Journal of Engineering Sciences

Vol 12, Issue 07, July/2021

ISSN NO:0377-9254

EXPERIMENTAL INVESTIGATION OF WASTE FOUNDRY SAND ON STRENGTH PROPERTIES OF PLAIN CONCRETE AND COMPARISON WITH BINARY BLENDED CONCRETE

G.NAGAMANI[1], J.V.SAI SUMANTH[2]

[1]Assistant Professor, Dept of Civil Engineering, AVANTHI'S scientific technology and research academy.

[2]Assistant Professor, Dept of Civil Engineering, AITS, Kadapa.

***Abstract*—** An acute shortage of river sand which is generally used as a fine aggregate in concrete has been affecting the construction sector. The scarcity has led to the skyrocketing price of sand, escalating construction costs. The situation has dashed the dreams of many in the lower- and middle-income groups to own a house. There were studies about the depletion of river sand and the need for scientific management and exploitation of the available resource. Following the shortage of river sand, some research institutions are searching alternatives that can be used for construction.

Ferrous and non ferrous metal casting industries produce several million tons of byproduct in the world. In India, approximately 2 million tons of waste foundry sand is produced yearly. WFS are a major byproduct of metal casting industry and successfully used as a land filling material for many years. In an effort to use the WFS in large volume, research is being carried out for its possible large scale utilization in making concrete as partial replacement of fine aggregate. Foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins) and dust. Foundry sand can be used in concrete to improve its strength and other durability factors. Foundry Sand can be used as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete.

Several admixtures have been developed to improve the strength and workability properties of concrete. Of all admixtures used in concrete, Micro Silica occupies a special position for quite a few reasons. The improvement of durability, resistance to chloride, sulphate, freezing and thawing, alkali silica reaction, frost attack, increase in compressive strength, reduces the permeability and bleeding.

This experimental investigation was performed to evaluate the strength properties of concrete mixtures, in which river sand was partially replaced with Waste Foundry Sand by weight. Compression test was carried out at the age of 7, 28 and 56days of curing. Split tensile test was performed at the age of 28 and 56 days. Flexural strength was tested at 28 days of curing. 10% Cement was replaced with Micro Silica and Fine aggregate was partially replaced with waste foundry sand by weight. Compressive strength at 7 and 28 days, Split tensile test at 28 days and Flexural strength was tested at 28 days of curing.

Test results indicate an increase in compressive strength of plain concrete by inclusion of WFS as a partial replacement of fine aggregate. The maximum strength was achieved at 40% replacement, after which there was loss in compressive strength. Flexural strength decreased with the inclusion and increase in the percentage of waste foundry sand. Compared with plain cement concrete, binary concrete containing micro silica has exhibited greater improvements.

The results indicate effective use of waste foundry sand as an alternate material, as partial replacement of fine aggregates in concrete. However, the partial replacement should not exceed 40% in plain concrete.

I. INTRODUCTION

The word concrete comes from the Latin word "concretus" meaning compact or condensed. Concrete was used for construction in many ancient structures. Concrete is a composite material composed of gravels or crushed stones (coarse aggregate), sand (fine aggregate) and hydrated cement (binder). Concrete, in the broadest sense, is any product or mass made by the use of a cementing medium. Generally, this medium is the product of reaction between hydraulic cement and water. For concrete to be good concrete it has to be satisfactory in its hardened state and also in its fresh state while being transported from the mixer and placed in the formwork. The requirements in the fresh state are that the consistence of the mix is such that the concrete can be compacted and also that the mix is cohesive enough to be transported and placed without segregation.

As far as the hardened state is considered, the usual requirement is a satisfactory compressive strength. Many properties of concrete are related to its compressive strength such as density, impermeability, durability, resistance to abrasion, resistance to impact, tensile strength, resistance to sulphates.

Aggregate: The coarse aggregate are granular materials obtained from rocks and crushed stones. They may be also obtained from synthetic material like slag, shale, fly ash and clay for use in light-weight concrete.

The sand obtained from river beds or quarries is used as fine aggregate. The fine aggregate along with the hydrated cement paste fill the space between the coarse aggregate.

The important properties of aggregate are as follows.

1) Shape and texture
2) Size gradation
3) Moisture content
4) Specific gravity
5) Unit weight
6) Durability and absence of deleterious materials.

Cement: In present day concrete, cement is a mixture of lime stone and clay heated in a kiln to 1400 - 1600ºC. The types of cement permittedas per IS:456 - 2000,Plain and Reinforced – Concrete Code of Practice.

1) Ordinary Portland cement confirming to IS: 269 - 1989,
2) Portland slag cement confirming to IS: 455 - 1989,
3) Rapid-hardening Portland cement confirming to IS:8041 - 1990,

Water: The water should satisfy the requirements of Section 5.4of IS:456 - 2000.

"Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete and steel".

Admixtures: IS: 1343 - 1980allows to use admixtures that conform to IS: 9103 - 1999, Concrete Admixtures – Specification. The admixtures can be broadly divided into two types: chemical admixtures and mineral admixtures. The common chemical admixtures are as follows.

1) Air-entraining admixtures
2) Water reducing admixtures
3) Set retarding admixtures
4) Set accelerating admixtures
5) Water reducing and set retarding admixtures
6) Water reducing and set accelerating admixtures.

The common mineral admixtures are as follows.

