITERATURE

Throughout the world, a vast number of scholars have carried out their studies on the usage of the waste sand foundry as a standardized and efficient substitute of sand as a component in concrete. Below are a comprehensive description and summary of the research studies on the subject.

2.1. BACKGROUND

Because of rapid enhancements in concrete technology, special practices were used to provide concrete with even more improvement than previous compressive strengths. High strength and High-performance concrete for use in large and massive structures is a new technology and required advancement to specify the compressive strength of concrete greater than 50ksi (Ma and Schneider, 2002).

The modern techniques within the discipline of concrete have made it viable to create high-strength concrete with a range of compressive strength achieved above 30,000 psi. Those modern techniques are typically due to the improvement in chemical and mineral admixtures, specifically silica fume and other enhancing properties admixtures (Kwan, 2003).

2.2.SUPPORT THEORY

2.2.1. CEMENT

Cement for the use in construction works are of various types to obtain the similar properties as required, e.g., ordinary Portland cement is used as normal works, low heat cement is used in such condition where less heat of hydration is required, Sulphate resisting cement and high early strength cement to works in water where early strength, as well as silicates reaction, are not permissible to deteriorate the concrete.

The most important element in deciding on the type of cement is the need for strength, workability, and durability. Calcium silicates and calcium aluminates are the cement components that are mainly responsible for the ultimate strength of the hydrated products of cement. Also, C_3A affects early strength development, its presence is commonly considered undesirable and can lead to durability problems in the future (Neville and Brooks 1997).

2.2.2. SILICA FUME

Silica fume is a derivative from the manufacturing of zirconia, silicon, and alloys of ferrosilicon, which is known for its superior pozzolanic features and has been notably utilized in the preparation of high power concretes. Made from particles that are notably fine and round in form, silica fume correctly fills the voids among cement and other substances and outcomes in an extra discontinuous porous assembly. Also, silica fume fastens the pozzolanic motion in the course of the hydration technique and hence growing quantity of calcium silicate hydrate, therefore, reducing the dimensions of pores inside the concrete frame (De Larrard (1989)).

2.2.3. FOUNDRY WASTE SAND

Many authors have reported the use of foundry waste sand as a replacement of fine-grained (sand) in concrete and found it very productive and achieving little higher strength than using the normal sand. Abichou et al. (1998), More (1993), Javed and Lovell (1994), and Kleven et al. (2000) reported the use of foundry sand in highway applications. Engroff et al. (1989), Fero et al. (1986), Ham and Boyle (1989), and Ham et al. (1990) reported on the leaching aspect of usage of foundry sand.

Fresh concrete properties such as slump flow, compaction factor, etc., were determined according to ASTM specifications by Rafat Siddique et al. (2011). The results are presented for seven numbers of different mix designs. The 150 mm concrete cubes and 150×300 mm cylinders were cast for compressive strength and 150×300 mm cylinders for split-tensile strength. The various tests performed were compressive strength to validate the strength property of different mix designs with various replacement percentages of foundry waste sand as substitution of standard sand.

Fiore and Zanetti (1986) studied foundry sand reuse and recycling manner. They investigated the foundry sand of various sizes. At the grounds of the collected outcomes, they concluded that residues could be divided into three classes in line with the particle-length dimensions: underneath 0.1 mm, among 0.1 and 0.6 mm, and above 0.6 mm.

Saveeria Monsi et al. (2010) are concerned with the investigation of foundry waste sand as a replacement of normal sand with different percentages of water-cement ratio in both mortar and concrete. As per the design of Saveeria Monsi et al. (2010), the mixed design table is detailed in Table 2.1 Compressive strength properties obtained by different types of mix design, i.e., several percent replacements of foundry sand with natural sand, including varying the water-cement ratio percentage, are described in Figure 2.1 and Figure 2.2.

Table 2. 1: Mix design according to Saveeria Monsi et al. (2010)

MIX	C1	C1-7	C1-10	C2	C2-10
cement (kg)	350	350	350	355	355
natural sand (kg)	645	515	460	655	456
coarse aggregate (kg)	1210	1210	1210	1230	1230
foundry sand (kg)	-	130	185	-	187
water (kg)	175	175	175	165	165
water/cement (w/c) (-)	0.50	0.50	0.50	0.46	0.46
superplasticizer %	0.75	0.95	1.4	0.95	1.7
slump (mm)	160	130	150	130	120
unit weigth (kg/m^3)	2378	2367	2356	2404	2389
air content (%)	1.8	1.9	1.8	1.5	2.3

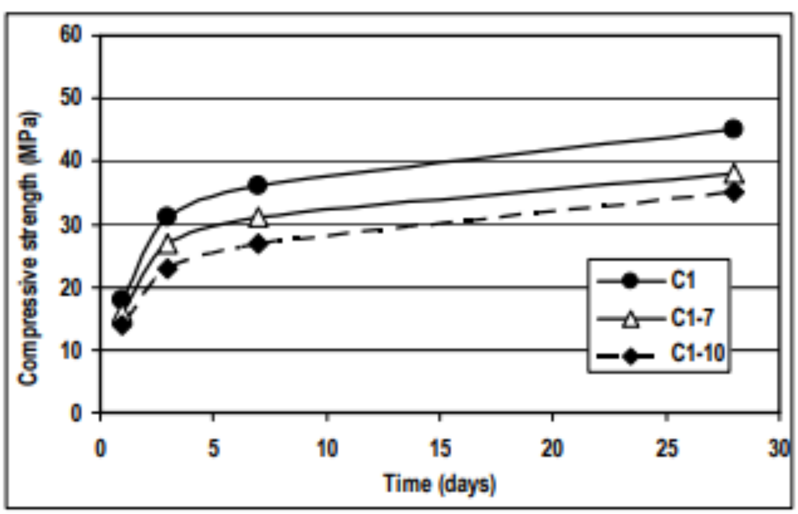

Figure 2. 1: Compressive strength properties according to Saveeria Monsi et al. (2010)

