EXPERIMENTAL ANALYSIS OF WASTE FOUNDRY SAND IN PARTIAL REPLACEMENT OF FINE AGGREGATE IN CONCRETE

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***Abstract*: Now a day the worldwide consumption of sand as fine aggregate in concrete production is very high. Several developing countries have encountered some strain in the supply of natural sand in order to meet the increasing need of the infrastructural development in recent year, to overcome the stress and demand of river sand, researchers and practitioners in the construction industry have identified some alternative. One of them is foundry sand, it is a high quality silica sand with uniform physical characteristics and by product of ferrous and non-ferrous metal casting industry. It is proved that foundry sand used as fine aggregate will enhance the strength of concrete to a greater extend. This paper presents an experimental investigation on the properties of concrete in which fine aggregate is partially replacing by used foundry sand. The only variable considered in this study is volumetric replacement (10%, 20%, 30%, 40%, and 50%) of sand. Out of these 5 replacement levels best 3 were choose by trial works. The concrete was tested for slump test, compression test, flexural test, split tensile test for 7 & 28 days**

This paper also gives the potential of this area by providing the careful study of some number of research papers of this topic. The review integrates all the important results. The review paper summarizes the conclusion on the basis of teste conducted for various properties of concrete like strength , durability etc. the paper review shows the positive as well as negative changes in the properties of concrete on the partial replacement of fine sand by waste foundry sand. from the past researches and the conclusion made by us shows the positive change in the utilization of waste foundry sand in construction field. As this results gives the great potential towards the development on environment friendly and strengthen cementitious concrete.

***Keywords*: foundry sand, ordinary Portland cement, compressive strength, split tensile strength, flexural strength**

1. INTRODUCTION

Concrete is a major construction material that is used world-wide, because of its considerable durability than other construction materials. But now a day there is a scarcity in fine aggregates. So we have to look for different materials to reduce the quantity of basic natural materials in the concrete mix without changing any mix design procedure and consideration. The use of cheaper materials without loss of performance is very crucial to growth of developing countries. We cannot replace the whole basic materials in the concrete, but we can replace with other materials to some extent. So this study was undertaken to explore the possibility of waste foundry sand as a sand replacement in concrete.
The main objective of this experimental work is to compare the effect of foundry sand in concrete with the conventional concrete and to see the effect of foundry sand inclusion in concrete. Also the study is summarize based on compressive strength, split tensile strength, flexural strength and acid attack test of concrete with the replacement of fine aggregate by foundry sand.

Concrete is a material which is composed of coarse aggregate, fine aggregate, cement, admixtures, and water these each material in concrete contributes its strength. So, by partial or percentage replacing of the material affects different properties of concrete. By using such waste material which harms the environment can be used for the development of low cost and eco-friendly building materials. In this study, an experimental investigation is carried out by varying percentage of fine aggregate with used foundry sand to produce low cost and eco-friendly concrete.

2. MATERIAL TESTING:

All tests are carried out as per the IS 2386(part-II, III)-1963.Following tests are conducted to find out physical properties of fine aggregate, coarse aggregate and foundry sand.

2.1 SIEVE ANALYSIS:

The main purpose of Sieve analysis of aggregates is to determine the particle size distribution of the coarse and fine aggregates. From the result of sieve analysis, fineness modulus has found out for fine and coarse aggregate. The fineness modulus is only a numerical index of fineness, giving some idea of the mean size of the particles in the entire body of the aggregate. For the fine aggregate standard sieve size used are 4.75mm, 2.36 mm, 1.18 mm, 600 µm,425µm, 300µm, 150µm, 75µm while for coarse aggregate standard sieve size are 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600µ, 150µ.

Sieve analysis of fine aggregate.

