Durability study of concrete using foundry waste sand

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Abstract: In the present work, experimental investigation were performed such as compressive strength of concrete for M20 grade of concrete, porosity, water absorption, permeability and effect of alternate heating and cooling, alternate wetting and drying, effect of accelerated curing(44^{0}C and 55^{0}C) and acid attack test on concrete for 100% replacement of foundry waste sand in place of fine aggregate. curing is choosen was 28 days. The results of compressive strength were in range of 27.758 to 28.049 N/mm^2 .The results of porosity and water absorption were in the range of 17.90% to 16.00% and 2.149% to 1.958%. The results of permeability were in the range of 4.38 to 1.85 cm. The results of alternate heating and cooling and alternate wetting and drying were in the range of 33.572 to 26.595 N/mm^2 and 28.212 to 38.676 N/mm^2.The results of accelerated curing were in the range of 31.950 to 35.456 N/mm^2 and 33.940 to 40.380 N/mm^2 respectively. The results of acid attack test were in the range of 24.852 to 37.496 N/mm^2

Keywords: Foundry waste sand (Weathered sand, Burnt black sand), Porosity and Water absorption, Permeability, Compressive strength, Acid attack.

I. Introduction

In India nowadays metal casting industries dump lot of foundry sand as a waste, which is creating dangerous environmental related problems, on the other hand we are facing a problem of sand scarcity in construction. With the aim of resolving these two problems, attempt is made to utilize 100% of foundry waste sand in the preparation of concrete. Xerses.N.Irani et.al.,[1] investigated the foundry waste sand (FWS) and determined the physical properties of foundry waste sand such as specific gravity:2.42, 2.52, fineness modulus:4.09, 4.25, water absorption: 8.1%, 11.02%, bulk density 1.64g/cc, 1.56g/cc, for burnt black sand and weathered sand respectively. Eknath P Salokhe and D.B.Desai[2] analysed the slump of concrete containing FWS and the outcome of the research was: slump value decreased because of higher water absorption, when the concrete made up of foundry sand was used. Sohail Md et.al.,[3] considered the fresh property of concrete i.e., workability and observed that as the % of FWS increased in the concrete workability decreased, this was due to filling of voids by fine particles of FWS. Muhammad Umar Farooq et.al.,[4] carried out the study on non ferrous FWS and summarized that compressive strength of concrete containing non ferrous FWS increases up to 30%replacement and found optimum value at 10% replacement, and use of non ferrous FWS can be economical and can save the cost of concrete up to 10% replacement, and ultimately the cost of the structure. Pathariya Saraswati et.al.,[5] researched on concrete containing FWS at replacement of 0%, 20%, 40%, 60% and found that maximum compressive strength was observed at 60% replacement. Many of the researchers like J.M.Khatib et.al., Rafat Siddique et.al.,[6] carried out the investigation on resistance of concrete containing FWS when immersed in 50g/l $MgSo_4$ solution and observed that for 10% replacement of FWS an increase in strength was observed but for 15% and 20% replacement decrease in strength was observed. Rafat Siddique et.al.,[7] referred number of research papers and concluded that water absorption of concrete with 5% replacement of FWS was higher than that of concrete without FWS at the age of 56 days. Alok Khanduri[8] investigated on concrete containing FWS and the outcome of the study was: Porosity and voids ratio of the mortar decreases with increase in replacement of FWS. Eknath.P.Salokhe et.al.,[9] examined the influenced of FWS on concrete and concluded that water absorption increases with the increase in FWS and compressive strength of the concrete containing FWS decreases.

II. Materials used: Ultratech cement OPC confirming to IS: 1489-1991[7] procured from single source was used. Physical properties of the cement are as follows: Specific gravity: 3.14, Normal consistency: 34%, initial and final setting time 50 minutes and 180 minutes respectively. Basalt coarse aggregate of two fractions i.e., 20mm (40%) and 12.5mm (60%) were used in the present work with specific gravity of 2.76, Fineness modulus of aggregate was 8.34, Bulk density in loose and compacted condition was 1.4g/cc and 1.59g/cc respectively, and aggregates had a crushing value of

25.05%, impact value of 16.12% and water absorption of 2.5%. Sieve analysis test was carried to determine the grading of basalt aggregate and it was concluded that aggregates were nearly graded. Locally available fine aggregate (sand) belonging to Zone II was used. FWS (Weathered sand and Burnt black sand) belongs to Zone III. Sieve analysis result and physical properties of all the three types of fine aggregate are presented in Table1 and Table2 respectively.

