AN EXPERIMENTAL STUDY ON STRENGTH PROPERTIES OF CONCRETE CONTAINING WASTE FOUNDRY SAND AS A PARTIAL REPLACEMENT OF RIVER SAND

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ABSTRACT

India is modernizing its infrastructure at a fast pace and concrete is an essential requirement of infrastructural development. The main constituents of concrete are cement, sand (fine aggregate), gravel (coarse aggregate) and water. The high consumption of natural resources like sand and gravel affects the sustainable development. The study aims to determine the maximum percentage of waste foundry sand (WFS) for partial replacement of fine aggregate in concrete for different ratios (10%, 20%, 30% and 40%) by conducting strength tests on hardened concrete such as compressive strength, split tensile strength and flexural strength. From the durability point of view, tests such as acid resistance and alkalinity measurement are conducted. The strength and durability properties of concrete containing WFS indicate that there is a significant increase in mechanical strength for 30% sand replacement. The basic principle that the industrial waste by - products can be successfully used as building materials, thereby minimizing or eliminating the environmental degradation by way of hiding the same within a building structure has been test verified with WFS and has promising replacements for the conventional fine aggregate in the concrete.

Keywords: Concrete, Fine aggregate, Waste foundry sand, Sustainable development

I. INTRODUCTION

Structural members plays major role in development of our world such as improvement of basic infrastructure, sanitation facilities, proper planned cities, waste management etc. Waste management is considered as a key factor in achieving urbanization. Reuse, recycle, reduce are factors to be considered for waste management. The main solid wastes which are dumped on ground are industrial by-products. Recycling of these wastes are very rare and not every individual on the earth. India expends an expected 450 million cubic meter of cement yearly and which roughly comes to 1 tone for every Indian. Regardless we have far to pass by worldwide utilization levels yet do we have enough sand to make cement and mortar? Estimation of development industry developed at stunning rate of 15 % every year even in the monetary log jam and has added to 7-8 % of the nation's GDP (at current costs) for as far back as eight years. Along these lines, it is ending up progressively discomforting for individuals like encouraged by many industries due to cost and time constraints. Major construction material of infrastructural facilities in the 21st century in concrete. The fundamental fixings are utilized in solid blend is bond, coarse total, fine total and water. However at this point a-days there has been an extraordinary interest for all these essential constituents, so that there has been an incredible climb in the cost of lodging industry. A possibly maintainable new type of cement has been as of late made that may make it the most earth neighborly sort of structure material. Tragically concrete isn't an earth amicable material, either to make, or to utilize, or even to discard. To pick up the crude materials to make this material, much vitality and water must be utilized, and quarrying for sand and different totals causes natural devastation and pollution. Concrete is also claimed to be a huge source of carbon emissions into the atmosphere. Some claim that concrete is responsible for up to 5% of the world's total amount of carbon emissions, which contribute to greenhouse gases. This is created in the heat that is needed to create the raw cement. The Irrespective of position, area, scale, sort of any structure, concrete is the base for the development action. Truth be told, concrete is the second biggest consumable material after water, with about three tones utilized every year for sort and great quality total nearby site. As of late characteristic sand is turning into an in all respects expensive material as a result of its interest in the development business because of this condition examine started for shoddy and effectively available alternative material to natural sand. At the same time such material should be eco-friendly and not hurt the earth at any cost. While seeing the other side of our world. world is resting over a landfill of waste perilous materials which may substitutes for common sand Mechanical waste and results from practically all industry, which have been raising unsafe issues both for the environment, human and farming wellbeing can have major use in construction activity which may be useful for not only from the economy point of view but also to preserve the environment as well.

