STUDY ON FOUNDRY SAND AS A REPLACEMENT FOR THE FINE AGGREGATE IN CONCRETE

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Abstract: This paper demonstrates the use of waste foundry sand as a replacement of fine aggregate. Foundry sand is a by-product of ferrous and non-ferrous metal casting industry which contains high silica content with specific physical properties. This study presents the information about the civil engineering applications of foundry sand, which is technically sound and is environmentally safe. This research is carried out to produce a eco-friendly and low lost concrete. An experimental study has been carried out on concrete with waste foundry sand about replacing percentage of 15%. In the present study, effect of foundry sand as fine aggregate replacement on the compressive strength of concrete having mix proportions of M 20 grade was investigated. The resulted material was tested and compared with the conventional concrete in terms of its strength and workability. The tests were carried out with standard cube of dimensions 150*150*150*mm and cylinder 150*300* mm and for prism 500*100*100* mm for 3 days to determine its strength. Through the experimental result we conclude that compressive strength increases with increase in partial replacement of waste foundry sand. The aim of the experiment is to know about the mechanical properties of the concrete by addition of waste foundry sand in different proportion and also its strength.

1. Introduction:

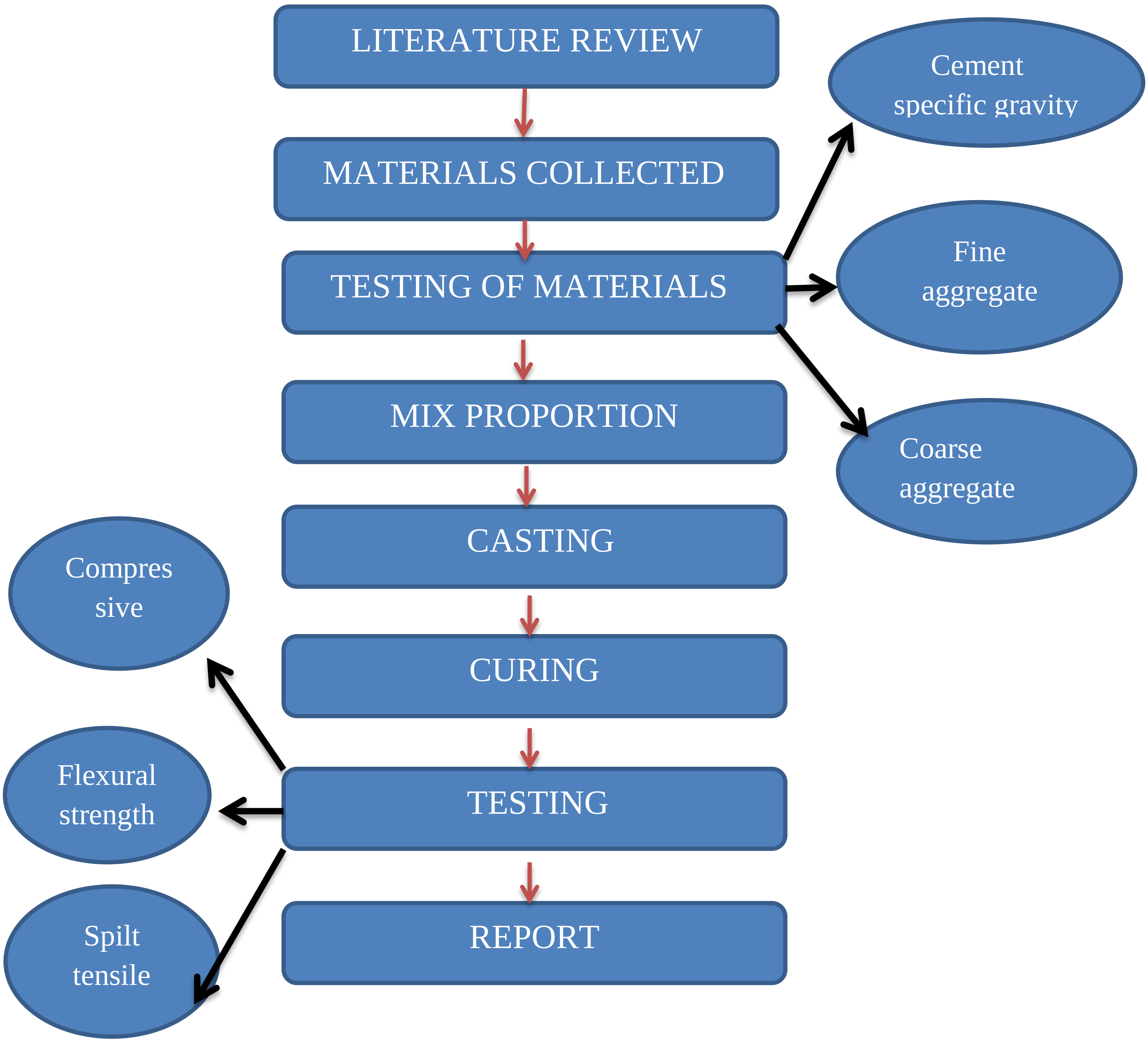
Concrete usually Portland cement is a composition of coarse aggregate, fine aggregate, cement and water. Cement acts as a binder in concrete. When aggregate mixed with dry Portland cement and water they form fluid slurry which is easily pourable and get into any shape. These ingredients lead to the formation of hard matrix which is like a durable stone like structure. Concrete plays a major role in construction as they provide strength and durability which is known as back bone in construction. We are in a situation to develop and to introduce new things to make our future generation's improvement. The ingredients in concrete are getting replaced by many products to make an innovative project. In our project foundry sand is replaced by means of river sand. Primarily foundry sand is defined as uniformly sized clean sand which has high silica quality. This sand was formerly used for preparing molds. In our project we are using the wasted sand used for molding known as foundry sand. This replacement is to improve the strength of concrete. There were many types of foundry sand. We are using non-leaded spent foundry sand which is non-hazardous.15 to 20% of river sand is replaced by foundry sand. Total replacement of foundry sand will not provide strength to the concrete. Up to an optimum replacement foundry sand will provide good strength. When the amount of foundry sand is increased there will a lack of binding properties, which leads to decrease in strength. By using foundry sand of 15-20%, concrete with a mix design of M20 is designed. With the above designed mix proportion we have casted some number of cubes with a dimensions of 150*150*150, cylinder with a diameter of 150mm and length of 300mm, prism with a dimension of 500*100*100. Casting is followed by curing. Curing takes up to 7 days but we have cured up to 3 days. We also used accelerated curing tank to check the strength obtained within 19 hrs. Accelerated curing is a method which provides compressive strength more primarily that means the strength which gained in normal curing will obtained within 19 hours in accelerated curing. Accelerated curing tank involves hot water within which the mold was placed and gets cured. After curing it is used to determine strength. The casted materials undergo certain test to check the strength obtained by foundry sand by curing and accelerated curing method. It involves certain strength which is as follows:

