Sustainable Use of Waste Foundry Sand in Concrete

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Abstract: **The effect of waste foundry sand (WFS) as a partial substitute for fine aggregates (natural sand) on concrete mixtures was investigated using an experimental program. The 28-day compressive strength of control concrete mixtures (M25) was engineered to be 31.60 MPa, respectively. The fine aggregate (natural sand) was then replaced with a replacement ratio (0%, 5%, 10%, 15%, 20%) of WFS by weight.**

The focus of this study is to prevent sandpits from being dug up, as a result of the construction industry's rapid production of a variety of fine aggregates. Compressive strength, splitting tensile strength, flexural strength, carbonation depth, water absorption, were used to investigate the performance of concrete for up to 56 days. In this analysis, 105 concrete specimens were cast. The specimens were prepared for concrete mixes of M25 grade, with a water-to-cement ratio of 0.50. This research looked at the impact of waste foundry sand on various properties of concrete. The properties of fresh and hardened concrete were determined by testing specimens of concrete mixes.Mechnaical properties and durablity Properties of M25 grade concrete increased with the up to 15% replacement ratio, however there is a small declination found at above 15% replacement ratio.

Keywords: **Durability;cement;concrete; wastefoundrysand; Strength**

I. INTRODUCTION

New techniques and technologies are being implemented on a daily basis to meet the demands of rapid industrial development. Significant quantities of solid and toxic waste in the form of products resulted from the use of these methods to manufacture materials and goods. Waste can be used to create new items, allowing for more productive use of natural resources. Sustainability has three components: the environment, the economic system, and culture. Its aim is to ensure that life on Earth can be sustained in the future.Sustainable development must preserve the health and balance of these three components in order to achieve its aim. The climate, on the other hand, is typically the most important aspect, and an engineer or architect defines sustainability as having no net negative environmental effect.In order to mobiliseall natural capital for economic purposes, an effective national development plan looks inward (Ukpata et al. 2012).

Concrete, the most widely used building material on the planet, serves as the basis for all construction and development activities.For the manufacture of concrete, the main constituents are cement, fine aggregate (sand), coarse aggregate, and water.Waste production has increased as a result of population growth and technological advancements. As a result, many researchers and scientists around the world are looking for new ways to reduce these wastes or find a better way to use it as a valuable resource. Alternative materials have been integrated into concrete to improve both mechanical and durability properties, and this technique can help to ensure that concrete continues to evolve in a sustainable manner. Waste foundry sand (WFS) is one such promising material that needs to be thoroughly investigated as a fine aggregate replacement in concrete.

II. WASTE FOUNDRY SAND

Foundry sand is a by-product of the ferrous and non-ferrous metal casting industries, with ferrous foundries processing the most sand. It has a sub-angular to circular form and a high thermal conductivity, which makes it suitable for moulding and casting operations.During the casting process, sand is recycled and reused many times. Recycled sand eventually degrades to the point that it can no longer be used in the casting process.Then, as a by-product, the old sand is discarded, and new sand is added to the cycle. Waste foundry sand (WFS) is a big waste material produced by metal alloy casting industries around the world, which produces millions of tonnes of by-products. It has been effectively used as a landfill for many years, but dumping is becoming a major concern due to rising operating and disposal costs.Scenario in Today's World There are approximately 35,000 foundries in the United States, producing 90 million tonnes a year and employing approximately 2 million people.

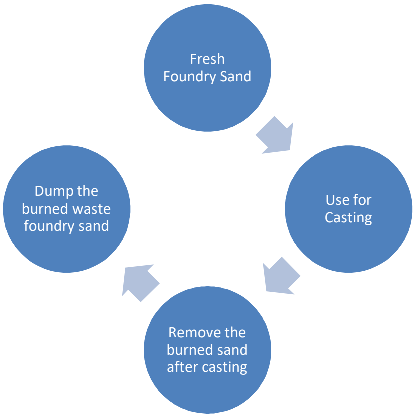

Fig. 1 Genration of Waste Foundry Sand

The United States leads the way in alloy manufacturing, led by China, Japan, Germany, and the Commonwealth of Independent States. China has the most foundries (9374), followed by India (6000), and then the Commonwealth of Independent States (CIS) (4000).After China, India's foundry industry is the world's second largest casting producer. The annual output of nearly 12.06 million tonnes is reported for 2018–19, with approximately 6,000 foundries. Since the sector is mostly unorganised (approximately 85%) and does not report to the public, installed capacity and output could be higher than expected.