II. FOUNDARY SAND

Moulding sand, also known as foundry sand, when moistened and compressed or oiled or heated tends to pack well and hold its shape. It is used in the process of sand casting. Sand casting is one of the earliest forms of casting practiced due to simplicity of materials involved. It remains one of the cheapest ways to cast metals because of simplicity. Other methods of casting, such as those using shell moulds, give higher quality of surface finish, but at a higher cost. Foundry sand is a mixture of sand, bentonite clay, pulverized coal, and water. Its principal use is in making moulds for metal casting. The largest portion of the mixture is always sand, which can either be silica or olivine. Foundry sand has good pozzolanic property. Foundry sand is high quality silica sand with uniform physical characteristics. It is a by-product of the ferrous and nonferrous metal casting industry, where sand has been used for decades as a moulding material because of its different engineering properties. In modern foundry practice, sand is typically recycled and reused through many production cycles. Approximately, 100 million tons of sand are used in production annually according to industrial estimates. Out of that, 6- 10 million tons of spent foundry sand are disposed throughout the world without proper treatment.

APPLICATIONS OF WASTE FOUNDRY SAND

As the production in India of WFS is increasing the rate of disposing problems also increases with its prices for disposing and maximum usage of regular sand from natural sources from environment increasing the problems with negatively affecting the environment. Solution for these problems is to recycle waste in a very appropriate manner. Waste foundry sand properties are almost similar to natural sand which draws researcher’s attention towards it and much research are conducted for using it in various construction applications as manufacturing processes i.e., controlled low-strength material (CLSM), asphalts, roofing materials, plastics, glass, paints, grout, concrete, cement, cement manufacturing, rock wool etc.,

Some of the beneficial applications in which WFS can be used is given below.

a) WFS can be suitably used in flowable fills for reinforcement, soil stabilization and construction of roads.

b) Waste foundry sand contains various components like iron and aluminum oxide that can enhances the agricultural soil performance.

c) Waste foundry sand can be effectively used in various landfill processes such as highway construction and filling of embankments.

d) Waste foundry sand can be used in pipe bedding and backfill processes.

III.OBJECTIVE OF PRESENT WORK

The main objectives of the present research work are :

- To evaluate the mechanical properties of the WFS concrete and compare with conventional concrete.
- To encourage concrete industry to use WFS in making good quality concrete thereby reducing environmental pollution and conserving natural resources namely sand.
- To determine the compressive, tensile, flexural and modulus of elasticity of concrete by replacing the natural fine aggregate with waste foundry sand.

IV. LITERATURE REVIEW

Anil Kumar and Devika Rani (2016) studied the performance of concrete using paper sludge ash and foundry sand. This paper studied the strength parameters such as compressive and tensile strength of paper sludge ash (5%, 10%, and 15%) as a partial replacement of cement and foundry sand (20%, 40% and 60%) as a partial replacement of fine aggregate for a design mix of M25. Based on the compressive strength of specimen with different replacement level these conclusions were found. For the grade of concrete considered for the study, FS2 i.e. the ratio of 60:40 of conventional sand, foundry sand has replacement of sand. This could be due to dense matrix because WFS is fine sand and its particle size varies between 600microns to 150microns. Reduction in compressive strength with the inclusion of 20% WFS could probably due to increase in surface area of fine particles led to the reduction in water cement gel in matrix. Split tensile strength was similar to compressive strength. At the age of 28 days it was observed that concrete mixture containing 15% WFS has higher modulus of elasticity. RCPT value was found to be less for mixes of 10% and 15% of WFS. The ultrasonic pulse velocity value was found increased with the increase in WFS and also with age.

Siddhique et.al(2011) investigated strength, durability, and micro structural properties of concrete made with used foundry sand. A poly carboxylic ether based super plasticizer if CICO brand was used. In this experimental investigation, mechanical properties and durability properties are examined. Fine aggregate was replaced with used foundry sand with 0, 10, 20, 30, 50 and 60% replacements. Slump value for control mix was 40mm and that of other mixes were 30 to 40mm. The water content was maintained constant up to 30% replacement and thereafter increased. There was a increase in compressive strength up to 30% at all ages. Split tensile strength was similar to that of compressive strength. It was found that carbonation depth increases with an increase in age. Similar results have been reported for the control mixes that carbonation increases with age. It was evident that foundry sand incorporation of its own demonstrated increase in carbonation depth with increase in foundry sand percentage. This study resulted in less RCPT value thereby indicating good permeability on addition of foundry sand in concrete. From XRD studies the presence of C2S, C3S and C4AF peaks are visible indicating that they are totally consumed. From SEM analysis, the number of voids in the mix in the mix has significantly compared to control mix.