Cube will undergo compressive strength that means by applying certain load the cube gets compressed and cracks will occur at certain load which is taken as compressive strength of cube.

Cylinder will undergo split tensile load which means by applying some load the cylinder splits at a particular load which breaks at the center and gets spilt. That load is noted as spilt tensile load of cylinder.

Prism will undergo flexural load which means by applying some load the prism gets flexural strength and breaks at a particular load that is known as flexural load of a prism

2. Methodology:



3. Material tesing:

The material used to construct concrete is to be tested to find their strength. The ingredients used in concrete are as follows

- Cement
- Fine aggregate – Foundry sand
- Coarse aggregate

3.1 Cement:

Cement plays a major role in concrete as it acts as a binder. It acts as adhesive to join with other materials. Cement is used in construction field which holds up all the materials together and hardens it. Cement has many grades we have used 43 grade cement which means it provides strength of 43N/mm^2 after28 days of curing.

DESCRIPTION	TEST RESULT
Type of cement	Open Portland cement
Specific gravity of cement	3.15

Table 1: Cement

3.2 Fine Aggregate:

In this project fine aggregate refers foundry sand. Foundry sand is defined as uniformly shaped clean sand with high quantity of silica sand. They are used for ferrous and non-ferrous molds. Mostly 95 % of foundry sands are used in foundry. In our project we are using spent foundry sand. 15-20% of river sand is replaced by foundry sand.

IS SIEVE SIZE	PERCENT RETAINED	CUMULATIVE % RETAINED	PERCENT PASSING
10mm	0.00	0.00	100.00
4.75mm	5.20	5.20	94.80
2.36mm	3.00	8.20	91.80
1.18mm	8.60	16.80	83.20
600 microns	25.80	42.60	57.40
300 microns	32.80	75.40	24.60
150 microns	20.70	96.10	3.90

Table 2: Sieve analysis of fine aggregate (Foundry sand)

3.3 Coarse Aggregate:

Coarse aggregate is defined as the crushed pieces of rocks which were available in the size of 40,32,25,20,16,12,10 and 4.75mm. In this project we are using aggregate of about 20mm and 10mm. We are not using same size of aggregate the reason behind this is same size and shape not join as they are angular in shape. So we are using the mixture of aggregate which leads to very good binding properties.