Sl. No	Properties	Currently used foundry sand	Locally available sand	Weathered sand	Burnt Black Sand
1.	Specific gravity	2.55	2.63	2.60	2.59
2.	Fineness modulus	2.81%	2.90%	3.81%	3.67%
3.	Water absorption	2.15%	0.30%	11.02%	8.1%
4.	Silt Content	Nil	Nil	Nil	Nil
5.	Bulk density a)Loose b)Compacted	2.53g/cc 1.67g/cc	1.80g/cc 1.97g/cc	1.69g/cc 1.81g/cc	1.78g/cc 1.93g/cc

Table1: Sieve analysis results of locally available sand, weathered sand, burnt black sand

Sieve size	Cumulative % finer for locally available sand	Cumulative % finer currently used foundry sand	Cumulative % finer weathered sand	Cumulative % finer burnt black sand	Values as per IS standards Zone II	Values as per IS standards Zone III
4.75 mm	95.142	100	100	100	90-100	90-100
2.36 mm	90.285	99.890	99.295	99.294	75-100	75-100
1.18 mm	72.777	64.462	63.345	68.720	55-90	60-79
600µ	43.631	15.230	10.377	20.290	35-59	12-40
300µ	4.467	2.471	1.400	2.030	8-30	0-10
150µ	0.060	2.770	0.210	0.310	0-10	-
Pan	0.000	0.03	0.010	0.010	0-10	-
Zone	II	III	III	III		

Fig:1 Black sand,weathered sand & local sand

Table2: Comparison of locally available sand with foundry waste sand

It is observed from the Table1 that locally available sand belongs to Zone II and FWS belongs to Zone III and both the FWS has same particle size. Table2 represents physical properties of locally available sand and FWS (weathered sand and burnt black sand). It is clear from the table that Specific gravity and fineness modulus for all three types of sand is nearly same. Water absorption of FWS is quite high compared to locally available sand 0.3%, this is because of the polymer resin chemical is added to FWS for moulding process. Therefore water absorption of FWS is to be taken into account during mix design of both type of FWS. Otherwise there will be seriously decrease in workability of the concrete.

III. Mix design:M20 grade of concrete was designed as per IS 10262-2009[9].The trail casting was carried out for basalt CA+locally available sand i.e control mix (Mix1), basalt CA+weathered sand (Mix2) and basalt CA+burnt black sand (Mix3) for different w/c ratio for a period of 7 days and the w/c ratio which has resulted in strength satisfying the strength requirements of M20 grade of concrete was used for the final castings. The mix proportion are given in Table3.

Table3: Finalized mix proportions for locally available sand, weathered sand and burnt black sand for M20 grade concrete.

Casting and curing: Total no of 150 cubes were cast and cubes were demolded after 24 hours of casting .The cubes were kept for curing under water immersion at laboratory temperature and water is being changed at regular intervals.

IV. Experimental results and discussion

4.1 Slump test: The slump test was carried out as per IS: 7320-1974 and results are presented in Table 4. From the Table4 it is clear that the slump is higher for Mix1 compared to Mix2 and Mix 3. For both the concrete containing FWS, slump is nearly same. The lower workability of concrete using FWS is due to higher fineness of the sand and higher water absorption compared to concrete mix1.