V. EXPERIMENTAL INVESTIGATION

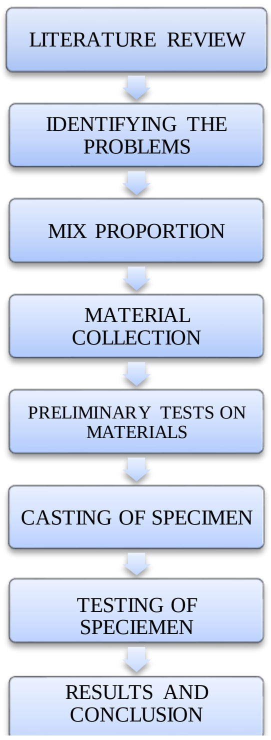


Fig 1 Methodology of work

PROPERTIES OF MATERIALS

The materials used are cement, fine aggregate, WFS, coarse aggregate, water, and super plasticizer.

1. **Cement**

The cement used was Portland Slag Cement. It was tested as per the Indian Standard specifications IS 12269-2013. The cement was kept in humidity-controlled room to prevent it from being exposed to moisture.

2. **Fine Aggregate**

Sand used in this experimental program was locally procured. It was tested for various physical properties in accordance with IS 2386 (Part 3) - 1963.Fine aggregate was natural sand conforming to zone III of IS 383-2016 passing through 4.75 mm size sieve. The specific gravity and fineness modulus are found to be 2.59 and 2.64.

3. **Coarse Aggregate**

Locally available crushed granite aggregates having the size of 20mm were used in the present work. Testing of coarse aggregates was done as per IS 2386 (Part 3) -1963. The specific gravity, fineness modulus and bulk density results are 2.72 and 6.87.

4. **Water**

Distilled water was used for treatment process of WFS, and locally available water fit for concreting was used for the casting and the curing of specimens.

5. **Superplasticizer**

Modified melamine formaldehyde chemical-based admixture with relative density of 1.20 kg/l was used to increase the workability. The dosage was uniform for all mixes at 0.3% by weight of cement.

6. **Waste foundary sand (WFS)**

Foundry industries reuse the sand many times and after some cycles it is removed and disposed to nearby sites. This waste sand from foundry is termed as Waste Foundry Sand (WFS).

MIX PROPORTION

The quality of concrete mainly depends on proportioning of its materials. In this research work mix design was prepared as per IS 10262-2009.

Mix Designation	R0	R10	R20	R30	R40
Cement (kg/m^3)	554.2	554.2	554.2	554.2	554.2
Sand (kg/m^3)	624.18	561.06	497.94	434.82	371.7
Coarse aggregate(kg/m^3)	1194.28	1194.28	1194.28	1194.28	1194.28
WFS (kg/m^3)	0	63.12	126.24	189.36	252.48
Water (lit/m^3)	198.5	198.5	198.5	198.5	198.5

SPECIMEN PREPARATION AND CASTING

The required quantities of materials were weighed, and machine mixed for casting specimens. The cement and the natural sand along with partial replacement WFS were mixed dry until a uniformly colored and thoroughly blended mixture was obtained. The coarse aggregate was then added and mixed until the coarse aggregate was uniformly distributed though out the entire batch. Half of the required quantity of water was added and mixed thoroughly afterwards super plasticizer modified melamine formaldehyde was added along with remaining water and entire batch was mixed until the concrete appeared homogeneous. The 150 mm concrete cubes were cast for compressive strength, 150 mm diameter x 300 mm high cylinders for splitting tensile strength and100 mm x100mm x500mm beams for flexural strength. All the specimens were prepared in accordance with IS 1199-1959. Compaction was done using vibrating table to ensure adequate compaction.