IS SIEVE SIZE	% RETAINED	CUMULATIVE % RETAINED	PERCENT PASSING
40mm	0.00	0.00	100.00
20mm	0.60	0.60	99.40
10mm	73.50	74.10	25.90
4.75mm	22.90	97.00	3.00

Table 3: Sieve analysis of coarse aggregate

4. Mix design

Mix design for conventional (IS 10262:2009 & IS 465:2000)

4.1 Stipulations for proportioning:

a) Grade designation : M-20

b) Type of cement : OPC53-IS 8112(2013)

c) Maximum nominal size of aggregate : 20mm

d) Type of aggregate : crushed angular aggregate

e) Workability : 75-100mm slump

f) Type of exposure : severe

g) Degree of supervision : Good

h) Method of concrete placing : Normal placing

i) Maximum water-cement ratio : 0.50

j) Minimum cement content : 320 kg/m3

k) Maximum cement content : 450 kg/m3

l) chemical admixture : super plasticizer

4.2 Test for materials:

a)Type of cement used : OPC53 grade

b) Specific gravity of cement : 3.10

c) Chemical admixture : SP conplast 430

d) Water absorption

i) Coarse aggregate : 0.97%

ii) Fine aggregate : 1.23%

e) Specific gravity

i) Coarse aggregate : 2.70

ii)Fine aggregate : 2.56

f) Free (surface) moisture : Nil

g) Sieve analysis:

i) Coarse aggregate : Sieve analysis as per IS 777: 383

ii) Fine aggregate : zone II

4.3 TARGET MEAN STRENGTH OF CONCRETE:

$f'_{ck} = f_{ck} + 1.65$ s S Where

f'_{ck} = target average compressive strength at 28 days

f'_{ck} = characteristic compressive strength at 28 days

S = standard deviation

S = 5, from table-1(IS10262:2009)

f'_{ck} =26.6 N/mm^2

4.4 SELECTION OF WATER CEMENT RATIO:

From Table 5 of IS 456, maximum water-cement ratio = 0.45

Based on experience, adopt w/c = 0.45,

hence ok.

4.5 SELECTION OF WATER CONTENT:

From Table 2, Maximum water content = 186 liter (for 25 to 50mm slump range) for 20 mm aggregate.

For 100mm slump, estimated water content =186+(0.06 x 186)

=197.16 liters

4.6 DETERMINATION OF CEMENT CONTENT:

Water cement ratio = 0.50

Cement content = 197.16/ 0.50 =394.32 kg/m^3

From Table 5(IS 456), the minimum cement content for severe exposure condition = 320 kg/m^3. 394.32>320 kg/m^3

Hence ok

4.7 CALCULATION OF AGGREGATE:

From Table 3 (IS 10262:2009),volume of coarse aggregate corresponding to 20mm aggregate, and fine aggregate for w/c of .50= 0.62.

In present case, w/c ratio is 0.40. volume of coarse aggregate is to be increased to decrease the fine aggregate content.

As w/c is lowered by 0.10, proportion of volume of coarse aggregate is increased by 0.02(@rate of -/+ 0.01 for every ±0.05 change in w/c ratio)

Corrected proportion of volume of coarse aggregate for w/c of 0.4 = 0.62+0.02=0.64

Volume of coarse aggregate = 0.64 m3

Volume of fine aggregate = 1- 0.64= 0.36 m^3

4.8 MIX CALCULATIONS:

Mix calculations percent volume of concrete,

Volume of concrete =1m^3

1. Volume of cement = mass of cement / (specific gravity x 1000)

= 394.32/(3.10 x 1000)

= 0.127 m^3

2. Volume of water = mass of water / (specific gravity x 1000)

= 197.16/(1x 1000)

= 0.197m^3

1m^3 concrete = volume cement + volume of water +volume of aggregate +volume of chemical admixture

4. Volume of total aggregate = 1 – (volume of cement + volume of water)

= 1 – (0.127+0.197)