1) Fly ash
2) Ground granulated blast-furnace slag
3) Silica fume
4) Rice husk ash
5) Metakaolin

These are cementitious and pozzolanic materials.

II. LITERATURE REVIEW

M.J. Shannag (2000) dealt with various combinations of a local natural pozzolan and silica fume to produce workable high to very high strength mortars and concretes with a compressive strength in the range of 69-110 MPa. The mixtures were tested for workability, density, compressive strength, splitting tensile strength, and modulus of elasticity. The results of this study suggest that certain natural pozzolan+silica fume combinations can improve the compressive and splitting tensile strengths, workability, and elastic modulus of concretes, more than natural pozzolan and silica fume alone. Furthermore, the use of silica fume at 15% of the weight of cement was able to produce relatively the highest strength increase in the presence of about 15% pozzolan than without pozzolan. This study recommends the use of natural pozzolan in combination with silica fume in the production of high strength concrete, and for providing technical and economical advantages in specific local uses in the concrete industry.

S. Bhanja and B. Sengupta (2004)carried out an experiment over water–binder ratios ranging from 0.26 to 0.42 and silica fume–binder ratios from 0.0 to 0.3. For all the mixes, compressive, flexural and split tensile strengths were determined at 28 days. The compressive, as well as the tensile, strengths increased with silica fume incorporation, and the results indicate that the optimum replacement percentage is not a constant one but depends on the water–cementitious material (w/cm) ratio of the mix. Compared with split tensile strengths, flexural strengths have exhibited greater improvements. Based on the test results, relationships between the 28-day flexural and split tensile strengths with the compressive strength of silica fume concrete have been developed using statistical methods.

Rafat Siddique, Geert de Schutter and Albert Noumowec (2008) presented the results of an experimental investigation carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate (regular sand) was partially replaced with waste foundry sand. Fine aggregate was replaced with three percentages (10%, 20%, and 30%) of WFS by weight. Tests were performed for the properties of fresh concrete. Compressive strength, splitting-tensile strength, flexural strength, and modulus of elasticity were determined at 28, 56, 91, and 365 days. Test results indicated a marginal increase in the strength properties of plain concrete by the inclusion of WFS as partial replacement of fine aggregate (sand) and that can be effectively used in making good quality concrete and construction materials.

Yogesh Aggarwal, Paratibha Aggarwal, Rafat Siddique, El-Hadj Kadri and Rachid Bennacer (2010)presented the design of concrete mixes made with waste foundry sand as partial replacement of fine aggregates up to 40%. Various mechanical properties are evaluated (compressive strength, and split tensile strength). Durability of the concrete regarding resistance to chloride penetration, and carbonation is also evaluated. Test results indicate that industrial by-products can produce concrete with sufficient strength and durability to replace normal concrete. Compressive strength, and split-tensile strength, was determined at 28, 90 and 365 days. Comparative strength development of foundry sand mixes in relation to the control mix i.e. mix without foundry sand was observed. Thereby, indicating effective use of foundry sand as an alternate material, as partial replacement of fine aggregates in concrete.

Gurpreet Singh and Rafat Siddique (2011) carried out an experimental investigation to evaluate the strength and durability properties of concrete mixtures, in which natural sand was partial replaced with (WFS). Natural sand was replaced with five percentage (0%, 5%, 10%, 15%, and 20%) of WFS by weight. Compression test and splitting tensile strength test were carried out to evaluate the strength properties of concrete at the age of 7, 28 and 91 days. Test results indicate a marginal increase in strength properties of plain concrete by inclusion of WFS as a partial replacement of fine aggregate.

Gurpreet Singh and Rafat Siddique (2011) investigated the abrasion resistance and strength properties of concrete containing waste foundry sand (WFS). Sand (fine aggregate) was replaced with 0%, 5%, 10%, 15% and 20% of WFS by mass. The water-to-cement ratio and the workability of mixtures were maintained constant at 0.40 and 85 ± 5 mm, respectively. Properties examined were compressive strength, splitting tensile strength, modulus of elasticity and abrasion resistance expressed as depth of wear. Test results indicated that replacement of sand with WFS enhanced the 28-day compressive strength by 8.3–17% and splitting tensile strength by 3.6–10.4% depending upon the WFS content, and showed continuous improvement in mechanical properties up to the ages of 365 days.

Rafat Siddique and El-Hadj Kadri (2011) dealt with the effect of foundry sand (FS) and metakaolin (MK) on the near surface characteristics of concrete. A control concrete having cement content 450 kg/m^3 and w/c of 0.45 was designed. Cement was replaced with three percentages (5%, 10%, and 15%) of metakaolin weight, and fine aggregates were replaced with 20% foundry sand. Tests were conducted for initial surface absorption, sorptivity, water absorption and compressive strength at the ages of 35, 56, and 84 days.

III. OBSERVATIONS AND DISCUSSION OF TEST RESULTS

Results obtained from experimental investigation to study the strength properties of plain concrete mixes in which fine aggregate is replaced by waste foundry sand at various percentages are presented here for discussion they are compared with the binary blended concrete.

The study was conducted to find out the influence of waste foundry sand on strength properties of plain and binary blended concrete.

The effects of following parameters were studied.

1) The various percentage replacement of fine aggregate with waste foundry sand on some of the strength properties of plain concrete.

2) The optimum percentage replacement of micro silica with cement and various percentage replacement of fine aggregate with waste foundry sand on some of the strength properties of binary blended concrete.