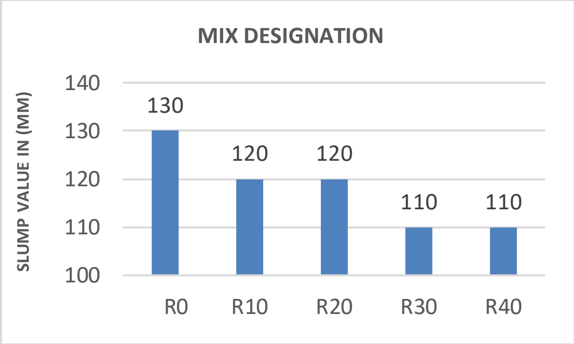
Fig 2 Test specimens

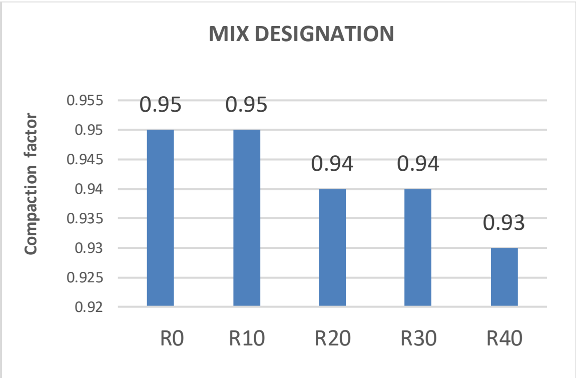
Fig 3 Specimens after demoulding

Fig 4 Curing of specimens

VI. RESULTS & DISCUSSIONS

1.PROPERTIES OF FRESH CONCRETE

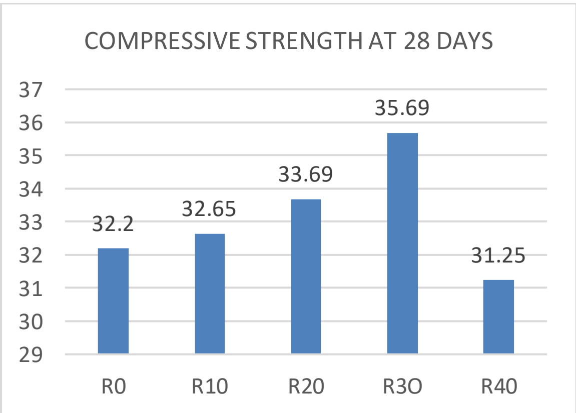




2. PROPERTIES OF HARDENED CONCRETE

1. Compressive Strength

MIX	SPECIMEN	CURING DAYS	LOAD	Strength in (N/mm^2)
R0	Cube	28	672750	32.2
R10	Cube	28	680625	32.65
R20	Cube	28	719325	33.69
R3O	Cube	28	727425	35.69
R40	Cube	28	703125	31.25

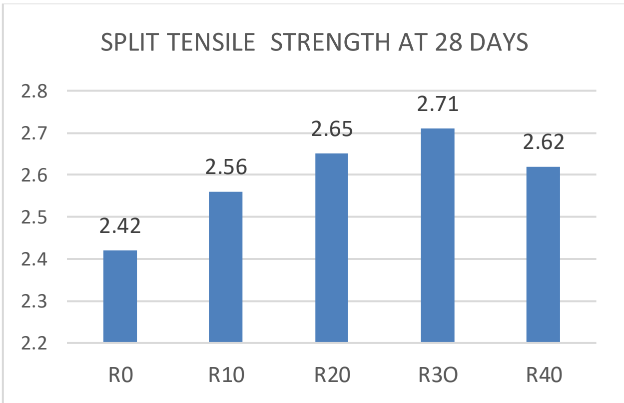


It is seen clear from the above graph that the compressive strength at 28 days is max at R30 i.e., 35.69 N/mm^2 which is we can replace up to 30% of natural fine aggregate with WFS.