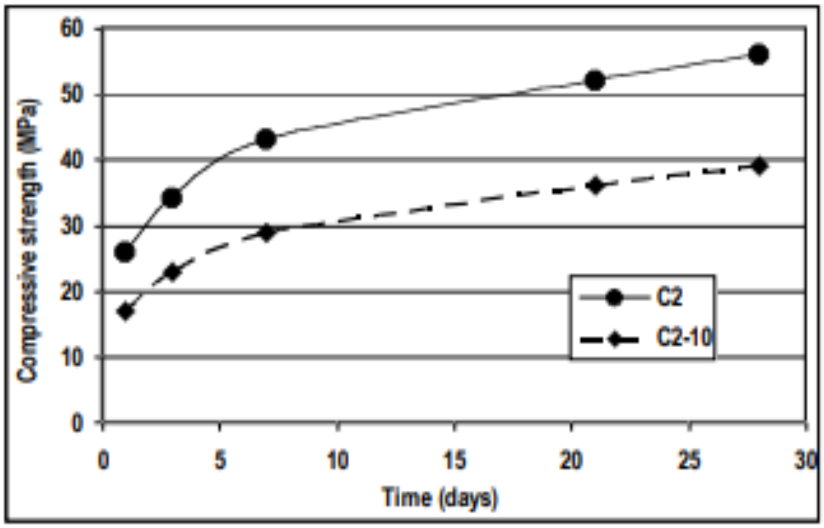

Figure 2. 2: Compressive strength properties according to Saveeria Monsi et al. (2010)

There is now extensive literature on greensand concrete plus many papers which do not disclose the form of foundry sand used despite the obvious impact that this could have on the resulting concrete properties; however, based on the composition and color indicated, it can be concluded that most of them used greensand. A variety of cement have been used in these works, others including agricultural or manufacturing by-products, and some projects have even replaced rough aggregates with other waste materials.

However, the associated scientific data is inadequate for its application in industrial-scale structural concrete production; the various manufacturing methods, the number of chemical binders, and the characteristics of foundry waste sand may have different effects on the resultant concrete properties.

This research was undertaken to determine the strength and resilience properties of concrete by replacing the different percentages of the foundry waste sand with the natural sand. The percentage of replacing the quantity of foundry waste is by 0%, 5%, 10%, 15 and 20%. The compression test, as well as tensile test, were carried out to determine the strength properties of the concrete at the age of 7, 28, 91 days, further according to Gurpreet Singh (2012). Modulus of elasticity and ultrasonic pulse velocity tests were conducted to get the desired examination and properties.

Khattib and Ellies (2001) investigated the properties (compressive strength and shrinkage) of concrete containing foundry sand as a partial replacement of natural sand. Natural sand replaced with foundry sand was 0%, 25%, 50%, and 100%. Based on the test results, they concluded that there is a clear change in strength property, and similar strength is achieved in all percentages of replacement. Including this, the drying shrinkage value was lower in concrete made with white sand and higher in concrete containing WFS.

2.3. SUMMARY

Usage and recycling of ferrous and non-ferrous metal casting industry waste is an important concern in today's world. WFS (Waste foundry sand) big metal casting industry waste is used as a by-product. In this work, therefore, WFS was used as a partial substitution of fine aggregates in concrete to investigate the impact of WFS on the strength and toughness properties.

CHAPTER III

METHODOLOGY

3.1. RESEARCH DESIGN

To carry out a thorough review of the research subject and to meet the goals set at the outset of the project, a possible conceptual set-up for the testing and assessment of different materials and mixtures was possible. For the good quality material, an appropriate sample of the aggregate should be collected from the source, and after proper testing, the source is stated as approved. For sample preparation, the product should be thoroughly mixed and reduced to the required size. The degree of gradation would be calculated by the waste sand foundry and its applicability.

The average user must be tested to design the sample for proper testing. This research procedure includes the calculation of relative density (specific gravity) and the absorption of fine aggregates. Relative density (specific gravity), dimensionless consistency, is expressed as oven-dry (OD), saturated-dry surface (SSD), or as apparent relative density (specific gravity).

The workability of concrete describes the ease or difficulty with which the concrete is handled, transported, and placed between the forms with minimum loss of homogeneity.

3.2. CONCEPT DESIGN

To design the sample for proper testing, the aggregate must be tested. This test method covers the determination of relative density (specific gravity), sieve analysis of course and fine aggregate, silica fume, material properties, and the absorption of fine aggregates.

The Specific Gravity test is done according to the **ASTM C-128** standard.

3.2.1. ACCELERATING ADMIXTURE:

The accelerator is brought to concrete to reduce the setting time of the concrete and to increase the early strength. The amount of discount in setting time varies depending on the amount of accelerator used.