A. Test Results of Plain Concrete

Various tests were done to investigate the effect of replacement of fine aggregate with waste foundry sand in different proportions on workability, compressive strength, split tensile strength and flexural strength on plain concrete. The replacement percentage of waste foundry sand was taken at 0%, 10%, 20%, 30%, 40%, 50% and 60%. The test results of the experimental investigations performed on Plain Concrete are tabulated in the Table 4.1 to 4.4.Test results are also shown graphically in the Figures 4.1 to 4.4.

1. Workability

Workability of concrete mixes soon after mixing in machine was tested using slump cone test as per IS: 1199-1959. Test results are given in Table 3.1 and represented in Fig 3.1.

Table 3.1 Workability of Plain Concrete with Various Percentages of Waste Foundry Sand

S.No.	Mix ID	Slump (mm)
1	WF0	70
2	WF10	64
3	WF20	59
4	WF30	52
5	WF40	44
6	WF50	32
7	WF60	21

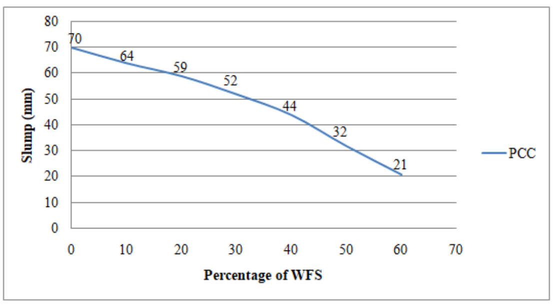

Figure 3.1: Workability of Plain Concrete with Various Percentages of Waste Foundry Sand

As the waste foundry sand percentage increased in the concrete the workability was reduced. This may be due to the void filling action of the waste foundry sand as it is finer than the fine aggregate, which gives a high cohesion to the mix. Mix with increase in waste foundry sand content tends to become harsh, sticky and stiff. At 50% replacement of fine aggregate with waste foundry sand the concrete mix became harsh.

2. Compressive Strength Test

Cube specimens were tested for compression and ultimate compressive strength was determined from failure load measured using compression testing machine. The average value of compressive strength of 3 specimens for each category at the age of 7 days, 28 days and 56 days are tabulated in the Table 3.2. The relative compressive strength of various concrete mixes at different ages is shown in Figure 3.2.

Plate 7 Failure of Cube Specimen of Plain Concrete

Table 3.2 Compressive Strength of Various Concrete Mixes with Replacement of Fine Aggregate over Waste Foundry Sandat Different Ages

S.No.	Mix ID	Compressive Strength (MPa)		
		7 days	28 days	56 days
1	WF0	32.88	52.14	54.81
2	WF10	33.18	52.44	55.85
3	WF20	33.77	53.55	55.85
4	WF30	33.92	53.92	56.21
5	WF40	34.36	54.51	56.44
6	WF50	34.21	51.84	53.33
7	WF60	32.6	46.95	49.77

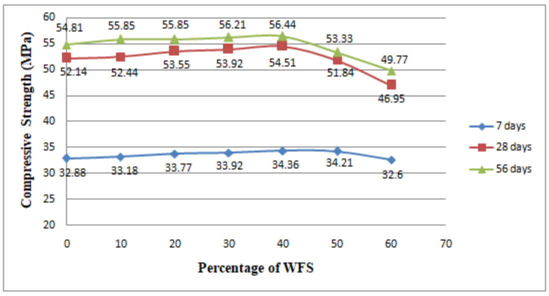

Figure 3.2: Compressive Strength of Various Concrete Mixes with Replacement of Fine Aggregate over Waste Foundry Sandat Different Ages

About 63% of the 28 days strength was achieved in 7 days. Compressive strength of 32.88 MPa for control mix was achieved at 7 days of curing. There was marginal increase in the compressive strength of concrete mixes with increase in the percentage of waste foundry sand. The compressive strength of concrete mixes increased up to 40% replacement of fine aggregate with waste foundry sand. With further increase in the percentage of waste foundry sand the compressive strength started to decrease. Maximum compressive strength of 34.36 MPa was achieved with 40% replacement of fine aggregate with waste foundry sand at 7 days.

Compressive strength of 52.14 MPa was achieved at 28 days which is higher than the target strength of 48.25 MPa. There is a considerable improvement in the compressive strength of concrete with inclusion and increase in the percentage of waste foundry sand up to 40%. Referring to Table 3.3 and Table 3.8, 48% of the aggregate lies between 600μ and 150μ size whereas 80% of foundry sand lies between 600μ and 150μ size. Hence foundry sand is finer than aggregate thus increasing the strength of concrete up to 40% replacement. Maximum compressive strength of 54.51 MPa was achieved with 40% of waste foundry sand with 4.5% increase in the strength compared to control mix of 52.14 MPa. However on replacement of 50% aggregate the concrete started losing its workability and hence the strength decreased. The strength 51.84 MPa was lower than the control mix but higher than the target strength. At 60% replacement of fine aggregate strength of 46.95 MPa was achieved at 28 days which is less than the target strength. About 5% increase in the compressive strength was observed at 56 days when compared to 28 days strength. Strength of 54.81 MPa with 100% river sand and maximum strength of 56.44 MPa with 40% waste foundry sand was achieved at 56 days. It is observed that the compressive strength increased with increasing age of curing. The maximum compressive strength was achieved with 40% replacement of fine aggregate with waste foundry sand at all ages.