Metal foundries produce 100 million tonnes of foundry sand per year to help with metal casting (Benson and Bradshaw 2011).The foundry discards the sand when it is no longer available, resulting in approximately 10 million tonnes of spent sand per year (FHWA 2004). Foundries in the United States have recently set a target of diverting 50% of spent sands to non-landfill applications, up from the current rate of 28%. (AFS-FIRST 2016).

Sand is made up of silica sand, 5% to 10% bentonite clay, 2% to 5% water, and less than 5% sea coal and is generated in foundries.Waste foundry sand is being studied as a potential partial substitute for fine aggregates in concrete in large quantities. In their moulding and casting operations, foundries often use high-quality, size-specific silica sands.Waste foundry sand is being studied as a potential partial substitute for fine aggregates in concrete in large quantities. In their moulding and casting operations, foundries often use high-quality, size-specific silica sands.

Escalating cost of fine aggregate

Many building projects were harmed by the rise in aggregate prices, which nearly doubled as a result of the state government's closure of stone factories. The tenfold increase in the price of river aggregate over the last ten years has caused concern among builders and government infrastructure projects, as well as having an effect on state economic growth.

Fine aggregate, which cost between Rs. 0.7 and Rs. 0.8 per cubic metre previously, now costs between Rs.1.6 and Rs.1.7 per cubic metre. Owing to environmental concerns regarding aggregate mining, less permits for fine aggregate trucks to load and supply have been issued, and river sand has become scarce due to loading issues at riverbeds during the rainy season.As a result of rising fuel prices, the cost of transporting river aggregate and other construction materials is rising. It's causing havoc in the real estate market and jeopardising the livelihoods of tens of thousands of construction workers in the country.

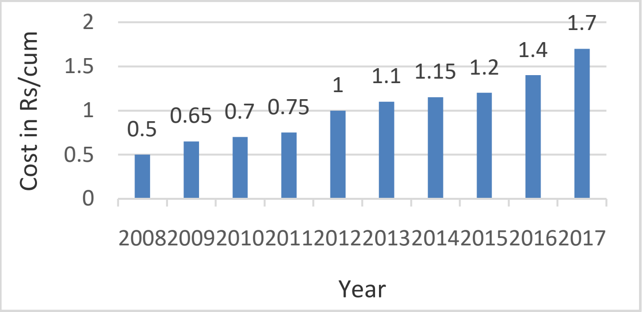

Fig. 2 Escalating cost of fine aggregate

II. LITERATURE REVIEW

Many studies have been conducted to determine the benefits of waste foundry sand processing in improving the properties of concrete. This chapter examines previous research on the use of waste foundry sand in concrete for building projects. The following headlines summarise the most recent analysis of the literature.

*Siddiqueet al. (2009)*The effect of the foundry sand used on the concrete's mechanical properties was investigated. He bet that used sand came from the ferrous and non-ferrous metal casting industries. Sand has been successfully recycled and reused in foundries on many occasions.Industrial waste can be used after so many uses, and research has been done on its potential large-scale use in the manufacture of concrete as a partial substitute for fine aggregates in concrete. The findings of this study indicate that used sand can be used to make high-quality concrete and construction materials with relative ease.

Guneyet al. (2010) The effect of waste foundry sand (WFS) on slump concrete was investigated, and it was discovered that WFS reduced the fluidity and slump value of fresh concrete. This may be because fine-grained clay materials were used in the waste foundry sand, which were useful in determining the fluidity of fresh concrete. At the age of 56 days, it was discovered that the water absorption of the concrete containing 5% waste foundry sand was higher than that of the normal sand. After a certain replacement ratio, increasing the amount of waste foundry sand replaced with conventional fine sand decreased the mechanical properties of the concrete.