Sieve Aperture	Weight Retained(g)	Cumulative Weight Retained (gm)	Cumulative Weight Retained (%)	Passing (%)
4.75	16	16	1.45	98.5
2.36	306	322	29.27	70.27
1.18	356	678	61.63	38.36
0.6	136	841	76.45	23.54
0.3	106	947	86.09	13.90
0.15	79	1026	93.27	6.73
Pan	74	1100	100	0

From the above table, grading zone of aggregate,

% Passing	Zone I	Zone II	Zone III
98.5	90-100	90-100	90-100
70.27	60-95	75-100	85-100
38.36	30-70	55-90	75-100
23.54	15-34	35-59	60-79
13.90	5-20	8-30	12-40
6.73	0-10	0-10	0-10
	✓	-	-

Fineness modulus: Cumulative percentage retained/100 = 348.16/100 =3.48

Total weight of sample: 1.1 kg

Zone- 01

Fineness modulus= 3.48

Type= River sand.

Sieve analysis of coarse aggregate (10 mm size)

Sieve Size	Weight Retained(g)	Cumulative Weight Retained (gm)	Cumulative Weight Retained (%)	Passing (%)
20mm	-	-	-	100
10mm	2376	2376	47.56	52.44
4.75mm	2340	4716	94.4	5.6
2.36mm	284	5000	100	-
1.18mm	0	5000	100	-
600 µ	0	5000	100	-
150 µ	0	5000	100	-
Pan	0	5000	100	-

Fineness Modulus = Cumulative percentage retained/100=541.96/100 =5.42

Total weight of sample: 5 kg

Sieve analysis of coarse aggregate (20 mm size)

Sieve Size	Weight Retained(g)	Cumulative Weight Retained (gm)	Cumulative Weight Retained (%)	Passing (%)
40mm	-	-	-	100
20mm	1940	1940	38.8	61.2
10mm	2956	4896	97.62	2.08
4.75mm	62	4958	99.16	0.84
2.36mm	42	5000	100	-
1.18mm	0	5000	100	-
600 µ	0	5000	100	-
150 µ	0	5000	100	-
Pan	0	5000	100	-

Fineness modulus = Cumulative percentage retained/100 =735.84/100 =7.35 Total weight of sample: 5 kg

CONCRETE MIX DESIGN OF M30 BY I.S CODE METHOD (IS 10262-2009):

Stipulations for proportioning:

1. Grade designation : M30
2. Type of cement : OPC 53 grade conforming to IS 12269
3. Maximum nominal size of aggregate : 20 mm
4. Minimum cement content : 320 kg/m3
5. Maximum water-cement ratio : 0.55
6. Workability : 100-120 mm (Slump)
7. Exposure condition : Moderate (For Reinforced Concrete)
8. Degree of supervision : Very Good.
9. Type of aggregate : Crushed angular aggregate.
10. Maximum cement content : 450 kg/m3
11. Chemical admixture type : None

The following materials are to be tested in the laboratory and results are to be ascertained for the design mix

(a) Cement Used : OPC 53 Grade Confirming to IS 12269

(b) Specific gravity of cement : 3.15

(c) Specific gravity

1. Specific gravity of fine aggregate (sand) : 2.70
2. Specific gravity of coarse aggregate : 2.80

(d) Water absorption

1. Coarse aggregate : 0.4%
2. Fine Aggregate : 1.0%

(e) Free (surface) moisture

1. Coarse Aggregate : Nil

2. Fine Aggregate : Nil

Aggregates are assumed to be in the saturated surface dry condition usually while preparing design mix (f) Sieve Analysis

1. Fine aggregates : Confirming to Zone I of Table 4 IS – 383

2. Coarse aggregates : As per grain of fine aggregate.

Step 1 : Determining the target mean strength for mix proportioning

F'ck = fck + 1.65 x S

Where,

F'ck = Target mean strength at 28 days fck = Characteristic compressive strength at 28 days
S = Assumed standard deviation in N/mm2 = 5 (as per table -1 of IS 10262- 2009)

= 30 + 1.65 x 5.0 = 38.25 N/mm2

Note: Under control conditions if Target average compressive strength is achieved then at field the probability of getting compressive strength of 30 MPa is very high

Step 2: Selection of water-cement ratio

From Table 5 of IS 456, Maximum water-cement ratio = 0.55 for mild condition.