3. Split Tensile Strength Test

Table 3.3 and Figure 3.3 show the graphical representation of variation of split tensile strength of plain concrete at 28 and 56 days.

Table 3.3 Split Tensile Strength of Various Concrete Mixes with Replacement of Fine Aggregate over Waste Foundry Sandat Different Ages

S.No.	Mix ID	Split Tensile Strength (MPa)	
		28 days	56 days
1	WF0	4.60	4.87
2	WF10	4.66	5.23
3	WF20	4.95	5.30
4	WF30	5.02	5.44
5	WF40	5.09	5.51
6	WF50	5.16	5.51
7	WF60	4.66	5.37

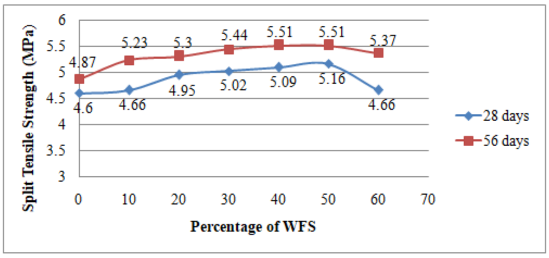

Figure 4.3: Split Tensile Strength of Various Concrete Mixes with Replacement of Fine Aggregate over Waste Foundry Sandat Different Ages

Split tensile strength of 4.6 MPa for control mix was achieved at 28 days. Split tensile strength of concrete mixes increased up to 50% replacement of fine aggregate with waste foundry sand. Maximum strength of 5.16 MPa was achieved at 50% replacement which is 12% more than the control mix. With further increase in the percentage of waste foundry sand the split tensile strength of concrete mix started to decrease. About 6% increase in the split tensile strength was observed at 56 days when compared to 28 days strength. Strength of 4.87 MPa with 100% river sand and maximum strength of 5.51 MPa with 40% and 50% waste foundry sand was achieved at 56 days.

4. Flexural Strength Test

Beam specimens were tested for flexural strength. The tests were carried out confirming to IS 516-1959the specimens were tested under two point loading. The average value of 2 specimens for each category at the age of 28 days is tabulated in the Table 3.4. Figure 3.4 shows the graphical representation of variation of flexural strength of plain concrete at the age of 28 days.

Plate 8 Failure of Beam Specimen of Plain Concrete

Table 3.4 FlexuralStrength of Various Concrete Mixes with Replacement of Fine Aggregate over Waste Foundry Sand

S.No.	Mix ID	Flexural Strength (MPa) 28 days
1	WF0	6.9
2	WF10	6.6
3	WF20	6.4
4	WF30	6.0
5	WF40	5.9
6	WF50	5.8
7	WF60	5.6

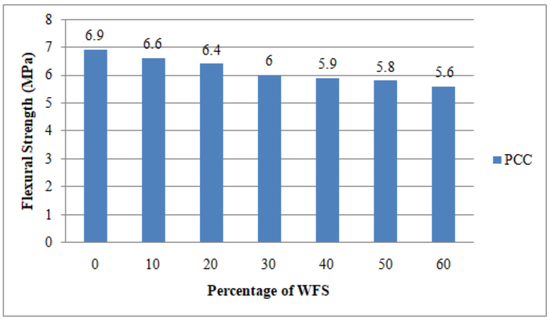

Figure 3.4: FlexuralStrength of Various Concrete Mixes with Replacement of Fine Aggregate over Waste Foundry Sand

Flexural strength of 6.9 MPa was achieved at 28 days of curing for the control mix. There is marginal reduction in the flexural strength of concrete with the inclusion and increase in the percentage of waste foundry sand. 23% loss of flexural strength was obtained with 60% of waste foundry sand when compared to the control mix.

B. Test Results of Binary Blended Concrete

1. Trial Mixes to find Optimum Percentage of Micro Silica

Cement was replaced with 5%, 10% and 15% micro silica and the compressive strength of concrete was found at 7 and 28 days. The maximum strength was achieved with 10% of micro silica. Test results for compressive test are given in Table 3.5 and represented in Fig 3.5.

Table 3.5 Compressive Strength of Various Concrete Mixes with Different Percentage of Micro Silicaat Different Ages

S.No.	Mix ID	Compressive Strength (MPa)	
		7 days	28 days
1	MS5	37.10	55.10
2	MS10	38.43	58.22
3	MS15	37.32	57.47

Vol 12, Issue 07, July/2021
ISSN NO:0377-9254

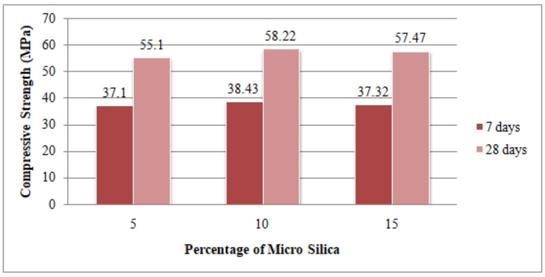

Figure 3.5: Compressive Strength of Various Concrete Mixes with Different Percentage of Micro Silicaat Different Ages

10% of cement was replaced with micro silica and various tests were done to investigate the effect of replacement of fine aggregate with waste foundry sand in different proportions on workability, compressive strength, split tensile strength and flexural strength on binary blended concrete. The replacement percentage of waste foundry sand was taken at 0%, 20%, 40% and 60%. The test results of the experimental investigations performed on binary blended concrete are tabulated in the Table 4.6 to 4.9.Test results are also shown graphically in the Figures 4.6 to 4.9.