*Khatib et al. (2010)*The properties of concrete containing foundry sand as a partial substitute for fine aggregate were investigated. There were three types of sand used in foundries: white fine sand without clay or coal, cast-iron sand (blended), and cast-iron sand (spent).It was discovered that as the amount of conventional sand replaced with foundry sand increased, the strength of concrete decreased. At all points of replacement, white sand concrete had a marginally higher strength than spent sand concrete.

*Monosiet al. (2010)*In both fresh and hardened conditions, the properties of mortars and concretes containing different dosages of used foundry sand (UFS) as partial sand replacement were investigated. The tests revealed that (a) concrete containing foundry sand reduced workability (at the same w/c) and that a higher amount of superplasticizer was required to maintain the same workability.

Siddique et al. (2011) The use of waste foundry sand collected from foundries was used to investigate the concrete's hardness properties. In comparison to traditional concrete sand, WFS had a lower unit weight, higher water absorption, and a higher percentage of void, according to their research.The addition of waste foundry sand as a partial substitute for fine aggregates causes the concrete to slump. Concrete's water absorption ability decreased as the WFS portion increased.

*Salokheet al. (2013)*Fresh concrete data must have shown that the addition of both ferrous and non-ferrous foundry waste sand resulted in low slumping, owing to the existence of very fine binders, necessitating the use of high doses of superplasticizers to preserve good workability.In comparison to the standard mixture, the compressive strength of both ferrous and non-ferrous mixtures increased in 7 days. With 20 percent WFS of both types of sand, the greatest increase was observed. However, 20% ferrous WFS increases compressive strength more than 20% non-ferrous WFS increases compressive power.At least 20% ferrous WFS and 10% non-ferrous WFS is absorbed in water. The mixture of 10% non-ferrous WFS, on the other hand, has the lowest water absorption value.

Prabhu et al. (2014) showed no significant loss in workability up to a 10% substitution ratio, but it began to affect workability as soon as the replacement ratio was exceeded**.**This reduction in workability was likely caused by the inclusion of water-absorbing fine-grained particles in WFS, such as clay-like fine materials, ashes, and impurities, which reduced the fluidity of the fresh concrete and increased the amount of water required.

Siddique et al. (2018) It was based on the fact that using up to 20% foundry sand as a partial sand replacement improved the strength and durability properties of concrete. The percentage improvement in the strength and durability of the foundry sand concrete compared to the handled concrete started to decrease as the replacement range was increased by up to 20%.

*Coppioet al. (2019)*The surface electrical resistance of concrete formed by using waste foundry sand as the fine aggregate of the mixture varies depending on its composition, according to research. With an increase in the substitution ratio, compressive strength appears to decrease.They discovered that the higher the porosity of the concrete, the lower the compressive power, and that waste foundry sand-moulded concrete proved to be more porous and less robust. Sample F (100 percent WFS) had a low compressive strength, indicating that this waste foundry sand, which substituted 100% of the conventional fine aggregate, was not ideal for use in concrete.

III. MATERIALS USED AND THEIR PROPERTIES

Cement, fine aggregate (waste Foundry Sand and natural Sand), and coarse aggregate were used in this investigation.

5.1. Cement: For the projection of specimens of all concrete mixtures, 43-grade Ordinary Portland Cement (Ultratech Cement) from the local shop was used. All of the cement used in the experiments came from the same place. The cement was all the same dark colour. The cement was tested for various properties in accordance with IS: 4031-1988, as well as the validation of various determinations in accordance with IS: 12269-1987.

5.2. Fine Aggregate

*5.2.1 Natural River Sand:*It's been sieved and cleaned to eliminate any particles larger than 4.75mm. This investigation will use locally available river sand that passes a 4.75mm sieve according to IS:383 (2016) as a fine aggregate.