S. No	Mix designation	Compressive strength (N/mm^2)			
		7 Days	28 days	56 days	90 Days
1	R0	27.9	32.2	32.02	34.78
2	R10	29.65	32.65	34.34	37.62
3	R20	30.25	33.69	35.94	39.25
4	R30	32.42	35.69	36.9	40.35
5	R40	30.98	31.25	35.64	38.65

2. Tensile strength

MIX	SPECIMEN	CURING DAYS	LOAD	Strength in (N/mm^2)
R0	Cylinder	28	42764.91	2.42
R10	Cylinder	28	45238.91	2.56
R20	Cylinder	28	46829.34	2.65
R3O	Cylinder	28	47889.63	2.71
R40	Cylinder	28	46299.2	2.62



From the graph above, the tensile strength at 0% replacement of waste foundry sand is 2.42 N/mm^2, the strength at 10% replacement of waste foundry sand is 2.56 N/mm^2, the strength at 20% replacement is 2.65 N/mm^2, the strength at 30% replacement of waste foundry sand is 2.71 N/mm^2 at 28 days which is the maximum value. After that the value gets decreases with the increase in waste foundry sand replacement of 40% which is 2.62 N/mm^2. Hence the optimum percentage we obtained here is 30%.

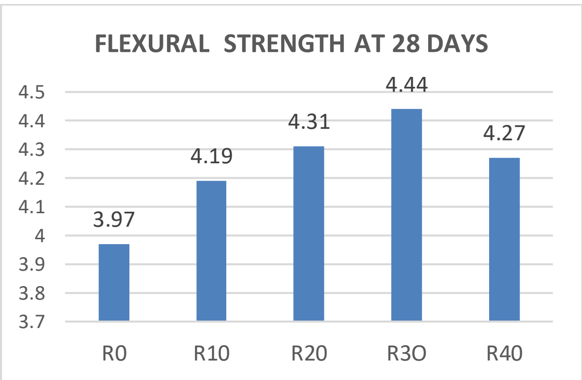
 ISSN NO: 1001-1749

S.No	Mix designation	Split tensile strength (N/mm²)			
		7 days	28 days	56 Days	90 Days
1	R0	1.82	2.42	3.12	3.79
2	R10	2.12	2.56	3.21	3.89
3	R20	2.16	2.65	3.35	4.09
4	R30	2.18	2.71	3.42	4.15
5	R40	2.22	2.62	3.27	3.92

It is found from, that there is a continuous increase in splitting tensile strength from 0 to 30% replacement similar to compressive strength. It starts decreasing beyond 30%, but it is still higher than the control concrete at 40%. The same trend is noticed irrespective of the age.

3. Flexural strength

MIX	SPECIMEN	CURING DAYS	LOAD	Strength in (N/mm²)
R0	Prism	28	89325	3.97
R10	Prism	28	94275	4.19
R20	Prism	28	96975	4.31
R3O	Prism	28	99900	4.44
R40	Prism	28	96075	4.27

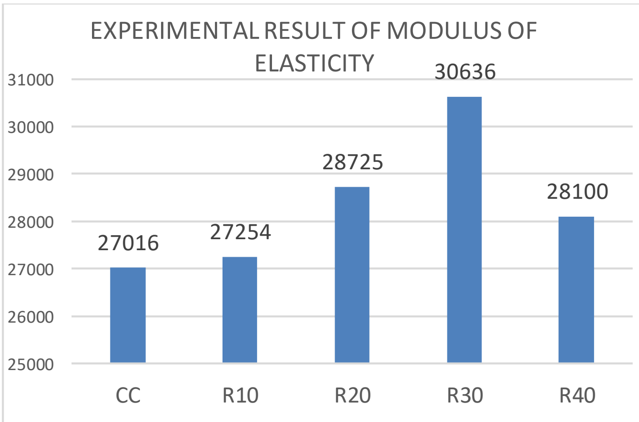


From the graph above, the flexural strength at 0% replacement of waste foundry sand is 3.97 N/mm², the strength at 10% replacement of waste foundry sand is 4.19 N/mm², the strength at 20% replacement is 4.31 N/mm², the strength at 30% replacement of waste foundry sand is 4.44 N/mm² at 28 days which is the maximum value. After that the value gets decreases with the increase in waste foundry sand replacement of 40% which is 4.27 N/mm². Hence the optimum percentage we obtained here is 30%.