2. Workability

Workability of concrete mixes soon after mixing in machine was tested using slump cone test as per IS: 1199-1959. Test results are given in Table 3.6 and represented in Fig 3.6.

Table 3.6 Workability of Concrete Mixes with Micro Silica and Various Percentages of Waste Foundry Sand

S.No.	Mix ID	Slump (mm)
1	MS10WF0	78
2	MS10WF20	72
3	MS10WF40	66
4	MS10WF60	58

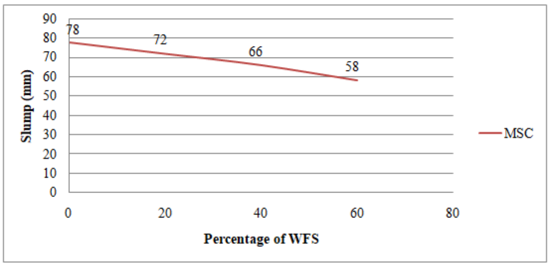

Figure 3.6: Workability of Concrete Mixes with Micro Silica and Various Percentages of Waste Foundry Sand

Workable mixes were achieved with 10% replacement of cement by Micro silica. With increase in the percentage of waste foundry sand the slump value started decreasing. However, concrete mix containing 60% waste foundry sand was still workable.

3. Compressive Strength Test

Compressive strength of concrete at the age of 7 days and 28 days of curing with 10% micro silica and various percentage replacement of fine aggregate with waste foundry sand were tested. Test results are given in Table 3.7 and represented in Fig 3.7.

Plate 9 Failure of Cube Specimen of MSC

Table 3.7 Compressive Strength of Concrete Mixes with Micro Silica and VariousPercentage of Waste Foundry Sandat Different Ages

S.No.	Mix ID	Compressive Strength (MPa)	
		7 days	28 days
1	MS10WF0	36.36	58.96
2	MS10WF20	37.77	61.48
3	MS10WF40	38.43	62.66
4	MS10WF60	33.10	52.14

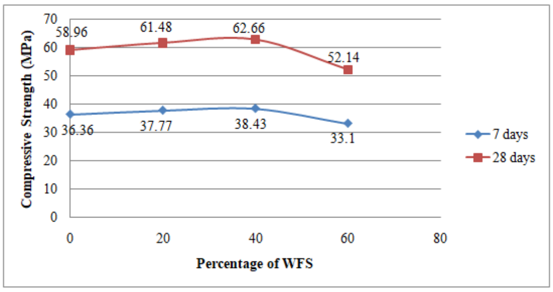

Figure 3.7: Compressive Strength of Concrete Mixes with Micro Silica and Various Percentage of Waste Foundry Sandat Different Ages

About 62% of the 28 days strength was achieved in 7 days. There was marginal increase in the compressive strength of concrete mixes with increase in the percentage of waste foundry sand. The compressive strength of concrete mixes increased up to 40% replacement of fine aggregate with waste foundry sand. With further increase in the percentage of waste foundry sand the compressive strength started to decrease. Maximum compressive strength of 38.43 MPa was achieved with 40% replacement of fine aggregate with waste foundry sand at 7 days.

Compressive strength of 58.96 MPa was achieved at 28 days which is higher than the target strength of 48.25 MPa. The higher strength is achieved by incorporating micro silica into the concrete which is much finer than the cement particles thus filling the void spaces. There is a considerable improvement in the compressive strength of concrete with inclusion and increase in the percentage of waste foundry sand up to 40%. Maximum compressive strength of 62.66 MPa was achieved with 40% of waste foundry sand. At 60% replacement of fine aggregate, strength of 52.14 MPa was achieved at 28 days which is more than the target strength.

4. Split Tensile Strength Test

Split tensile strength of concrete at 28 days of curing with 10% micro silica and various percentage replacement of fine aggregate with waste foundry sand were tested. Test results are given in Table 3.8 and represented in Fig 3.8.

Plate 10 Failure of Cylindrical Specimen

Table 3.8 Split Tensile Strength of Various Concrete Mixes with Micro Silica and Different Percentages of Waste Foundry Sand

S.No.	Mix ID	Split Tensile Strength (MPa) 28 days
1	MS10WF0	5.16
2	MS10WF20	5.30
3	MS10WF40	5.58
4	MS10WF60	5.02

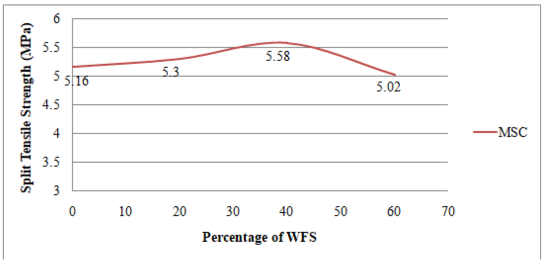

Figure 3.8: Split Tensile Strength of Various Concrete Mixes with Micro Silica and Different Percentages of Waste Foundry Sand

Split tensile strength of 5.16 MPa was achieved at 28 days. Split tensile strength of concrete mixes increased up to 40% replacement of fine aggregate with waste foundry sand. Maximum strength of 5.58 MPa was achieved at 40% replacement. With further increase in the percentage of waste foundry sand the split tensile strength of concrete mix started to decrease.