S. No.	Physical Property	Requirement as per IS (4031-1988)	Test results
1	Consistency	26-33%	33%
2	Initial setting time Final setting time	30 minutes (min.) 600 minutes (max.)	118 minutes 311 minutes
3	Specific gravity	3.12-3.19	3.15

Table. 1 Physical properties of cement

5.2.2 Waste Foundry Sand: If waste material like foundry sand have used as construction material, it can help to reduce the amount of disposal material. Foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (sea coal, resins), and dust. It can be used as a partial replacement of fine aggregate. The size of the WFS will be less than 4.75mm.

S. No.	Particulars	Chemical Components (%)					
		SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	LOI
1	Natural Sand	79.59	0.48	0.05	5.65	13.45	0.78
2	Waste Foundry Sand	85.93	0.41	.30	0.95	4.79	7.62

Table. 2 Chemical properties of fine aggregates

Symbol	Particulars	Physical Properties		
		Specific Gravity	Water Absorption (%)	Fineness Modulus (%)
R-S	River Sand	2.65	0.65	2.44
S-1	Waste Foundry Sand	2.56	0.45	2.20

Table. 3 Physical properties of fine aggregates

5.3. Coarse Aggregate: Coarse aggregate is the number that passes through an 80 mm sifter and is held in a 4.75 mm strainer. The coarse aggregate sizes used in this analysis were 10 mm and 20 mm. Dust, vegetation, organic matter, and clay should all be removed from coarse aggregate.

5.4. Water: The meaning of water plays an important role in the production of concrete. Potable water will be used in the project to ensure that the water is free of impurities including suspended solids, organic matter, and dissolved salts. The same source of water was used in the investigation, as stated in IS: 456-2000.

VI. METHODOLGY

6.1. Experimental program

An experimental software was used to investigate the impact of waste foundry sand (WFS) as a partial replacement for fine aggregates (natural sand) in one grade of concrete mixtures. The fine aggregate (natural sand) was then replaced with a five-percentage-point replacement of WFS by weight (0 percent, 5 percent, 10%, 15%, and 20%).

Because of the construction industry's rapid development of a variety of fine aggregates, the aim of this study is to prevent sandpits from being dug up. The output of (M25) for up to 56 days was investigated using compressive strength, splitting tensile strength, flexural strength, carbonation depth, and water absorption.

6.2. Mix Proportions:

Mixture No.	Concrete Type (M25 grade)				
	M-1	M-2	M-3	M-4	M-5
Cement (kg/m^3)	394	394	394	394	394
Natural Sand (kg/m^3)	683	649	615	581	547
WFS (%)	0%	5%	10%	15%	20%
WFS (kg/m^3)	0	34	68	102	136
Coarse aggregate (kg/m^3)	1194	1194	1194	1194	1194
Water (kg/m^3)	197	197	197	197	197
W/C ratio	0.50	0.50	0.50	0.50	0.50

Table. 4 Concrete mix proportions with and without spent foundry sand

The mix proportion of concrete was prepared in this study using the concrete mix design process, which has all of the necessary properties. The concrete mix concept for M25 grade was created using the IS code: 10262-2019 as a reference. With different ratios up to 20%, waste foundry sand was applied to the mix by the weight of concrete as a partial substitute for fine aggregate.The water to cement ratio (W/C) was maintained at 0.5.

6.3 Preparation of material

All of the materials were brought to room temperature before the experiment began. Cement, river sand, and foundry waste sand were all stored in a dry location. Each batch of concrete's aggregate samples is air-dried and graded according to the specifications. In general, a IS Sieve of 4.75 mm was used to distinguish the fine and coarse fractions.

6.4 Proportioning and Weighing

The amounts of cement, fine aggregate, coarse aggregate, and water in each batch were determined by weight with a precision of 0.1 percent of the total batch weight.

6.5 Mixing

Since mixing is such an essential element of any effective investigation, it should be given careful consideration in order to produce the best results.

6.6 Preparation of specimens

MS moulds were used to shape the concrete, which included a beam, cube, and cylinder. Until casting, all of the beam, cube, and cylinder moulds were thoroughly cleaned and oiled.

6.7 Compaction

The method of compacting freshly placed concrete involves scraping trapped air pockets and compacting the remaining particles. Full compaction is needed in this case to reinforce the bond with the support as well as the overall strength and density of the concrete.