Based on experience, adopt water-cement ratio as 0.50. 0.50 < 0.55, hence O.K.

Step 3: Selection of water content

Clause 4.2, IS-10262-2009 shows that water content is influenced by aggregate size.

As per clause 4.2,

Maximum water content per cubic meter of concrete for nominal maximum size of aggregate

Nominal maximum size of aggregate (mm)	Maximum water content per cubic meter (kg)
10	208
20	186
40	165

Therefore, maximum water content for 20 mm aggregate = 186 Kg (for 25 to 50 slump)

We are targeting a slump of 100mm, we need to increase water content by 3% for every 25mm above 50 mm i.e. increase 6% for 100mm slump

i.e. Estimated water content for 100mm Slump = 186+(6/100) * 186 = 197 litre Water content = 197 litre.

Step 4: Calculation of cement content

Water-Cement Ratio = 0.50

Water content from Step – 3 i.e. 197 litre.

Cement Content = Water content / "w-c ratio" = (197/0.50) = 394 kgs

From Table 5 of IS 456,

Minimum cement Content for moderate exposure condition = 300 kg/m3 394 kg/m3 > 300 kg/m3, hence, OK.
As per clause 8.2.4.2 of IS: 456

Maximum cement content = 450 kg/m3, hence ok.

Step 5: Proportion of volume of coarse aggregate and fine aggregate content

From clause 4.4, Table 3 of IS 10262- 2009, Volume of coarse aggregate corresponding to 20 mm size and fine aggregate (Zone I) = 0.60

Volume of coarse aggregate per unit volume of total aggregate from

IS 10262-2009

Nominal maximum size of aggregate mm	The volume of coarse aggregate per unit volume of total aggregate as per the zone of fine aggregate			
	Zone IV	Zone III	Zone II	Zone I
10	0.50	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

In the present case, the water-cement ratio is 0.5., so there will be no change in coarse aggregate volume i.e. 0.60.

In case the coarse aggregate is not angular one, then also the volume of coarse aggregate may be required to be increased suitably based on experience.

Volume of fine aggregate = 1-0.60=0.40.

Step 6: Estimation of concrete mix proportion

The mix calculations per unit volume of concrete shall be as follows: a) Volume of concrete = 1 m3

b) Volume of cement = (Mass of cement / Specific gravity of cement) x (1/1000)

= (394/3.15) x (1/1000) = 0.125 m3

c) Volume of water = (Mass of water / Specific gravity of water) x(1/1000)

= (197/1) x (1/1000)

= 0.197 m3 d) Total volume of aggregate

= [a-(b + c)]

=1-(0.125+0.197)

= 0.678 m3

e) Mass of coarse aggregates = d x Volume of Coarse Aggregate x Specific Gravity of coarse aggregate x 1000

= 0.678 x 0.60 x 2.80 x 1000

= 1139 kgs/m3

f) Mass of fine aggregates = d x Volume of Fine Aggregate x Specific Gravity of fine aggregate x1000

= 0.678 x 0.40 x 2.70 x 1000

= 732 kgs/m3

Step-7: Concrete mix proportions

Cement = 394 kg/m3

Water = 197 kg/m3

Fine aggregates = 732 kg/m3

Coarse aggregate = 1139 kg/m3

Water-cement ratio = 0.50

Step-8: Mix proportion ratio:

C: F.A: C.A =1:1.86:2.89

3. DETAILS OF TEST SPECIMEN (MOULD):

The specimen used for the test are cubes, cylinder, and beam. IS:10086 – 1981 provides a specification for mould. The moulds shall be of metal and stout enough to prevent distortion. These shall be constructed in such a manner as to facilitate the removal of the moulded specimen Without damage and shall be so machined that, when they are assembled ready for use, the dimensions and Internal faces shall be accurate Within the specified limits, Internal faces of the moulds shall be smooth.

Followings are the specification of the mould used in concrete testing.