5. Flexural Strength Test

Flexural strength of concrete at 28 days of curing with 10% micro silica and various percentage replacement of fine aggregate with waste foundry sand were tested. Test results are given in Table 3.9 and represented in Fig 3.9.

Plate 11 Failure of Beam Specimen of MSC

Table 3.9 Flexural Strength of Various Concrete Mixes with Micro Silica and Different Percentage of Waste Foundry Sand

S.No.	Mix ID	Flexural Strength (MPa) 28 days
1	MS10F0	7.5
2	MS10F20	6.9
3	MS10F40	6.4
4	MS10F60	6.0

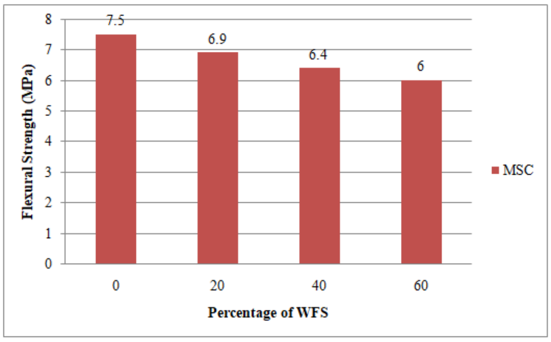

Figure 3.9: Flexural Strength of Various Concrete Mixes with Micro Silica and Different Percentage of Waste Foundry Sand

Flexural strength of 7.5 MPa was achieved at 28 days of curing. There is reduction in the flexural strength of concrete with the inclusion and increase in the percentage of waste foundry sand.

C. Comparison of Results of Tests on Plain Concrete and Binary Blended Concrete

The effects of replacement of fine aggregate with waste foundry sand in different proportions on workability, compressive strength, split tensile strength and flexural strength on Plain Cement Concrete (PCC) and Binary Blended Concrete incorporating 10% Micro Silica(MSC) have been studied in detail. A study of the results of various tests done on PCC and MSC are as follows. The comparison of test results of the experimental investigations performed on plain concrete and binary blended concrete are tabulated

Vol 12, Issue 07, July/2021
ISSN NO:0377-9254

in the Table 3.10 to 3.16. Test results are also shown graphically in the Figures 3.10 to 3.14.

1. Workability

Workability of concrete mixes soon after mixing in machine was tested using slump cone test as per IS: 1199-1959. Test results are given in Table 3.10 and represented in Fig 3.10.

Table 3.10Workability of PCC and MSC with Various Percentages of Waste Foundry Sand

S. No.	MIX ID	Slump (mm)	
		PCC	MSC
1	WF0	70	78
2	WF20	59	72
3	WF40	44	66
4	WF60	21	58

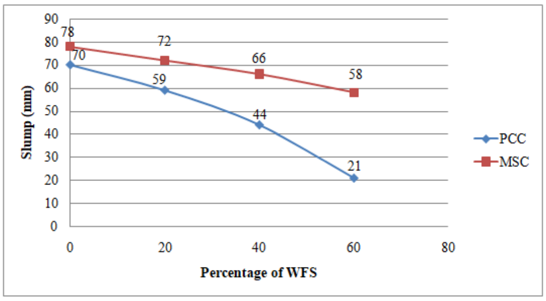

Figure 3.10: Workability of PCC and MSC with Various Percentages of Waste Foundry Sand

Concrete mixes containing micro silica showed better workability when compared to plain concrete. With the increase in the percentage of waste foundry sand the value of slump was decreasing in both PCC as well as MSC. In PCC mix with 50% replacement of fine aggregate with waste foundry sand the mix became harsh where as in MSC mix with 60% replacement of fine aggregate with waste foundry sand the mix was still workable. Hence by using micro silica a workable mix with 60% replacement can be achieved.

2. Compressive Strength Test

Test results for compressive test on PCC and MSC at 7 days are given in table 3.11 and represented in Fig 3.11.

Table 3.11 Compressive Strength of PCC and MSC with Various Percentages of Waste Foundry Sand at 7 days

S. No.	MIX ID	Compressive Strength (MPa)	
		PCC	MSC
1	WF0	32.88	36.36
2	WF20	33.77	37.77
3	WF40	34.36	38.43
4	WF60	32.60	33.10

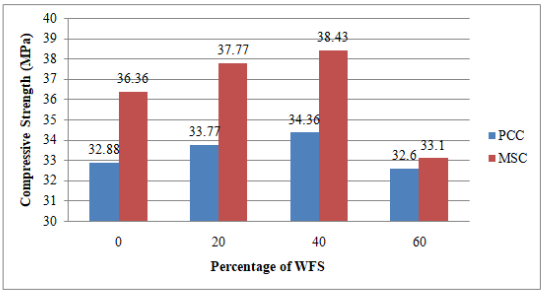

Figure 3.11: Compressive Strength of PCC and MSC with Various Percentages of Waste Foundry Sand at 7 days

Compressive strength of 36.36 MPa was achieved with 10% inclusion of micro silica into the mix at 0% replacement of fine aggregate. For 0% replacement, 10.5% increase was observed when compared to the compressive strength of control mix of strength 32.88 MPa at 7 days. Strength increased up to 40% replacement in both PCC and MSC mixes. At 40% replacement MSC mix showed strength of 38.43 MPa which is 11.8% more than the PCC mix at same percentage replacement. However, a marginal increase in the strength of MSC mix was observed at 60% replacement when compared to PCC mix at same percentage of replacement.