6.8 Curing

Curing is the method of avoiding moisture loss and maintaining a comfortable temperature range for the solid. This step hydrates the cement and increases the concrete's strength and imperviousness. Breaks, which can have a major effect on electricity, are often required to be repaired. All of the specimens were examined and removed from the moulds after 24 hours, and then put in the curing tank.

VII. TESTING RESULTS

The laboratory will look into the different properties of concrete made with M25 and waste foundry sand as a partial substitute for natural sand.

7.1 Workability

The workability of fresh concrete was determined using the slump test. Figure 3 depicts the workability of concrete containing waste foundry sand as a partial substitute for river sand in an M25 grade concrete mix.The workability of grade M25 concrete mix revealed that the control mix M1 had a slump value of 75mm, while we can see 72mm at 5% replacement ratio, 70mm at 10% replacement ratio, 65mm at 15% replacement ratio, and 65mm at 20% replacement ratio, and we can see a continuous decrement in slump value.As a result, concrete mixes containing river sand have been found to be more workable than concrete produced by partially substituting waste foundry sand for natural sand. To make the concrete workable, more water or superplasticizer will be needed.

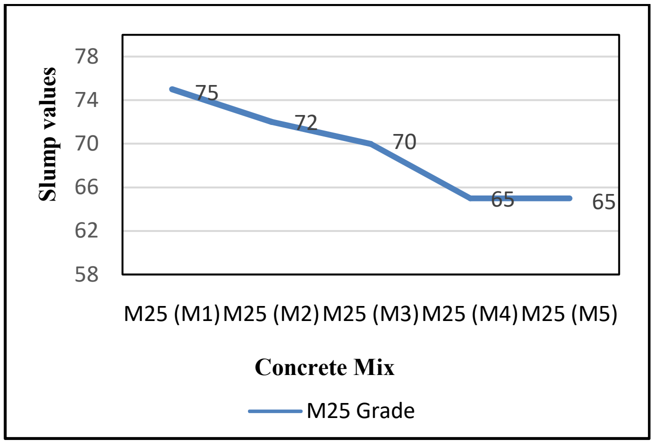

Fig. 3 Variation in slump values of different concrete mixes (M25)

7.2 Compressive Strength:

Figure 4 shows the compressive strength of both concrete grades up to the age of 28 days. The 28-day compressive strength of control concrete M-1 (0 percent WFS) for Concrete Grade M25 was 30.2 MPa. At 28 days, the percentage increase in compressive strength for mixtures M-2 (5 percent WFS), M-3 (10 percent WFS), M-4 (15 percent WFS), and M-5 (20 percent WFS) was 13.9 percent, 21.19 percent, 24.50 percent, and 22.50 percent, respectively, compared to control mix M-1 (30.2 MPa).

7.3 Split Tensile Strength

The effects of splitting tensile strength of concretes up to the age of 28 days are shown in Fig.5. At 28 days, the splitting tensile strength of control concrete of grade M25 was 3.44 MPa. At the same age, M-2 (5 percent WFS), M-3 (10 percent WFS), M-4 (15 percent WFS), and M-5 (20 WFS) showed increases of 8.14 percent, 12.21 percent, 12.79 percent, and 7.56 percent, respectively, over control concrete M-1 (0 percent WFS).The differences in splitting tensile strength with waste foundry sand followed the same patterns as the compressive strength variations. The splitting tensile strength of concrete mixtures increased as the WFS content and age both increased.This pattern was seen in all age groups and in all mixtures. It's possible that this is due to an increase in fine particles of spent foundry sand in concrete mixtures, which has resulted in a decrease in water cement gel.