Calcium chloride is a low fee accelerator. However, specification often requires a non-chloride accelerator to save you corrosion of reinforcing steel.

3.2.2. WATER REDUCING ADMIXTURES

Such admixtures, which tends to lower the amount of water to cement ratio, are normally added in the concrete to get the required strength property as a most required slump. Most low-range water reducers reduce the water needed in the mix by 5%-10%.

3.2.3. AGGREGATE MATERIAL

Literature reveals that concrete compressive strength increases up-to a maximum aggregate size of 1.5 inches. From the standpoint of minimum void space, round aggregate is more desirable than irregular.

The cement to be used is ordinary Portland cement (OPC) and sulfate-resistant cement (SRC). The justification for choosing this cement is that it is readily accessible and that it is one of the finest and highest performing cement that satisfies the necessary specifications and fulfills the requirements.

Aggregates in any mix of concrete are selected for their durability, strength, workability, and ability to receive finishes. For a decent mix of concrete, the aggregates need to be pure, rough, solid particles free from ingested contaminants or clay coatings and other fine materials that might induce the degradation of concrete. The aggregates are classified into either 'coarse' or 'healthy' groups. Coarse aggregates are particles larger than 4.75 mm. The normal scale used is between 9.5 mm and 37.5 mm in diameter. Fine aggregates are foundry waste sand, natural sand, or crushed stone, less than 9.55 mm in diameter. Usually, the most typical aggregate size used in the building is 20 mm. A larger scale, 40 mm, is more common in the mass of concrete.

3.2.4. FOUNDRY WASTE SAND METHODOLOGY

Foundry waste sand will be obtained from the source nearby area. The tests for the quality of sand including fineness and the presence of any impurities. Then different mix designs for as according to Saveeria Monsi et al. (2010) except the use of plasticizer will be established to check the different characteristics and strength properties of using foundry waste sand in concrete. The below describe Figure 3.1 is the Foundry waste sand used in the casting of the concrete cylinder.

The basic procedure is followed.

- Fineness, absorption, specific gravity test for the foundry waste sand.
- Slump and temperature test for fresh concrete.
- Cast the 20 samples cylinder (10 with Foundry waste sand and 10 with normal sand) and cure for 28 days.
- Takeout the specimen from the curing tank.
- Wipe out the excess water from the surface of the specimen.
- Place the specimen vertically on the platform of the compression testing machine.
- Apply the load until the cylinder fails.
- Record the maximum load taken.
- Compare the compressive strength in MPa using both foundry waste sand and normal sand.

Figure 3. 1: Foundry Waste Sand

3.3.MIXING PROCEDURE

According to the above-stated resources, when all the ingredients material selection is completed, the following is the standard procedure for mixing and preparing the cylinder cast concrete.

3.3.1. MACHINE MIXING:

- Put the coarse aggregate in the mixer, add some of the mixing water and the solution of admixture, when required.
- Start the mixer, then add the fine aggregate, cement, and water with the mixer running.
- Mix the concrete, after all, integrates are in the mixer, for 3 minutes followed by 3 minutes rest, following by 2 minutes final mixing.

3.3.2. HAND MIXING:

- In a watertight, clean, damp metal pan, mix the cement, insoluble admixture, if used, and the fine aggregate without the addition of water until they are thoroughly blended.
- Add the coarse aggregate and mix the entire batch without the addition of water until the coarse aggregate is uniformly distributed throughout the batch.
- Add water, and the admixture solution if used, and mix the mass until the concrete is homogenous in appearance and of the desired consistency.

3.4. MATERIAL TESTING

3.4.1. GRADATION TESTS

3.4.1.1. SIEVE ANALYSIS

Sieve analysis gives an idea regarding the gradation coarse and fine aggregate. It is used to proportion the selected sample to obtain the design properties and strength.

The test is conducted according to the **ASTM C136 / C136M Standard**.

GRADATION OF FINE AGGREGATE (SAND)

The sieve analysis for the fine aggregate (natural sand and foundry waste sand) used in the casting of the typical cylinder is carried out. The below described Table 3.1 described the sieve analysis data for the sand, and Table 3.2 described the sieve analysis for the foundry waste sand. The sieve analysis test plays a vital contribution to produce strength in the concrete. The below described Figure 3.2 describes the graph for both the sand and foundry waste sand to depict the material's distribution size. The graph is drawn between the sieve size on the x-axis and % percent of passing on the y-axis.

Total weight of sample=**500g**

Calculation

%Retain $= \frac{\text{weight retain on sieve}}{\text{total weight}} \times 100$

% passing =100-(%Retain)

Table 3. 1: Gradation of fine aggregate (sand) with the help of sieve analysis

Sieve No.	Retain wt. on each sieve (g)	% Retain	% Pass	% Retain Cumulative	Justification
#4	0	0	100	0	All the Aggregates are passes from this sieve.
#8	4	.82	99.12	.82	% passing= $\frac{500-4}{500} \times 100$
#16	30	6.63	92.49	7.51	% passing= $\frac{500-30}{500} \times 100$
#30	178	35.6	56.89	43.11	The opening size is 0.354 mm^2 (greater quantity is less than 0.354 mm^2
#50	168	33.16	23.73	76.27	Opening size=0.0882 mm^2
#100	72	14.4	9.33	90.67	Opening size=0.0222 mm^2
Total	**452**				**500-452=48 gm is left at pan**