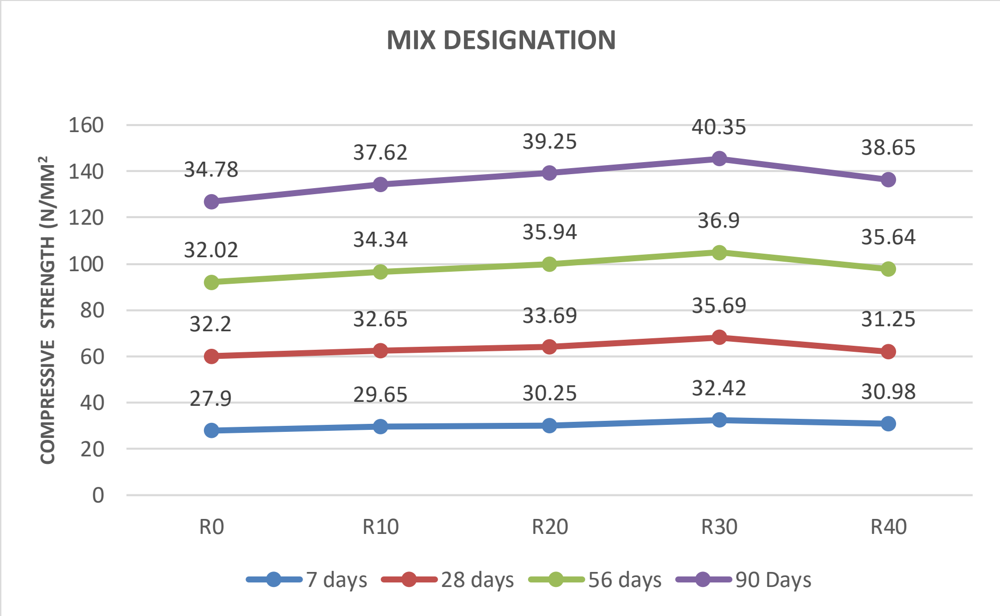
S.No	Mix designation	Flexural strength (N/mm²)			
		7 days	28 days	56 days	90 Days
1	R0	3.42	3.97	4.17	4.38
2	R10	3.55	4.19	4.34	4.79
3	R20	3.67	4.31	4.65	4.91
4	R30	3.85	4.44	4.92	5.12
5	R40	3.64	4.27	4.51	4.86

4. Modulus of Elasticity

S.no	MIX DESIGNATION	Experimental results (N/mm²)
1	R0	27016
2	R10	27254
3	R20	28725
4	R3O	30636
5	R40	27166



From the results, the percentage of increases in modulus of elasticity of WFS concrete is in the range from 3.85% to 13.39% than Control Concrete (CC). From this it is clearly understood that the modulus of elasticity increased with an increase in proportions of WFS up to 30%. At 40%, the values are reduced due to the presence of large number of fines. The modulus of elasticity of concrete with different WFS content determined experimentally and calculated using the expression given in IS 456- 2000. This result is similar to other strength properties like compressive strength, splitting tensile strength and flexural strength. The increase in bond strength due to the replacement of sand with WFS is attributed to the fine particle of WFS with good bondage. Obviously from experimental work, it shows that 30% WFS is optimum.