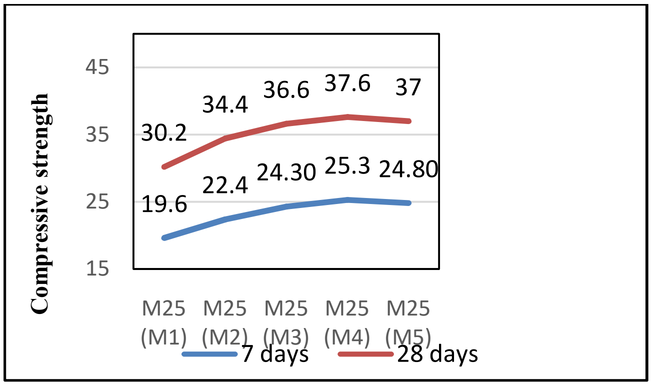

Fig. 4 Compressive Strength, 7 days and 28 days for M25 Grade

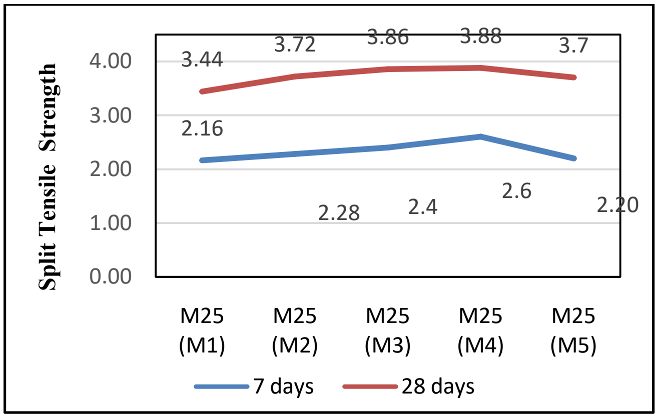

Fig. 5 Split Tensile Strength, 7 days and 28 days for M25 Grade

7.4.4 Flexural Strength

Figure6 shows the flexural power of concretes up to the age of 28 days. Control concrete of grade M25 had a flexural strength of 3.86MPa after 28 days. At the same age, M-2 (5 percent WFS), M-3 (10 percent WFS), M-4 (15 percent WFS), and M-5 (20 WFS) showed increases of 1.55 percent, 5.7 percent, 9.84 percent, and 6.74 percent, respectively, over control concrete M-1 (0 percent WFS).

7.5 Carbonation Test

One of the critical parameters associated with the corrosion of steel reinforcements is concrete carbonation. Carbonation depth was estimated at 28 and 56 days for all mixtures and summarised in Figure 7.The carbonation depth of the concrete is higher in control sample M1, i.e., 4.2, and decreases with increased substitution rate; additionally, the increase in depth was observed above the substitution rate of 15%. Sample M-4 has the shallowest carbonation depth.However, since the carbonation depth value of mixtures was similar to the cover of reinforced steel bars, concrete with a substitution rate greater than 15% is not recommended for structural concrete. This test is conducted on the prepared specimens at 28 days and 56 days after 28 days of curing, according to CPC-18 RILEM's prescribed guidelines.M25 indicates that the same graph can be used to determine the extent of carbon penetration. We can see that the carbonation depth increases with the length of CO_2 exposure in all samples in both grades. In almost all of the specimens made from different substitute ratios, there was no penetration in 28 days of exposure testing and a small rise in carbon depth in 56 days of exposure testing.

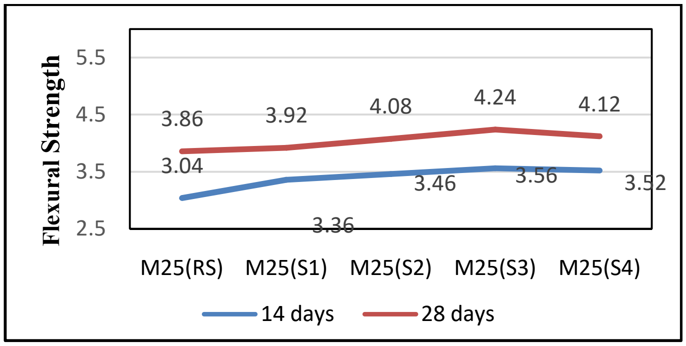

Fig. 6 Flexural Strength, 14 days and 28 days for M25 Grade

4.3.6 Water Absorption Test

Table 3 shows the effects of water absorption tests on concretes up to 28 days old. Water absorption was 5% in control concrete of grade M25. At the same period, the pattern for M-2 (5 percent WFS), M-3 (10 percent WFS), M-4 (15 percent WFS), and M-5 (20 WFS) was 4.6 percent, 4 percent, 3.8 percent, and 4.8 percent, respectively, over control concrete M-1 (0 percent WFS).