CUBES:

24 cubes of 150mm x 150mm x 150mm in size (the nominal size of the aggregate does not exceed 38 mm) has casted, out of this 12 for 7 days compressive test and 12 for 28 days test. 6 cube samples are prepared for each batch mix (6 cubes for each percentage variation of foundry sand).

CYLINDER:

16 cylindrical Mould of 150mm (Diameter)x 300mm (Height) in size has casted, out of this 8 for 7 days tensile test and 8 for 28 days test. 4 cylindrical samples are prepared for each batch mix (4 cylinders for each percentage variation of foundry sand).

BEAM:

16 beams of 150mm x150mm x700mm in size has casted, out of this 8 for 7 days tensile test and 8 for 28 days test. 4 beam samples are prepared for each batch mix (4 beams for each percentage variation of foundry sand).

TAMPING ROD:

As per IS:10086-1982, the tamping rod shall be 16±0.5 mm diameter and 600±2 mm long with a rounded working end and shall be made of mild steel.

4. TESTING OF CONCRETE:

The main objective of the testing was to know the behaviour of concrete with replacement of Used Foundry Sand to some percentage to Fine Aggregate at room temperature. The main parameters studied were compressive strength and tensile strength and flexural strength. The materials used for casting concrete samples along with tested results are described in this project, we are going to compare the strength of concrete block by using zero percentage Used Foundry Sand with the concrete block using some percentage of Used Foundry Sand by the following test.

4.1 SLUMP CONE TEST FOR WORKABILITY:

Workability is a term associated with freshly prepared concrete. This can be defined as the ease with which concrete can mix, placed, compacted and finished. The slump test is the most commonly used method of measuring 'workability' of concrete in a laboratory or at the site of work. It is used conveniently as a control test and gives an indication of uniformity of concrete from batch to batch. Vertical settlement of a standard cone of freshly prepared concrete is called 'slump'.

Apparatus:

Slump cone (bottom diameter = 20 cm, top diameter = 10 cm, height=30 cm), Weighing balance, tray, standard tamping rod, concrete mixer

Materials used:

Cement, Fine aggregate, Coarse aggregate, and water.

Concrete mix: 1:1.86.:2.89 (W/C=0.5). The ingredients are by weight.

Procedure:

1.Take Mix proportion: 1: 1.86:2.89 by weight; Use W/C ratio=-0.5.
2.Prepare three mixes.
3.Clean the internal surface of the mould thoroughly and it should be freed from superfluous moisture.
4.Place the mould on a smooth, horizontal, rigid and non-absorbent surface, such as a metal plate, and fixed it.
5.Fill the mould with freshly prepared concrete in four layers and compact each layer by tamping with 25 strokes of temping rod. After the top layer has been rodded, struck off the excess concrete, make a level with a trowel or tamping rod.
6.Carefully lift the mould vertically upwards, so as not to disturb the concrete cone.
7.Determine the level difference between the height of the mould and the highest point of the subsided concrete.
8.Height difference in mm is taken as slump of concrete.

Slump cone test

4.2 COMPRESSIVE TEST:

It is the test which carried out on hardened concrete after sufficient curing period. Testing hardened concrete plays an important role in controlling and conforming the quality of cement concrete work. The main factor in favour of the use of concrete in structures is its compressive strength. One of the important properties of the hardened concrete is its strength which represents its ability to resist forces. The compressive strength of the concrete is considered to be the most important and is often taken as an index of the overall quality of concrete.

Apparatus:

Cube moulds 150mm size, weighing machine, ramming rods, compression testing machine **2. Procedure:**

1.Take six cube moulds for each mix. Assemble the mould with a base plate so that it is rigidly held together.
2.Clean the inside of the mould and see that joints (at the edges) are perfectly tight.
3.Pour properly mixed concrete for the given mix to the cube mould
4.Compaction by needle vibrator will be preferred. If the vibrator is not available, hand compaction is to be done by placing concrete in three layers; each layer is compacted with the help of standard temping rod by means of 25 blows.
5.Level the concrete at the top of the mould by means of trowel and give proper identification mark of the specimen.
6.Keep the cubes in the laboratory for 24 hours.
7.After 24 hours, dismantle the plates of cube mould and take out the hardened concrete cubes carefully and keep it for curing up to 28 days.
8.Test the cubes after 7, and 28 days of curing under the UTM to find the compressive Strength.
9.The bearing surfaces of the testing machine shall be wiped clean. in the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is not to the top and bottom. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen.
10. The load shall be applied without shock and Increased continuously at a rate of approximately 140 kg/sq. cm/min until the resistance of the specimen to the Increasing load breaks down and no greater load can be sustained.