Test results for compressive test on PCC and MSC at 28 days are given in table 3.12 and represented in Fig 3.12.

Table 3.12Compressive Strength of PCC and MSC with Various Percentages of Waste Foundry Sand at 28 days

S. No.	MIX ID	Compressive Strength (MPa)	
		PCC	MSC
1	WF0	52.14	58.96
2	WF20	53.55	61.48
3	WF40	54.51	62.66
4	WF60	46.95	52.14

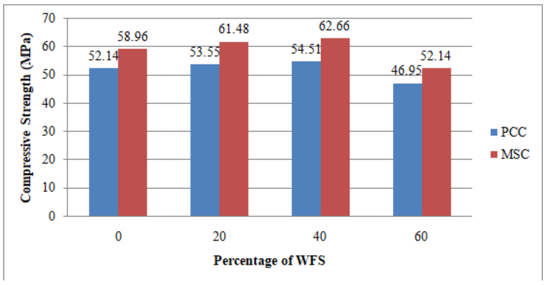

Figure 3.12: Compressive Strength of PCC and MSC with Various Percentages of Waste Foundry Sand at 28 days

Chemical analysis was carried out to know the reason for strength behavior of PCC and MSC mixes with various percentage replacement of fine aggregate over waste foundry sand.

Journal of Engineering Sciences
Vol 12, Issue 07, July/2021
ISSN NO:0377-9254

Table 3.13 shows the chemical composition of plain concrete mixes in dry state with replacement of fine aggregate over waste foundry sand.

Table 3.13 Chemical Composition of Plain Concrete Mixes in Dry State with Replacement of Fine Aggregate over Waste Foundry Sand

S.No.	Mix ID	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	SO_3 (%)	K_2O (%)	Na_2O (%)
1	WF0	69.72	3.26	1.37	23.88	0.78	0.54	0.30	0.13
2	WF20	68.46	3.14	2.05	24.21	0.88	0.56	0.43	0.24
3	WF40	67.18	3.03	2.74	24.55	0.98	0.60	0.55	0.34
4	WF60	65.90	2.91	3.44	24.90	1.08	0.62	0.70	0.45

Table 3.14 shows the chemical composition of binary blended concrete mixes incorporating 10% micro silica in dry state with replacement of fine aggregate over waste foundry sand.

Table 3.14 Chemical Compositionof Binary Blended Concrete Mixes in Dry State with Replacement of Fine Aggregate over Waste Foundry Sand

S.No.	Mix ID	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	SO_3 (%)	K_2O (%)	Na_2O (%)
1	WF0	72.33	3.09	1.27	21.55	0.78	0.52	0.30	0.12
2	WF20	71.09	2.97	1.95	21.80	0.88	0.54	0.43	0.23
3	WF40	69.83	2.85	2.64	22.20	0.98	0.57	0.56	0.33
4	WF60	68.56	2.74	3.34	22.53	1.07	0.60	0.70	0.44

Compressive strength of 58.96 MPa was achieved at 0% replacement of fine aggregate at 28 days which is 13% more than the compressive strength of control mix of 52.14 MPa. The strength of MSC mixes is greater when compared to the PCC mixes is due to the increase in the silica content in MSC mixes which forms C-S-H gel thus increasing the strength of concrete mix. With inclusion and increase in the percentage of waste foundry sand the strength increased up to 40% due to the increase in calcium content in the mix.

At 40% replacement of fine aggregate with waste foundry sand strength of 54.51 MPa was achieved which is 4.5% more than the control mix and for binary blended concrete strength of 62.66 MPa was achieved which is 20% more than the control mix. At 60% replacement the strength was decreased due to loss of workability and higher percentage of unwanted chemicals. At 60% replacement strength of 46.95 MPa was observed for PCC mix which is less than the target strength for M40 grade of concrete and strength of 52.14 MPa was observed for MSC mix which is greater than the target strength. Hence for plain concrete mix 40% replacement of fine aggregate with waste foundry sand is beneficial whereas on using 10% micro silica, 60% replacement of fine aggregate with waste foundry sand is beneficial with good workability.

3. Split Tensile Strength Test

Test results for split tensile strength test on PCC and MSC at 28 days are given in table 3.15 and represented in Fig 3.13.

Table 3.15 Split Tensile Strength of PCC and MSC with Various Percentages of Waste Foundry Sand at 28 days

S. No.	MIX ID	Split Tensile Strength (MPa)	
		PCC	MSC
1	WF0	4.60	5.16
2	WF20	4.95	5.30
3	WF40	5.09	5.58
4	WF60	4.66	5.02

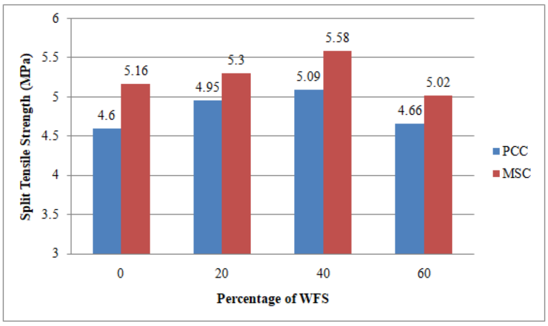

Figure 3.13: Split Tensile Strength of PCC and MSC with Various Percentages of Waste Foundry Sand at 28 days

12% increase in the split tensile strength was observed for binary blended mix at 0% replacement of fine aggregate when compared to the control mix. An increase in the split tensile strength of concrete was noticed when the percentage replacement of fine aggregate with waste foundry sand was increased up to 40% in both PCC and MSC mixes.