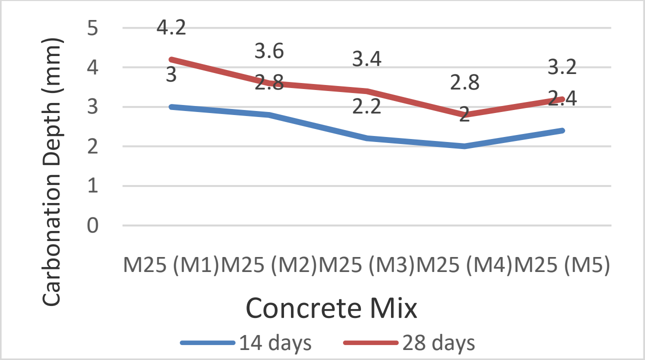

Fig. 7 Variation in the carbonation depth of the specimens (M25)

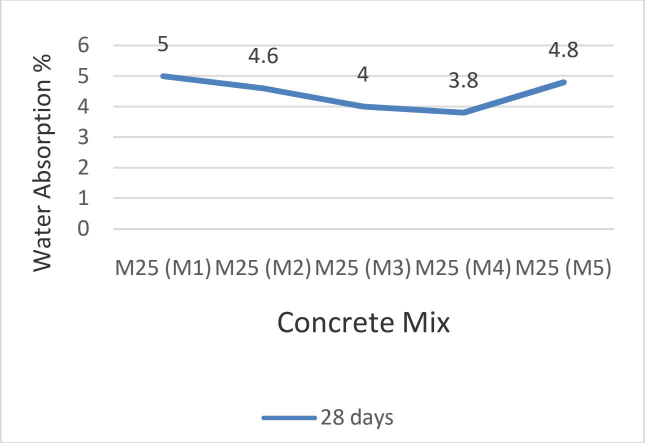

Fig. 8 Variation in the Water absorption of the specimens (M25)

VIII. CONCLUSION AND FUTURE WORK

8.1 Conclusion

The bulk density, specific gravity, and grain size distribution of WFS were found to be nearly identical to those of natural sand, with the exception that the particle size distribution of foundry sand does not reach IS-383–1970 grading limits due to the presence of impurities such as clay, saw dust, and other contaminants.

Compressive strength, split tensile strength, and flexural strength of M25 grade concrete all increased with the WFS content up to 15%, however there was a small declination at above 15% WFS.This may be because the increased surface area of fine particles causes a decrease in the water cement gel in the matrix, causing the coarse and fine aggregate binding mechanism to fail.

The carbonation depth of the concrete is higher in control sample M1, i.e., 4.2, according to the 56-day data. Carbonation depth decreased as the substitution rate increased; additionally, the increase in depth was found above the 15% substitution rate.

We found the lowest water absorption percentage in sample M-4, and we found more water absorption percentages in M25 grade concrete samples above 15%.

8.2 Recommendation For Future Work

Following is a recommendation for future work based on this investigation and its findings:

WFS may be used as a partial replacement for fine aggregates in concrete, eliminating waste and conserving fine aggregates. WFS will help save the planet by reducing global warming and resulting in environmentally friendly and cost-effective concrete.

All of the researchers used standard concrete ingredients with waste foundry sand, with no consideration given to admixtures or the use of fly ash or other materials that can alter the properties of concrete. Chemical admixtures, such as super plasticizers, can be used to improve the concrete's bonding properties.

Many properties of concrete mix, such as mechanical, basic durability properties, and microstructural characteristics, have been investigated in this study using waste foundry sand, but others, such as fatigue properties, chloride attack, and freezing-thawing effect at elevated temperatures, have also been determined.

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BIOGRAPHY

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