11. Tabulate Compressive strength for each cube and calculate average value for each mix.

Compressive test of cubes

4.3 SPLIT TENSILE TEST:

Concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength is necessary to determine the load at which the concrete members may crack. The cracking is a form of tensile failure.

Apparatus:
Cylindrical moulds 300mm height and 150mm diameter, weighing machine, ramming rods, compression testing machine.

Procedure:

1. Take four cylindrical moulds for each mix. Assemble the mould with a base plate so that it is rigidly held together.
2. Clean the inside of the mould and see that joints (at the edges) are perfectly tight.
3. Pour properly mixed concrete for the given mix to the moulds.
4. Compaction by needle vibrator will be preferred. If the vibrator is not available, hand compaction is to be done by placing concrete in three layers; each layer is compacted with the help of standard temping rod by means of 25 blows.
5. Level the concrete at the top of the mould by means of trowel and give proper identification mark of the specimen.
6. Keep the cylinders in the laboratory for 24 hours.
7. After 24 hours, dismantle the mould and take out the hardened concrete cubes carefully so that specimens are not damaged.
8. Immerse the cylinders in curing tank filled with water. Keep it for curing up to 28 days.
9. Test the cylinders after 7 and 28 days of curing to find the split tensile strength. 10. Test the cylinders after 7 and 28 days of curing to find the split tensile strength.

Split tensile test of cylinder

4.4 FLEXURAL TEST:

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unaltered reinforced concrete beam or slab to resist failure in bending.

Apparatus:

Beam mould, Tamping bar, Flexural testing machine

Procedure:

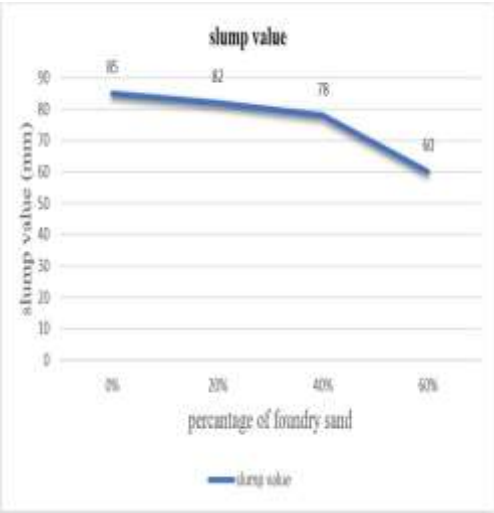
1. Prepare the four test specimens for each batch by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire cross section of the beam mould and throughout the depth of each layer.
2. Clean the bearing surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
3. Circular rollers manufactured out of steel having a cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be 3d and the distance between the inner rollers shall be d. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.
4. The specimen stored in water shall be tested immediately on removal from water; while they are still wet. The test specimen shall be placed in the machine correctly centred with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.
5. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.
6. Tabulate flexural strength for each beam and calculate average value for each mix.

Flexural strength of beam

5. SLUMP CONE TEST:

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is used to ensure uniformity for different loads of concrete under field conditions.

Sr. No.	W/C ratio	Foundry sand percentage %	Height of mould H1 (mm)	Height of subsided concrete, H2 (mm)	Slump H1-H2 (mm)
1	0.5	0	300	215	85
2	0.5	20	300	217	82
3	0.5	40	300	222	78
4	0.5	60	300	240	60



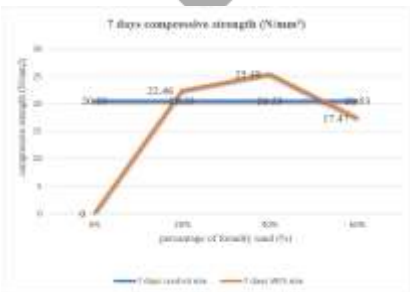
Slump value for M30

Slump value decreases as percentage of foundry sand increases with constant watercement ratio. It varies between 50mm to 100mm.