GRADATION OF FINE AGGREGATE (FOUNDRY SAND)

Total weight of sample=**500g**

Table 3. 2: Gradation of fine aggregate (Foundry sand)

Sieve No	**Retain wt. on each sieve (g)**	**% Retain**	**% Pass**	**% Retain Cumulative**	**Justification**
#4	0	0	100	0	All the Aggregates are passes from this sieve.
#8	9.4	1.88	98.12	1.88	% passing= $\frac{500-9.4}{500} \times 100$
#16	43.15	8.63	89.49	10.51	% passing= $\frac{500-43.15}{500} \times 100$
#30	216.9	43.38	46.11	53.89	The opening size is 0.354 mm^2 (greater quantity is less than 0.354 mm^2
#50	170.8	34.16	11.95	88.05	Opening size=0.0882 mm^2
#100	59.7	11.94	0.01	99.99	Opening size=0.0222 mm^2
Total	**499.95**				**500-499.95=0.05 gm is left at pan**

Graphical representation of sieve analysis data

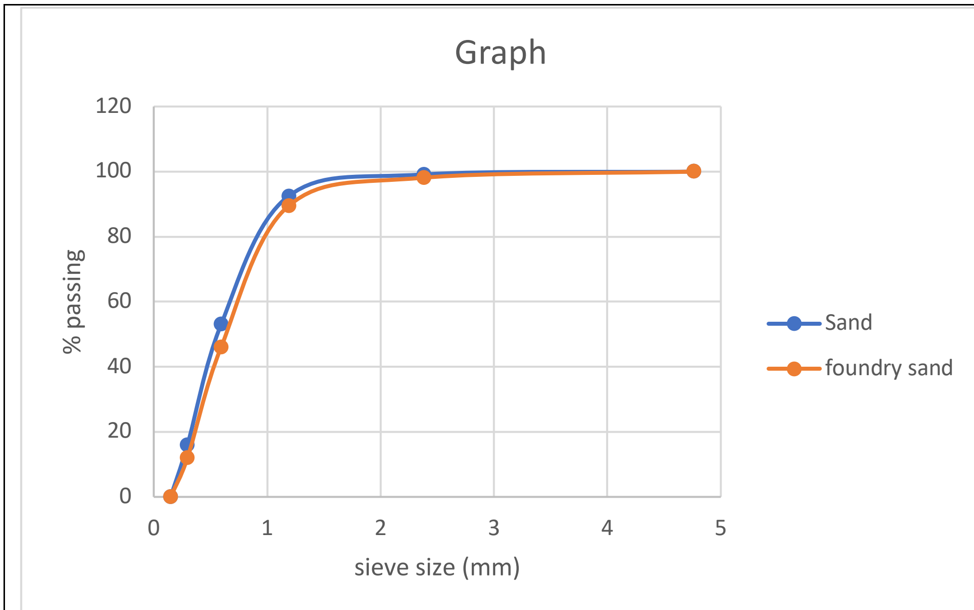

Figure 3. 2: Graph of fine aggregate data (Sand)

GRADATION OF COARSE AGGREGATE

The sieve analysis is conducted to determine this particle size distribution of coarse aggregate. The table of sieve analysis describes the detailed calculation.

Weight of Sample W=**3000 g**

Table 3. 3: Gradation of coarse aggregate

Sieve no	Retain weight (g)	% Retain weight	% Passing	Cumulative % Retain Weight	Justification
1.5”	0	0	100	0	All the Aggregates are passes from this sieve.
1”	0	0	100	0	All the Aggregates are passes from this sieve
¾”	440	16.4	83.6	16.4	% passing= $\frac{3000-400}{3000} \times 100$
½”	1080	40.20	43.4	56.6	The opening size of the sieve is 0.25mm^2 (greater quantity is less than 0.354 mm^2
3/8”	580	21.62	21.78	78.2	Opening size=0.1406in^2
#4	582	21.70	0.08	99.9	Opening size=0.035 in^2
Total	2682				3000-2682=**318gm** left in the pan

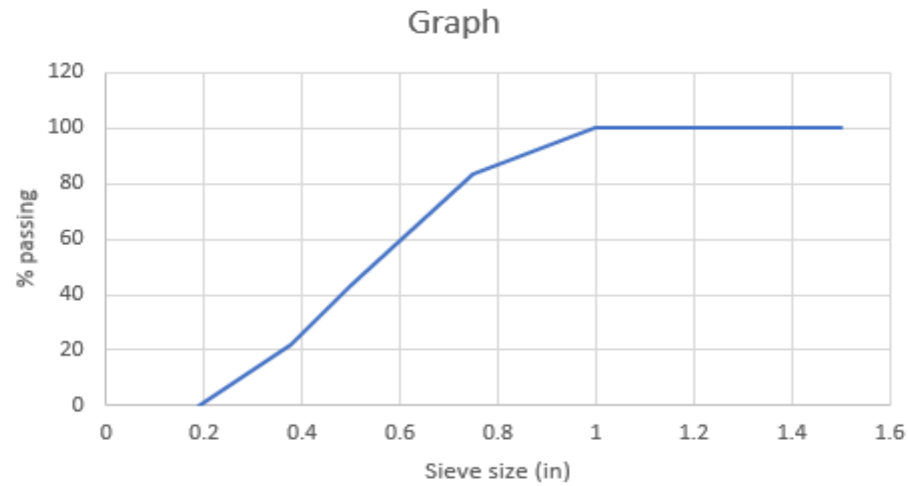

Figure 3. 3: Graph of Coarse Aggregate Data

GRADATION OF SILICA FUME

The American concrete institute (ACI) defines silica fume as "very fine non-crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon. It is usually a gray-colored powder, somewhat similar to Portland cement or some fly ashes. Figure 3.3 (a) and (b) shows typical Silica Fume materials. Table 3.5 shows the values from the Sieve analysis of Silica Fume.