= 0.676 kg/m3

5. Mass of coarse aggregate = 0.676 x volume of coarse aggregate x sp.gr x 1000

= 0.676 x 0.64 x 2.70 x 1000

= 1168.12 kg/m^3

6. Mass of fine aggregate = 0.74317 x volume of fine aggregate x sp.gr x 1000

= 0.74317 x 0.36 x 2.56 x 1000

= 684.90 kg/m^3

4.9 MIX PROPORTIONS:

Cement = 0.127 m^3

Water = 0.197 m^3

Fine aggregate = 684.90 kg/m^3

Coarse aggregate = 1168.12 kg/m^3

Water cement ratio = 0.45

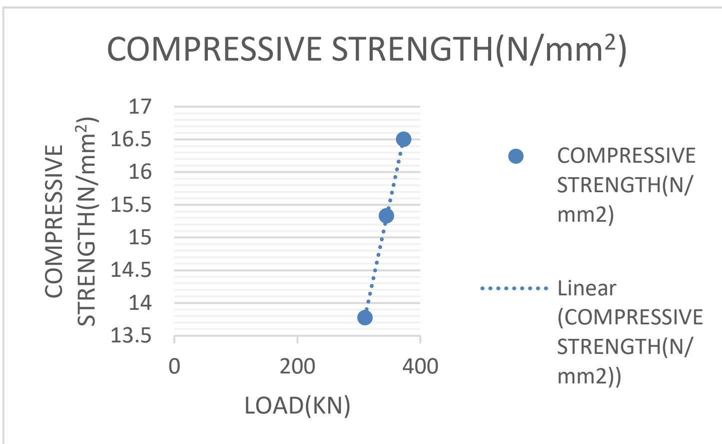
5. CONVENTIONAL CONCRETE

Normal concrete which is also known as conventional concrete that contains ordinary Portland cement, fine aggregate (m-sand or river sand) and coarse aggregate. This concrete does not have any special property as there is no replacement in any material. These concretes are formulated with high compressive strength and less tensile strength. The compressive strength for conventional concrete are as follows,

S.NO	LOAD(KN)	AREA (mm^2)	COMPRESSIVE STRENGTH(N/mm^2)
1	310	150x150	13.77
2	345	150x150	15.33
3	373	150x150	16.5

Table 4: Compressive strength for conventional concrete

GRAPH 1: compressive strength results



6. FOUNDRY SAND CONCRETE WITH A REPLACEMENT OF 15%

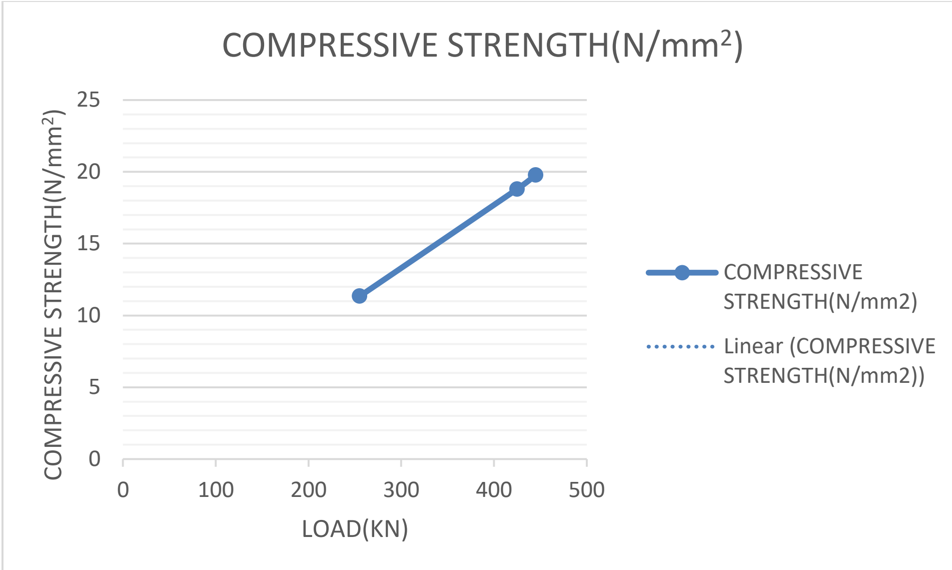
6.1 COMPRESSIVE STRENGTH:

Cube will undergo compressive strength that means by applying certain load the cube gets compressed and cracks will occur at certain load, which is used to calculate compressive strength of cube. The cube has a dimension of 150*150*150. The foundry sand is replaced with **15%** of the river sand. 2 cubes has cured for 3 days and the other one cube which attains a compressive strength of about **19.77 N/(mm^2)** undergoes accelerated curing for about 19 hours at a temperature of about 55°celsius. The following are the compressive strength of concrete cube they are as follows:

S.NO	LOAD (KN)	AREA (mm)	COMPRESSIVE STRENGTH (N/mm^2)
1	255	150*150	11.33 N/mm^2
2	425	150*150	18.8 N/mm^2
3	445	150*150	19.77 N/mm^2