MIX DESIGNATION
COMPRESSIVE STRENGTH (N/MM²)
160
140
120
100
80
60
40
20
0
34.78
37.62
39.25
40.35
38.65
32.02
34.34
35.94
36.9
35.64
32.2
32.65
33.69
35.69
31.25
27.9
29.65
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30.98
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R10
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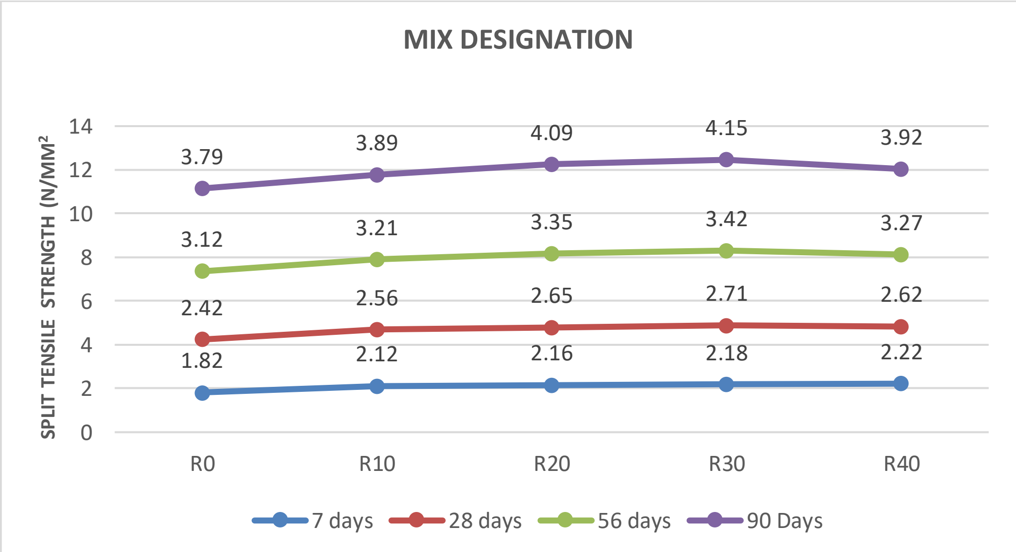
R30
R40
7 days
28 days
56 days
90 Days


MIX DESIGNATION
SPLIT TENSILE STRENGTH (N/MM²
14
12
10
8
6
4
2
0
3.79
3.89
4.09
4.15
3.92
3.12
3.21
3.35
3.42
3.27
2.42
2.56
2.65
2.71
2.62
1.82
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R0
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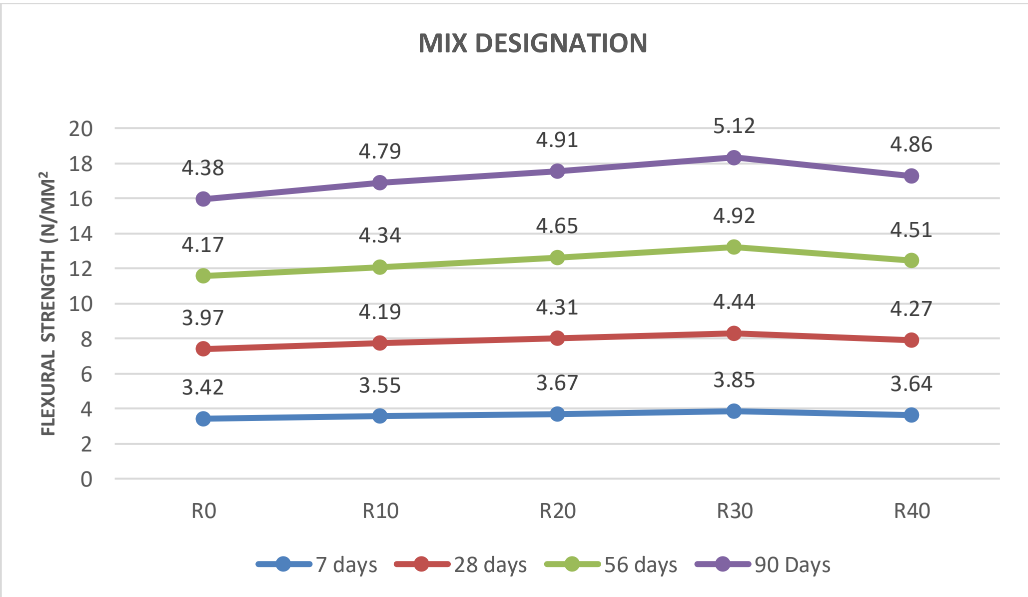
7 days
28 days
56 days
90 Days