(a) (b)

Figure 3. 4: (a) and (b) showing typical Silica Fume materials.

Table 3. 4: properties of silica fume

S. No	Property
1	Particle size < 1 micro meter
2	Bulk density 130 to 430kg/m^3 and 480 to 720 kg/m^3
3	Specific gravity 2.2
4	Specific surface 15000 to 30000m^2/kg

Table 3. 5: The Sieve analysis of Silica Fume

Sieve Size	Sieve Size	Weight	Weight	% Retained	Cumulative
#4	**4.75**	**0.37**	**0.00**	**0.00**	**0.00**
#8	**2.36**	**0.235**	**0.005**	**1.45**	**1.45**
#16	**1.18**	**0.33**	**0.01**	**2.90**	**4.35**
#30	**0.6**	**0.36**	**0.02**	**5.79**	**10.14**
#50	**0.3**	**0.37**	**0.08**	**23.188**	**33.328**
#100	**0.15**	**0.405**	**0.085**	**24.64**	**57.968**
Pan	**-**	**0.25**	**0.145**	**42.032**	**100.00**
Total					F.M = 2.07

3.4.1.2. FINES MODULES

The degree of gradation is also called the fineness modulus of sand. We find the fineness modulus of sand and compare it to the **standard recommended** values.

Fines modules= $\frac{\textbf{Total cumulative sum}}{\textbf{100}}$

Fines modules =$\frac{239.3}{100}$

=2.393

Normal Range of Fines Modules =2.3-3.1

So, the fineness modulus is well-graded according to **ASTM C33/C33M.**

3.4.2. UNIT WEIGHT OF COARSE AGGREGATE

It is the mass of the unit volume of bulk aggregate material. The term volume includes the volume of the individual particles and the volume of the voids between the particles. Bulk density is used in weight and volume batching.

Weight of an empty mold cylinder =**19 lb.**

Weight of mold cylinder + Aggregate =**40 lb.**

Volume of cylinder= **0.19963 lb/$\mathbf{ft^3}$**

Bulk Density = (loaded-empty)/volume of cylinder

$$= \frac{40-19}{0.19963}$$

$$= \mathbf{106.97 lb/ft^3}$$

So, it produces normal-weight concrete.

Unit weight of normal weight concrete =150 $\frac{lb}{ft^3}$

3.4.3. SPECIFIC GRAVITY OF FINE AGGREGATE

This test method covers the determination of relative density (specific gravity) and the absorption of fine aggregates.

The test is done according to the **ASTM C-128** standard.

Weight of SSD sample= **S**=200 g

Weight of water up to 250ml= **B**=250 g

Weight of water + Fine Aggregate up to 250ml=**C**=372 g

Specific Gravity $= \frac{S}{B+S-C}$

Specific Gravity of sand $= \frac{200}{250+200-372}$

Specific Gravity of sand =2.56

Specific Gravity of foundry waste sand =2.49

Such that,

A=mass of oven-dry sample in the air (g)
B = mass of pycnometer filled with water (g)
C = mass of pycnometer filled with SSD sample & water (g)
S = mass of SSD sample (g)

3.4.4. MIXING WATER

Water used for mixing concrete was clean and loose from any materials that are probably dangerous to concrete. The standard procedure for adding the water to prepare the concrete mix is followed like the first 70% of water is adding to the material. After a few rounds, the remaining amounts of water are added.

3.5 MIX DESIGN

To gain concrete of desired mix design properties in the most cost-effective way, the components of concrete are appropriately selected and comparatively proportioned through a method known as concrete mix percentage. But to set up a proper mix design for the manufacturing of concrete cylinders.

Table 3.6 presents the detail of the mix proportions investigated in this study.

These Mix Proportion quantities i.e. cement, silica fume, sand, foundry sand, were taken from the previous literature. These Mix Proportions were made by mechanical mixing in the concrete lab.

The overall process for construction of 20 Nos. standard cylinder.

Height of Cylinder= 12 inch

Diameter of cylinder= 6 inch

Volume of cylinder= $(3.14/4)\times(6)^2 = 28.26\ in^2 \times 12 = 339.12\ in^3 = 0.0056 in^3$

The concrete cylinders are designed according to the specification and having a design strength of M20, 20MPa, and 3000 Psi.