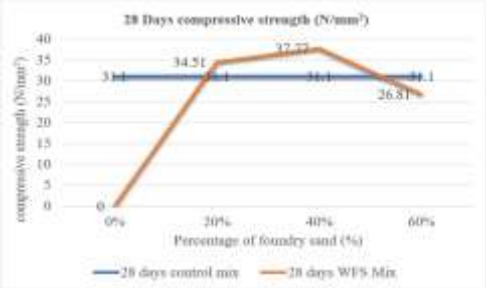
Type of slump: True slump.

6. COMPRESSIVE STRENGTH TEST:

Compressive strength tests were performed on compression testing machine of 2,000 KN capacity. The compressive strength for different replacement levels of foundry sand contents is carried out at the end of 7 days and 28 days. Three cubes of 150*150*150 mm from each batch were subjected to this test. Overall twenty-four number of cubes are subjected to compressive strength test. The comparative study was made on properties of concrete after percentage replacement of fine aggregate by waste foundry sand in the range of 0%, 20%, 40% and 60%.



7 days compressive strength (N/mm^2)



28 days compressive strength (N/mm2)

7, 28 days compressive strength (N/mm2)

The compressive strength increased with an increase in the amount of foundry sand, up to 40% replacement in concrete, compared to the control mix. But as the amount of foundry sand exceeded the amount of fine aggregate in concrete, the compressive strength gradually decreased. The progressive strength attainment rate of concrete with foundry sand replacement is more, in comparison with control mix concrete, up to 40% replacement results. The replacement of whole fine aggregate with foundry sand adversely affects the compressive strength of concrete by giving the lowest values.

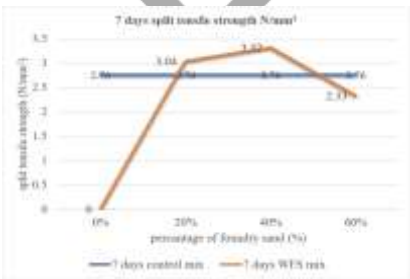
7. SPLIT TENSILE STRENGTH:

The split tensile strength for different replacement levels of foundry sand contents is carried out at the end of 7 days and 28 days. Four cylinders of 150mm diameter x300mm height from each batch were subjected to this test. Overall sixteen number of cylinders are subjected to split tensile strength test. The comparative study was made on properties of concrete after percentage replacement of fine aggregate by waste foundry sand in the range of 0%, 20%, 40%, and 60%.The split tensile strength is calculated by the following formula, $ft = 2P/\pi LD$ Where, ft – Tensile Strength of Concrete N/mm2

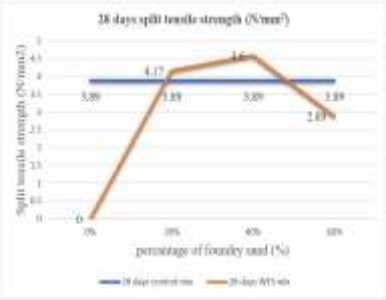
P – Maximum load in, N

L – Length of the Specimen, mm

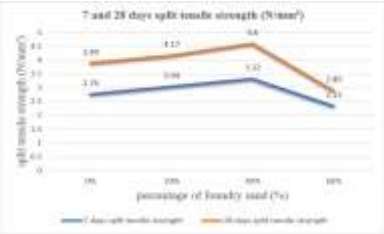
D – Diameter of the specimen, mm



7 days split tensile strength (N/mm^2)