MIX DESIGNATION
FLEXURAL STRENGTH (N/MM²
20
18
16
14
12
10
8
6
4
2
0
4.38
4.79
4.91
5.12
4.86
4.17
4.34
4.65
4.92
4.51
3.97
4.19
4.31
4.44
4.27
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7 days
28 days
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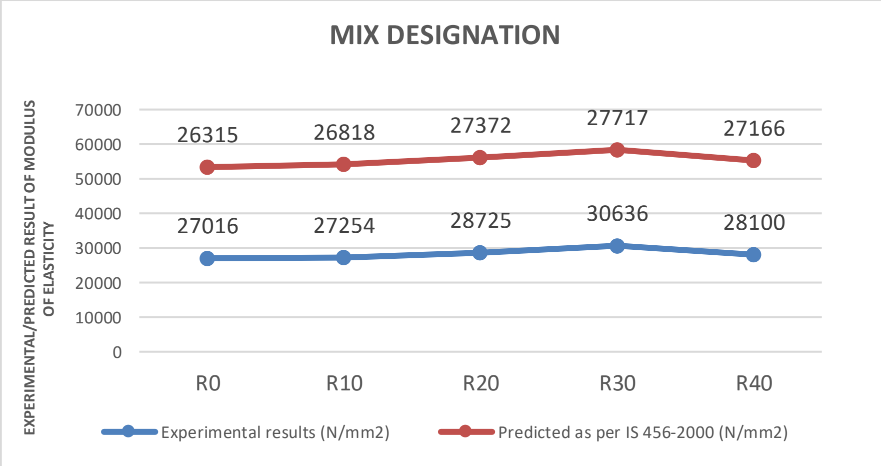

VII. CONCLUSION

This chapter presents the summary of conclusions made based on the experimental investigations. The effect of partial replacement of sand with WFS on fresh, hardened, durability and corrosion resistance characteristics has been investigated.

Effect of WFS on Fresh and Hardened Characteristics of Concrete

Based on the experimental investigations, the following conclusion are drawn, and recommendations are made.

- The fineness modulus of WFS is 1.74 which is lower than the normal sand. Due to this, densification of paste structures is good, and it increases the strength of the concrete.
- For mixes with 10% and 20% WFS, the slump value decreases by8%. In case of concrete having 30% and 40 % WFS, the slump value decreases by 18% compared to control mix.
- Increase in compressive strength varies between 4% and 11%depending on WFS percentage at 28 days compared to normal sand and the same is between 9% and 17% at 90 days. Concrete with 30%WFS gives the highest compressive strength.
- Similarly, the increase in splitting tensile strength varies between 4%and 11% depending on WFS percentage at 28 days compared to normal sand and the same is between 5% and 14% at 90 days. Concrete with30%WFS gives 11% and 14% increase in splitting tensile strength at 28 days respectively.
- So, it is evident that the mechanical properties of hardened concrete with WFS are better at all ages compared to control concrete. There is a slight decrease in strength at 40% WFS compared to 30% UFS, but it is still higher than the control concrete.

VIII. SCOPE FOR FURTHER WORK

1. The replacement of waste foundry sand can be done in combination with various alternatives like M-sand which can give additional strength to the paver blocks and can also be used in low traffic condition areas.
2. The rate of gain of strength for various replacement mixes for a period of 7, 14 and 28 days can be further studied.
3. The paver blocks can be tested for its durability strength
4. In areas of adverse climatic condition, the pavers are to be tested for freeze-thaw durability according to Annexure H of IS: 15658-2006.

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