The ratio of cement: sand: aggregate = 1:1.5:3

Now,

Amount of cement = 350 kg/m^3

Amount of sand = 525 kg/m^3

Amount of aggregate = 1050 kg/m^3

The volume required for casting this cylinder = 0.0056 m^3

Amount of cement for per cylinder = 350 kg/m^3 ×0.0056 = 1.96 kg = 2 kg

Amount of sand for per cylinder = 525 kg/m^3 ×0.0056 = 2.94 kg = 3 kg

Amount of aggregate for per cylinder = 1050 kg/m^3 ×0.0056= 5.88kg = 6 kg

Table 3. 6: Mix Design table to be used for casting of concrete cylinders

S.No.	Cement (kg)	Sand (kg)	Foundry Sand (kg)	Silica Fume (kg)	Aggregate (kg)	Comment (kg)
1.	2 kg ×4= 8 kg	3 ×4 =12 kg	0	0.55×4=2.2	6×4= 24	Ordinary Cylinder
2.	2 kg ×4= 8 kg	0	3 ×4 =12 kg	0.55×4=2.2	6×4= 24	Foundry Waste Cylinder
3.	2 kg ×4= 8 kg	0.9×4=3.6	2.1×4=8.4	0.55×4=2.2	6×4= 24	70 % Replacement of sand
4.	2 kg ×4= 8 kg	1.5×4=6	1.5×4=6	0.55×4=2.2	6×4= 24	50 % Replacement of sand
5.	2 kg ×4= 8 kg	2.1×4=8.4	0.9×4=3.6	0.55×4=2.2	6×4= 24	30 % Replacement of sand

Total	**40 kg**	**30 kg**	**30 kg**	0.55×4=2.2	**120 kg**	

3.6 COMPRESSIVE STRENGTH TEST

Concrete test cylinders shall be made and cured following ASTM C 31. The compression test is any test in which the sample encounters conflicting forces that drive the specimen inward from opposite sides or are otherwise compressed, "squashed" crushed, or flattened.

Further suggestion; the compressive strength, which shall be determined by test for compressive strength a sample cylinder or cube made for that purpose in addition to those required for routine quality testing following with "Tests during the Performance of the Work" by following the same procedure can also be followed. According to J.R del Viso et al., the below Figure 3.5 describes the compression test of cast cylinders.

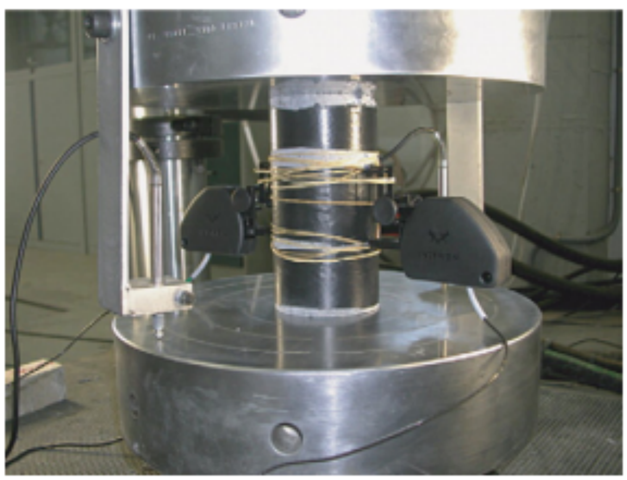

Figure 3. 5: Compressive strength test for concrete Cylinder (J.R del Viso et al.)

A compression test intends to determine the conduct or reaction of cloth whilst it experiences a compressive load with the aid of measuring essential variables, such as pressure, strain, and deformation. With the aid of checking out material in compression, the compressive power, yield strength, final energy, elastic restriction, and the elastic modulus, amongst other parameters, might also all be decided. With the information of those special parameters and the values associated with a particular fabric, it could be decided whether the material is ideal for specific packages or if it's going to fail under the required stresses.

Concrete mixtures may be designed to offer an extensive variety of strength and durability assets to fulfill a mix proportion's layout requirement. The compressive strength of concrete can be obtained by way of breaking the cylinder in compression. Compressive strength is calculated from the applied load at which the cylinder fails. The range of the cylinder is 2500 psi-5000psi.

A universal testing machine (UTM), also known as universal tester materials testing machine, is used to test the tensile strength and compressive strength of materials. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures.

3.7 CONCRETE PROPERTIES AND QUALITY

The quality control study optimizes the techniques for assuring quality construction in civil engineering works. Advancement in Civil Engineering Construction technics increases the theme for studying quality assurance as quality is somehow more important to control than speedy construction works. Therefore, continuous improvements are expected in quality functions and adopting advanced construction techniques. Good quality concrete starts with the quality of materials, cost-effective designs are a by-product of selecting the best quality material and good construction practices.

Stiffness is the resistance of an elastic body to deflection or deformation by an applied force. It is an extensive material property.

3.8 QUALITY MANAGEMENT SYSTEM

The Quality product is very important regarding the suitability to improve and manage the quality standard. The best concrete mix design is prepared by concerning the individual properties of the mix design material. Likewise, ASTM standards are available regarding every material. Like silica fume, a binding agent used in high-performance concrete has standard technique C 1240, which describes the testing and usage of silica fume in the concrete mix design. According to research, with the addition of the optimum quantity of silica fume, the concrete compressive strength is increased by greater than 105%.

3.9 COST ANALYSIS

For cost analysis, the cost of each material is found according to market statistics. Information and cost are evaluated for the whole samples and testing it. It was demonstrated that the aggregate packing could be used as a tool to optimize concrete mixtures, improve compressive strength, and economically feasible. The cost obtained for the above mention mix design is \$80/ $\mathbf{m^3}$.