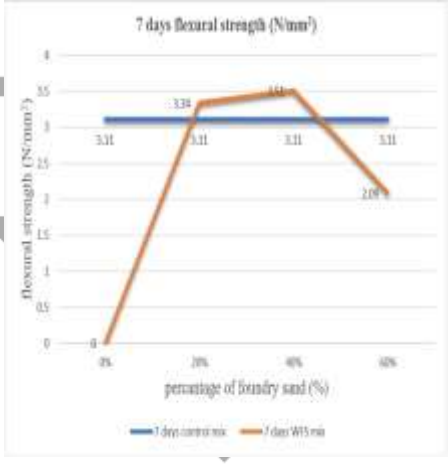
28 days split tensile strength (N/mm2)



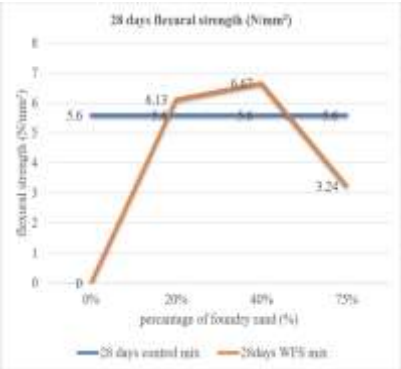
The variation in split tensile strength with foundry sand content follows similar to that observed in the case of compressive strength test.

8. FLEXURAL STRENGTH:

The flexural strength for different replacement levels of foundry sand contents is carried out at the end of 7 days and 28 days. Four beams of 150mmx150mm x700mm from each batch were subjected to this test. Overall sixteen number of cylinders are subjected to split tensile strength test. The comparative study was made on properties of concrete after percentage replacement of fine aggregate by waste foundry sand in the range of 0%, 20%, 40%, and 60%. The flexural strength is calculated by the following formula, $\sigma = PL/bd2$



7 days flexural strength



28 days flexural strength

7, 28 days flexural strength

CONCLUSION

Based on above study the following conclusions are made regarding the properties and behaviour of concrete on partial replacement of fine aggregate by waste foundry sand-

It was noticed that workability (slump) of concrete decreases as percentage of foundry sand. This maybe most likely because of the presence of clayey type fine substances in the WFS, high water absorption, and fineness which are compelling in diminishing fresh concrete fluidity.

1. Compressive strength, split tensile strength and flexural strength of concrete specimens increased, with increase in fine aggregate replacement by foundry sand, providing maximum strength at 40 % replacement on 7 and 28 days, and beyond that the strength parameters showed a decline in their respective values.

2. Maximum compressive strength is gained at 40% replacement of fine aggregate which is higher than normal concrete strength (M30) by 21.44%. (From table 6.2 D)

3. Beyond 40% replacement (60%) shows the decrement in compressive strength by 13.79%. (From table 6.2 D)

4. The variation in split tensile strength and flexural strength followed the similar trend as observed in compressive strength with a maximum increment by
18.20% and 19.10%. (From table 6.3 D)

5. The increase in strength parameters may be due to fineness of the foundry sand. The foundry sand fineness is higher than fine aggregate and reduces the porous nature in concrete thereby increasing density and strength. But reduction in compressive strength of concrete specimen with replacement percentage beyond 40 % is attributed to binders present in foundry sand, composed of very fine powder of clay and carbon, which results in a weak bond between cement paste and aggregate.

6. The replacement of natural sand with used foundry sand up to 40 % is desirable, as it is cost effective, reduces the amount of virgin fine aggregate, reduces land fill problems and preserves nature. (From table 6.5 B)

7. Making concrete using recycled materials (foundry sand) saves energy and conserve primary resources and it is concluded that the more material was reused, the fewer resources were consumed which leads to a safe, sustainable environment.

10. FUTURE SCOPE:

The research carried out so far is only the initial stage of this project.

1) Durability studies have not been done on concrete containing used foundry sand.

2) The durability properties like alkali-silica reaction, freeze-thaw, chloride ion permeability, interaction with air-entraining agents, fatigue strength, etc., of concrete made with used foundry sand concrete, can be experimented.

3) The present project has a wide future scope in experimenting the foundry sand with its partial replacement in the concrete.

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