Table 5: Compressive strength of cube with replacement of 15%

GRAPH 2: compressive strength results for FSC 15% replacement:



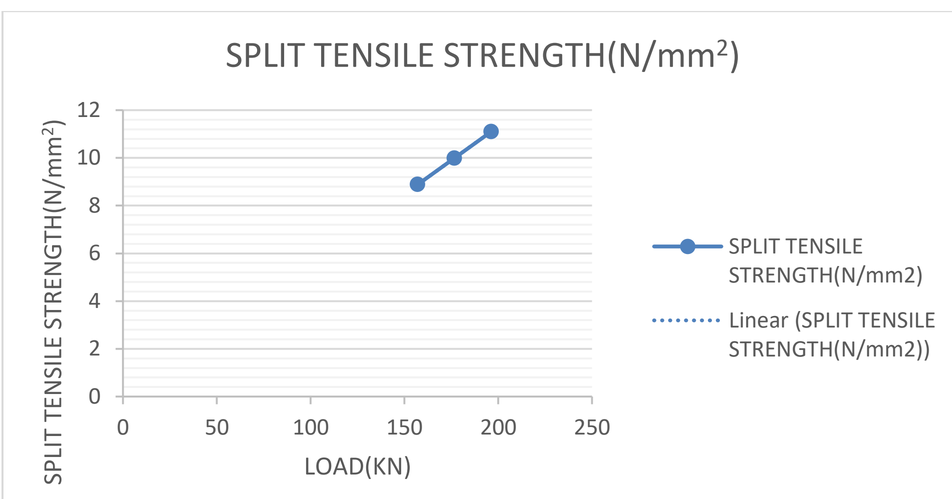
6.2 SPLIT TENSILE STRENGTH:

Cylinder will undergo split tensile load which means by applying some load the cylinder splits at a particular load which breaks at the center and gets spilt. That load is noted as spilt tensile load of cylinder. By using split tensile load spilt tensile strength of the cylinder was calculated. The replacement of foundry is about 15%. The cylinder has a diameter of about 150mm and length of about 300mm. The cylinder was cured for 3 days. The following are the split tensile load of cylinder and they are as follows:

S.NO	LOAD (KN)	AREA (mm)	SPLIT TENSILE STRENGTH (N/mm^2)
1	196.2* 10^3	17.66 * 10^3	11.10N/mm^2
2	176.58 * 10^3	17.66 * 10^3	9.99N/mm^2
3	156.96* 10^3	17.66 * 10^3	8.88N/mm^2

Table 6: Split tensile strength of cylinder with replacement of 15%

GRAPH3: split tensile strength:



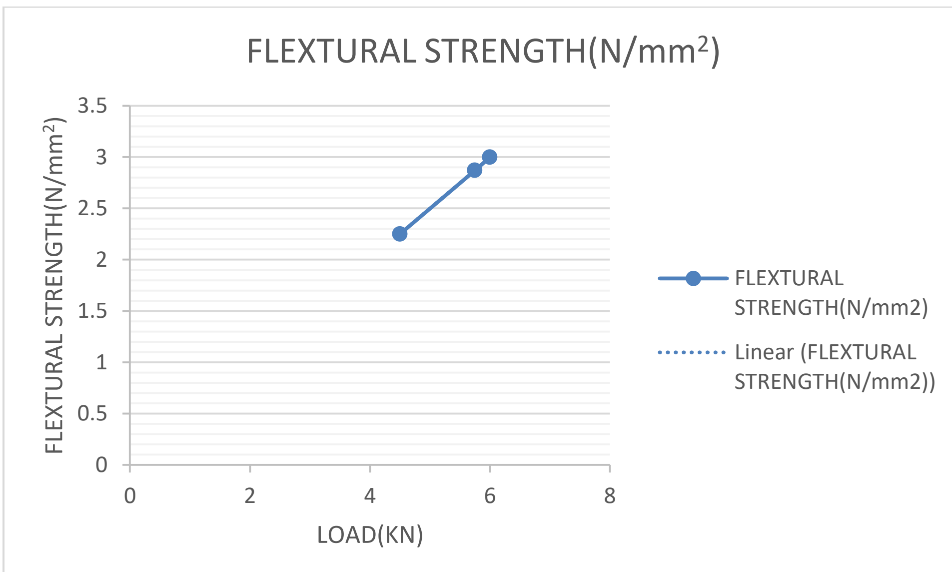
6.3 FLEXURAL STRENGTH OF PRISM:

Prism will undergo flexural load which means by applying some load the prism gets flexural strength and breaks at a particular load that is known as flexural load of a prism. By using flexural load of a prism flexural tensile strength of concrete was calculated. The replacement of foundry is about 15%. The prism was cured for 3 days. The following are the flexural strength of prism and they are as follows:

S.NO	LOAD (KN)	PL (N/mm)	BD^2 (mm^3)	FLEXURAL STRENGTH (N/mm^2) = PL/BD^2
1	6	3 *10^6	1*10^6	3 (N/mm^2)
2	5.75	2.87 *10^6	1*10^6	2.87(N/mm^2)
3	4.5	2.25 *10^6	1*10^6	2.25(N/mm^2)

Table 7: Flexural strength of prism with replacement of 15%

GRAPH 4: flextural strength:



7. FOUNDRY SAND CONCRETE WITH A REPLACEMENT OF 20%

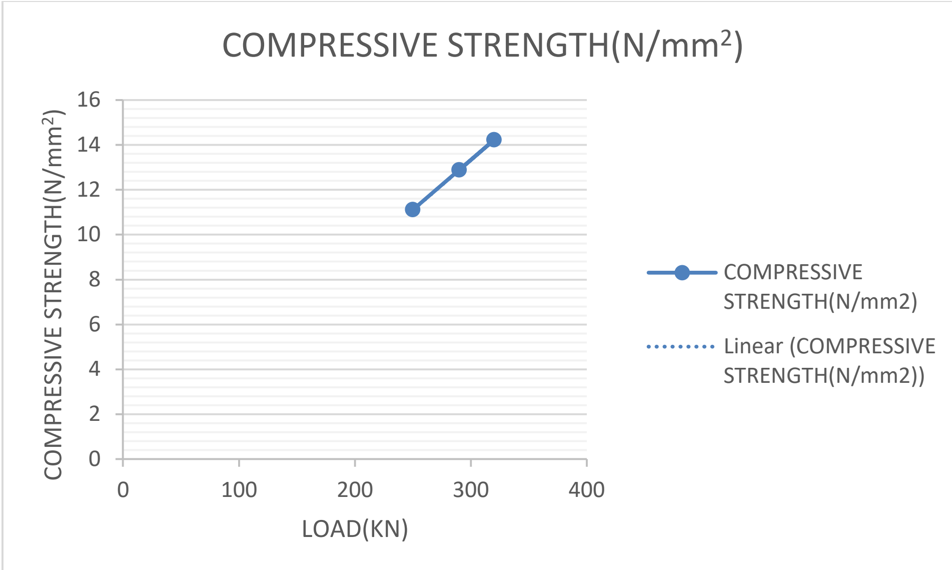
7.1 COMPRESSIVE STRENGTH:

Cube will undergo compressive strength that means by applying certain load the cube gets compressed and cracks will occur at certain load, which is used to calculate compressive strength of cube. The cube has a dimension of 150*150*150. The foundry sand is replaced with 20% of the river sand. Cubes have cured for 3 days. The following are the compressive strength of concrete cube they are as follows:

S.NO	LOAD (KN)	AREA(mm)	COMPRESSIVE STRENGTH (N/mm^2)
1	290	150*150	12.88 N/mm^2
2	320	150*150	14.22N/mm^2
3	250	150*150	11.11N/mm^2

Table 7: Compressive strength of cube with replacement of 20%

GRAPH 5: compressive strength:



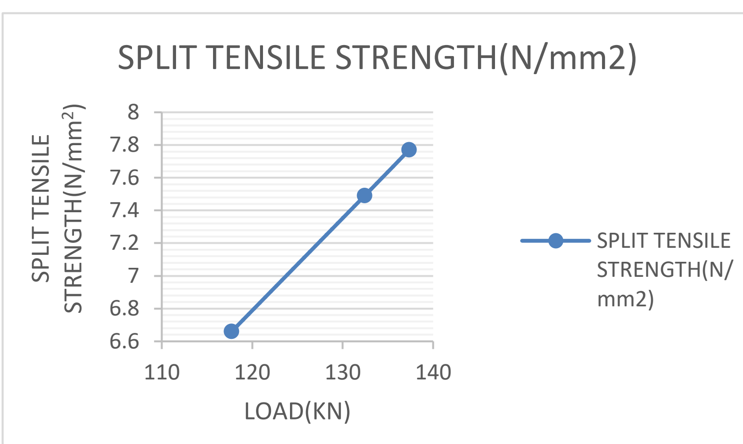
7.2 SPLIT TENSILE STRENGTH:

Cylinder will undergo split tensile load which means by applying some load the cylinder splits at a particular load which breaks at the center and gets spilt. That load is noted as spilt tensile load of cylinder. By using split tensile load spilt tensile strength of the cylinder was calculated. The replacement of foundry is about 20%. The cylinder has a diameter of about 150mm and length of about 300mm. The cylinder was cured for 3 days. The following are the split tensile load of cylinder and they are as follows:

S.NO	LOAD (KN)	AREA (mm)	SPLIT TENSILE STRENGTH (N/mm^2)
1	137.34* 10^3	17.66 * 10^3	7.77N/mm^2
2	132.43 * 10^3	17.66 * 10^3	7.49N/mm^2
3	117.72* 10^3	17.66 * 10^3	6.66N/mm^2

Table 8: Split tensile strength of cylinder with replacement of 20%

GRAPH 6: split tensile strength:



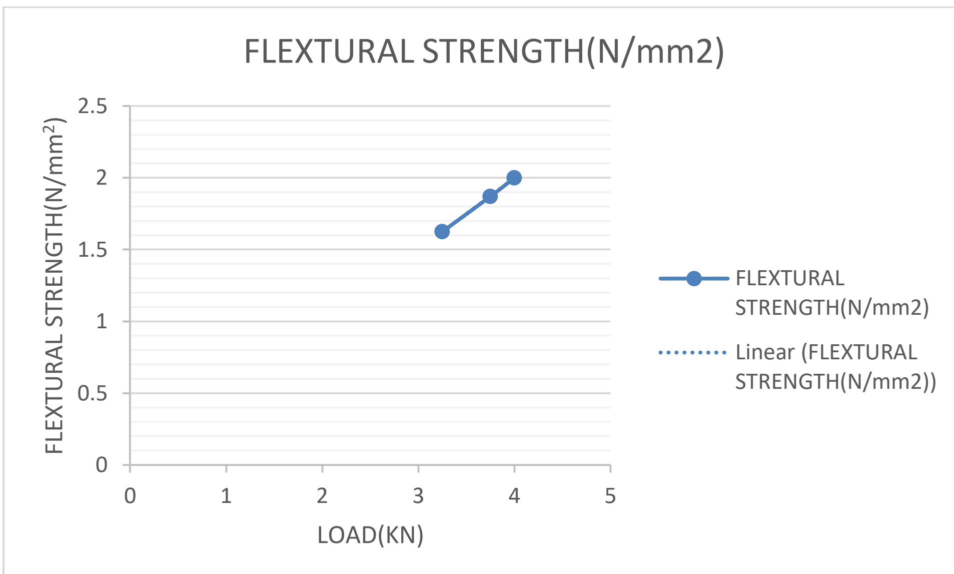
7.3 FLEXURAL STRENGTH OF PRISM:

Prism will undergo flexural load which means by applying some load the prism gets flexural strength and breaks at a particular load that is known as flexural load of a prism. By using flexural load of a prism flexural tensile strength of concrete was calculated. The replacement of foundry is about 20%. The prism was cured for 3 days. The following are the flexural strength of prism and they are as follows:

S.NO	LOAD (KN)	PL (N/mm)	BD^2 (mm^3)	FLEXURAL STRENGTH (N/mm^2)
1	4	2 *10^6	1*10^6	2 (N/mm^2)
2	3.75	1.875 *10^6	1*10^6	1.87 (N/mm^2)
3	3.25	1.625 *10^6	1*10^6	1.625 (N/mm^2)

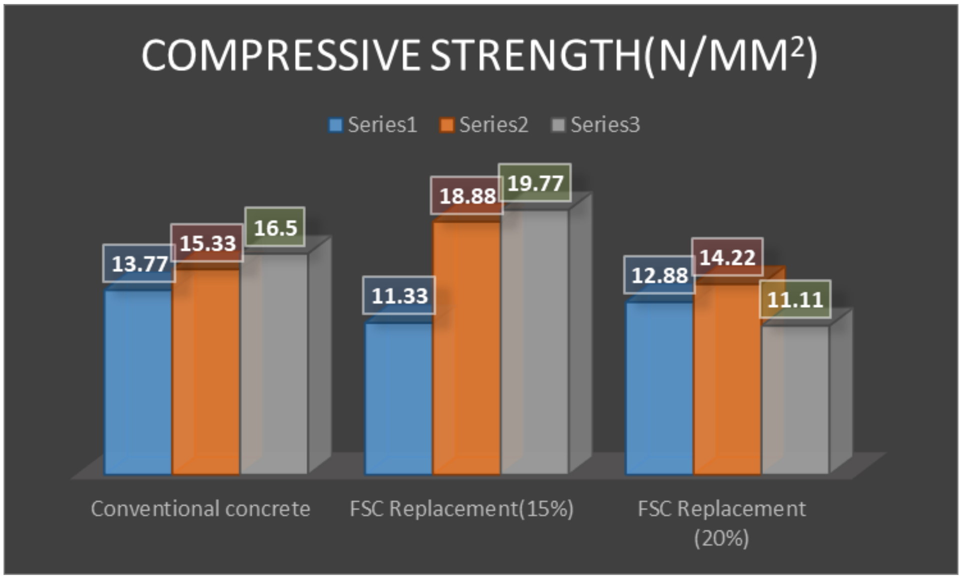
Table 9: Flexural strength of prism with replacement of 20%