CHAPTER IV

FINDING AND DATA ANALYSIS

4.1. PREPARATION OF SPECIMENS

When the mix with sand or foundry waste sand was ready, it was poured into the required molds, which were sprayed with mound oil to reduce the friction at the interface between the molds and concrete mix. The molds standard cylinders in size. To ensure adequate compaction, all samples were compacted with hand tamping using a tamping rod. The specimens were de-molded at least 24 hours after casting.

After finalizing the Mix Proportion, various specimens were cast according to standard procedures. For each mix, there were four types of specimens cast. For the appropriate casting of cylinders according to described mix design, all the material to be added must be properly weighted by electronic weight balance. This will completely depict the accurate process for the preparation of concrete mix. Below, Figure 4.1 describes the weight measurement of foundry sand.

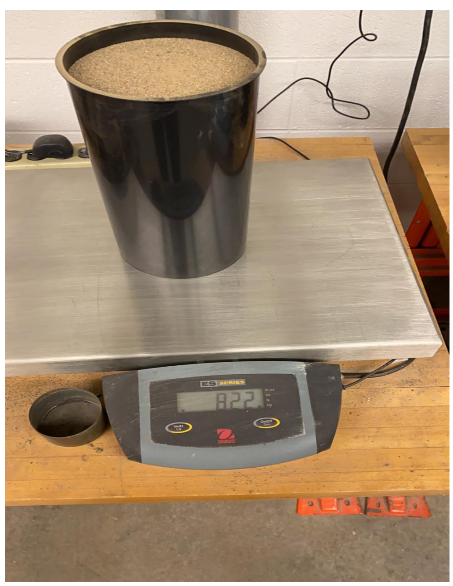

Figure 4. 1: Foundry Waste Sand Weight Measurement

4.1.1. SLUMP TEST

The slump test is a means of assessing the consistency of fresh concrete. It is used, indirectly, as a means of checking that the correct amount of water has been added to the mix. Figures 4.2 and 4.3 describe the generic procedure of slump test for every concrete mix. Table 4.1 describe the permissible slump test value in millimeters for the concrete usage in different structures.

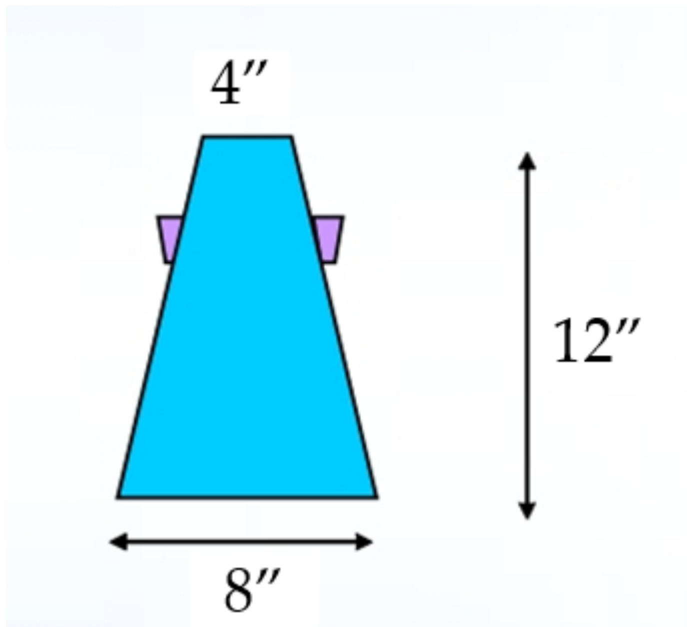

Figure 4. 2: Slump Test Cone

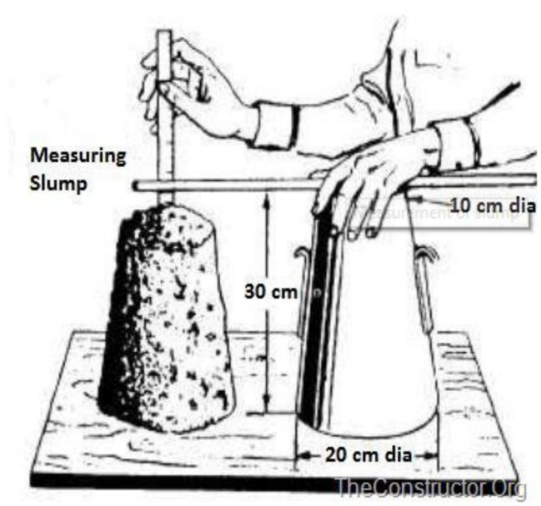

Figure 4. 3: Measuring Slump

Table 4. 1: Allowable slumps for different works

No.	Types of concrete	Slump
1	Concrete for road construction	20 to 40 mm
2	Concrete for tops of curbs, piers, slabs and wall	40 to 50 mm
3	Concrete for canal lining	70 to 80 mm
4	Normal RCC work	80 to 150 mm
5	Mass concrete	20 to 50 mm
6	Concrete to be vibrated	10 to 25 mm

4.1.2. WORKABILITY OF CONCRETE

Workability of concrete describes the ease or difficulty with which the concrete is handled, transported, and placed between the forms with minimum loss of homogeneity.