4. Flexural Strength Test

Test results for flexural strength test on PCC and MSC at 28 days are given in table 3.16 and represented in Fig 3.14.

Table 3.16 Flexural Strength of PCC and MSC with Various Percentages of Waste Foundry Sand at 28 days

S. No.	MIX ID	Flexural Strength (MPa)	
		PCC	MSC
1	WF0	6.9	7.5
2	WF20	6.4	6.9
3	WF40	5.9	6.4
4	WF60	5.6	6.0

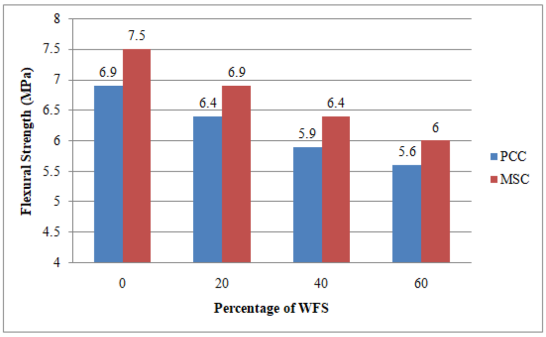

Figure 3.14: Split Tensile Strength of PCC and MSC with Various Percentages of Waste Foundry Sand at 28 days

Binary blended concrete incorporating micro silica showed better results when compared to plain concrete. About 8% increase in the flexural strength was observed in binary blended concrete mixes when compared to plain concrete mixes at all percentage replacement of fine aggregate with waste foundry sand. Hence for plain concrete mix 40% replacement of fine aggregate with waste foundry sand is beneficial whereas on using 10% micro silica, 60% replacement of fine aggregate with waste foundry sand is beneficial with good workability.

CONCLUSION

- When percentage of waste foundry sand was increased beyond 40% the mix started losing its workability.
- Replacement of fine aggregate with waste foundry sand showed increase in the compressive strength of plain concrete of grade M40 up to 40% and then there was a considerable decrease in the strength. Maximum strength was achieved at 40%.
- For Plain Concrete mix at 60% replacement of fine aggregate strength of 46.95 MPa was achieved at 28 days which is less than the target strength.
- Flexural strength of concrete decreased with the inclusion and increase in the percentage of waste foundry sand for plain concrete.
- 10% replacement of cement with micro silica was found to be optimum for M40 grade of concrete.
- Binary Blended Concrete mix containing 60% waste foundry sand was still workable.
- For Binary Blended Concrete mix at 60% replacement of fine aggregate, strength of 52.14 MPa was achieved at 28 days which is more than the target strength.
- Binary Blended Concrete incorporating micro silica showed better performance when compared to plain concrete.
- 13.08% increment in the compressive strength was found at 28 days using micro silica.
- 8% increase in the flexural strength was observed in Binary Blended Concrete mixes when compared to Plain Concrete mixes.

Scope for Further Investigations:

- Further research can be carried out to study the durability properties of concrete incorporating waste foundry sand as a partial replacement of fine aggregate.
- The investigation of concrete incorporating waste foundry sand can be carried out with addition of different types of fibers like steel fibers, recron fibers, synthetic fibers, dura fibers, natural fibers and glass fibers and with different aspect ratio.
- Further research can be carried out to study the properties of concrete with partial replacement of fine aggregate with waste foundry sand and partial replacement of cement with different mineral admixtures like GGBS, flyash, metakaolin, rice husk ash etc, with addition of different percentages of fibers.

REFERENCES

1) Rafat Siddique, Geert de Schutter and Albert Noumowe, (2008), "Effect of used-foundry sand on the mechanical properties of concrete", Construction and Building Materials, vol. 23, pp 976–980.
2) Yogesh Aggarwal, Paratibha Aggarwal, Rafat Siddique, El-Hadj Kadri and Rachid Bennacer, (2010), "Strength, durability, and micro-structural properties of concrete made with used-foundry sand (UFS)", Construction and Building Materials, vol. 25, pp 1916–1925.
3) Gurpreet Singh and Rafat Siddique, (2011), "Effect of waste foundry sand (WFS) as partial replacement of sand on the strength, ultrasonic pulse velocity and permeability of concrete", Construction and Building Materials, vol. 26, pp 416–422.
4) Khatib JM and Ellis DJ.,(2001), "Mechanical properties of concrete containing foundry sand".ACI special publication (SP-200), American Concrete Institute; pp. 733–748.
5) Siddique R., Gupta R and Kaur I.,(2007), "Effect of spent foundry sand as partial replacement of fine aggregate on the properties of concrete". In: 22nd International conference on solid waste technology and management, Widener University, Philadelphia, USA.
6) Gurpreet Singh and Rafat Siddique, (2011), "Abrasion resistance and strength properties of concrete containing wastefoundry sand (WFS)", Construction and Building Materials, vol. 28, pp 421–426.
7) Rafat Siddique and El-Hadj Kadri, (2011), "Effect of metakaolin and foundry sand on the near surface characteristics of concrete", Construction and Building Materials, vol. 25, pp 3257–3266.
8) Neelam Pathak and Rafat Siddique, (2012), "Effects of elevated temperatures on properties of self-compacting-concretecontaining fly ash and spent foundry sand", Construction and Building Materials, vol. 34, pp 512–521.