GRAPH 7: flextural strength:



7.4 COMPARISON

The following graph shows the comparison between conventional concrete, foundry sand replacement concrete with replacement percentage of about 15% and foundry sand replacement concrete with replacement percentage of about 20%.



8. CONCLUSION

In this experimental study spent foundry sand is used instead of fine aggregate.There is a millions of waste foundry sand produced every year in India,there is also a disposal problem and environmental effects.Also in concrete,River sand is used as a fine aggregate which is very less in amount.Unfortunately, we need a way to reduce the use of River sand and increase the use of Foundry sand.So Foundry Sand is used as a replacement for the fine aggregate in concrete.Here, Spent Foundry Sand (SFS) is used as a partial replacement for the fine aggregate by 15% and 20% in M20 grade of concrete.Finally the experimental results and graph were shown in this study.

9. REFERENCES:

1. Maria Auxiliadora de Barros Martins, Regina Mambeli Barros, Gilbert Silva, Ivan Felipe Silva dos Santos "Study on waste foundry exhaust sand, WFES ,as a partial substitute of fine aggregates in conventional concrete", Sustainable Cities and Society,Volume 45,February 2019,Pg 187-196.
2. N.Gurumoorthy, K.Arunachalam "Durability Studies on concrete containing Treated Used Foundry Sand",Construction and Building Materials,Volume 201,20 March 2019,Pg 651-661.
3. Cesar Cardoso, Aires Camoes, Rute Eires, Andre Mota, Jorge Araujo, Fernando Castro, Joana Carvalho "Using Foundry slag of ferrous metals as fine aggregate for concrete", Resources,Conservation and Recycling, Volume 138, November 2018, Pg 130-141.
4. Thiruvenkitam Manoharan, Dhamothiran Laksmanan, Kaliyannan Mylsamy, Pandian Sivakumar, Anirbid Sircar "Engineering properties of concrete with partial utilization of used foundry sand", Waste Management,Volume 71,January 2018,Pg 454-460.
5. G.Ganesh prabhu, Jung Hwan Hyun, Young kim " Effects of foundry sand as a fine aggregate in concrete production" Construction and building materials Volume 70, 15 November 2014, page 514- 521
6. Rafat siddique, Gurpreet Singh, Rafik Blearbi,Karim Ait- Mokhtar, kunal "Comparative investingation on the influence of spent foundry sand as a partial replacement of the fine aggregate on the properties of two grades of concrete", Construction and Building Materials, Volume 83, 15 May 2015, Pg 216-222.
7. Natt makul, Prakasit Sokrai, "Influences of fine waste foundry sand from the automobile engine-part casting process and water-cementitious ratio on the properties of concrete: A new approach to use of a partial cement replacement material", Journal of Building Engineering, Volume 20, November 2018, Pg 554-558.
8. Rafat Siddique, Gurpreet Singh, Malkit Singh, "Recycle option for metallurgical by-product (Spent Foundry Sand) in green concrete for sustainable construction", Journal of Cleaner Production, Volume 172, 20 January 2018, Pg 1111-1120.
9. Rafat Siddique, Yogesh Aggarwal, Paratibha Aggarwal, El-Hadj Kadri, Rachid Bennacer, "Strength, durability and micro-structural properties of concrete made with used foundry sand (UFS)", Construction and Building Materials, Volume 25, 4 April 2011, Pg 1916-1925.

10. V Divya Prasad, E Lalith Prakash, M Abishek, K Ushanth Dev, C.K. Sanjay Kiran "Study on concrete containing Waste Foundry Sand, Fly Ash and Polypropylene fibre using Taguchi method", Materialstoday: Proceedings, Volume 5,2018, Pg 23964-23973.