4.1.3. SLUMP TEST RESULT

The slump test done before the start of the work gives the slump of

= **1.85 in**

=47 mm

The slump test is done by the **ASTM C143-89a.**

4.1.4. CASTING OF SAMPLE

The mechanical mixtures are used for the proper mixing of material to prepare the concrete mix. The sample is cast according to the above-designated method. Overall, 20 cylinders of cylinders are cast to test the effectiveness of foundry waste sand. Below, Figure 4.4 describes the casting of the cylinder for checking the compressive strength.

Figure 4. 4: Cast of Concrete Cylinders

4.1.5. CURING OF SAMPLE

After casting the concrete cylinders, as shown in Figure 4.4 the specimens were left in molds. After 24 hours the specimens were removed from molds and placed for curing in a container containing clean water as shown in Figure 4.5. Water in the container was replaced after regular intervals to provide fresh and clean water for curing.

Curing condition: Immersed in the water at 25℃ for 28 days.

Figure 4. 5: Curing of Samples

4.2.PROCEDURE FOR COMPRESSION TEST

The basic procedure is followed.

- Cast the cylinder and cure for 28 days.
- Takeout the specimen from the curing tank.
- Wipe out the excess water from the surface of the specimen.
- Place the specimen vertically on the platform of the compression testing machine.
- Apply the load until the cylinder fails.
- Record the maximum load taken.

4.2.1. COMPRESSION TEST RESULT

Table 4.2 shows the compression test results, the cylinder is compressed under the applied load from the UTM, and load is applied until the cylinder fails. For all the 20 cylinders of the compressive test, the average value is calculated. The below-described graph Figure 4.6 shows the average compressive strength produced by each category of foundry waste sand replacement percent. Other figures shown below are the pictures carried out during the preparation and testing for compressive strength.

Table 4. 2: Mix Design Table

Serial No	Description	Strength psi	Average Value (psi)
1	Ordinary Cylinder #1	2885.63	(2885.63+2940.2+2978.3+2667.825)÷4 =2867.98
2	Ordinary Cylinder #2	2940.2	
3	Ordinary Cylinder #3	2978.3	
4	Ordinary Cylinder #4	2667.825	

5	Replacement by foundry sand 100% #1	3001.68	(3001.68+3012.7+2997.8+2934.3)÷4 2986.62
6	Replacement by foundry sand 100% #2	3012.7	
7	Replacement by foundry sand 100% #3	2997.8	
8	Replacement by foundry sand 100% #4	2934.3	
9.	Replacement by foundry sand 70% #1	3123.4	(3123.4+3100.4+3233.6+3456.12)÷4 3228.38
10	Replacement by foundry sand 70% #2	3100.4	
11	Replacement by foundry sand 70% #3	3233.6	
12	Replacement by foundry sand 70% #4	3456.12	
13.	Replacement by foundry sand 50% #1	2987.4	(2987.4+2809.1+3001.1+2954.3)÷4 2937.975
14	Replacement by foundry sand 50% #2	2809.1	
15	Replacement by foundry sand 50% #3	3001.1	
16	Replacement by foundry sand 50% #4	2954.3	
17	Replacement by foundry sand 30% #1	2887.3	(2887.3+2786.4+2874.2+2901.12)÷4 2862.255
18	Replacement by foundry sand 30% #2	2786.4	
19	Replacement by foundry sand 30% #3	2874.2	
20	Replacement by foundry sand 30% #4	2901.12	

Figure 4. 6: Graphical representation of Tabulated Average Compressive strength

Such that;

1= Ordinary Cylinder

2= Replacement by foundry sand 100%

3= Replacement by foundry sand 70%

4= Replacement by foundry sand 50%

5= Replacement by foundry sand 30%

Figure 4. 7: Cast Concrete Cylinders

Figure 4. 8: Preparing Cylinder Specimens

Figure 4. 9: Compression test of Cast Cylinders

Figure 4. 10: Concrete Cylinder after Compression test

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

1. The mix design is finalized as the proportion of cement: sand: aggregate proportion of 1:1.5:3.
2. The cylindrical concrete cylinder is cast and tested for compressive strength. The compressive test results reveal the strength as described in Table 4.2 and graphically in Figure 4.4.
3. By analyzing the compressive strength results, it is clear that the 70% replacement of foundry waste sand with normal sand shows more appropriate and greater compressive strength results than as compared to ordinary and replacement as at 50% and 30 %.
4. In the case of the present work, it was observed that the 70% replacement of foundry waste sand with normal sand is appropriate and then helps to reduce the usage of normal sand.
5. The use of foundry waste sand will definitely and massively reduce the waste (foundry sand) by using the most effective construction works.

5.2.FACTORS AFFECTING CONCRETE STRENGTH

There are several factors, some of it already pointed above but below in specific category some more of the factors are obtained below.

- Type and temperature as part of curing conditions effects strength.
- Atmosphere temperature
- Water to cement ratio
- Mix design
- Sample casting methodology
- Properties of material like coarse and fine aggregate
- Type of cement
- Admixtures usage accordingly

5.3.RECOMMENDATIONS

The test, as well as analysis, are carried out on M15 concrete mix for other concrete mix designs and then acquiring the required properties, the same procedure must be followed for other types of concrete mixes. Furthermore, for high-strength concrete and of more admixture, the following procedure can be used to estimate the properties of concrete.

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