Table4: Results of Slump values of concrete with three mixes

Grade of concrete	W/C ratio	Mix Combination	Avg. 28 days comp. Strength in N/mm^2	Avg. 56 days comp. Strength in N/mm^2	% change in strength.
M20	0.56	Mix1	42.292	40.00	5.73
	0.56	Mix 2	27.758	31.68	12.38
	0.56	Mix3	28.049	39.385	28.79

Sl.no	Mix combination	Slump (mm)
1.	Mix1	100
2.	Mix2	96
3.	Mix3	98

4.2 Hardened state concrete properties

4.2.1 Compressive strength test: The Compressive strength test at 28 days curing and at age of 56 days for M20 grade of concrete using 100% of locally available sand and FWS was carried out as per IS:516-1959.From Table 5 it is observed that compressive strength of concrete using FWS have attained the strength required for M20 grade concrete (i.e., more than the target mean strength 26.6 N/mm^2). Compressive strength of Mix1 has resulted in strength quite higher than Mix2 and Mix3. Compressive strength at 56 days(i.e., moist curing for 28 days and exposure to ambient temperature for 28 days) Marginal decrease in strength was observed in case of Mix1.Concrete using FWS has resulted in increase in compressive strength (56 days age) by 12.38% and 28.79% respectively compared to the 28 days cured compressive strength. This reveals that influence of ambient temperature exposure is more on FWS compared to locally available sand

Table 5: Results for different combination of M20 grade concrete at different curing period.

Sl No.	Mix combination	Cement	Fine Aggregate	Coarse Aggregate 12.5 mm	Coarse Aggregate 20mm	W/c Ratio	Compressive strength in N/mm^2
1.	Mix1	1	2.03	1.98	1.32	0.56	21.510
2.	Mix2	1	1.899	2.044	1.363	0.56	22.091
3.	Mix3	1	1.892	2.448	1.363	0.56	23.560

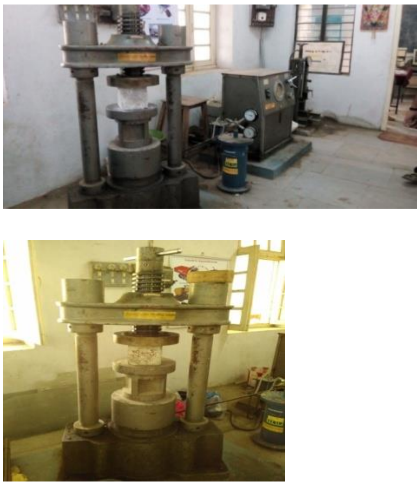

Fig:2 Testing of cubes under UTM machine

4.2.2 Compressive strength(Accelerated curing method): Test is carried out as per IS 9013-1978.To study the effect of accelerated curing on both the concrete (Mix2 and Mix3) compressive strength test was carried out and the results are presented in Table6. Results indicate that for both the mix accelerated strength (44^{0}C and 55^{0}C) has resulted in increase strength. Strength increases with increase in temperature. Therefore the effect of curing water at higher temperature is beneficial and it has no adverse effect on the strength of concrete using foundry waste sand. Concrete containing foundry sand has resulted in highest strength for both the temperature.

Table6: Results of accelerated curing for three different mix combination (at 56^{0}C and 44^{0}C temp)

Sl.no.	Mix combination	Avg. compressive strength after 28 days curing in N/mm^2	Avg. accelerated compressive strength in N/mm^2 at 44^{0}C (avg. ambient temp)	Avg. accelerated compressive strength in N/mm^2 at 55^{0}C (warm water method)
1.	Mix 2	27.758	31.950	33.940
2.	Mix 3	28.049	35.456	40.380

4.3 Durability Test

4.3.1 Porosity: The test is conducted according to "properties of mortar incorporating waste foundry sand" journal submitted by Alok khanduri.From the Table7 it is clear that highest porosity is observed in concrete using FWS i.e., Mix2 and next highest Mix3 it may be due to more fineness of foundry sand. Lowest porosity is observed in Mix1.

Table7: Results of porosity for three different types of concrete.

Sl.no	Mix combination	Porosity
1.	Mix1	13.60%
2.	Mix2	17.90%
3.	Mix3	16.00%

4.3.2 Water absorption: This test is conducted as per ASTM C-640.From the above Table8 it is observed that highest water absorption is for concrete using FWS i.e., Mix2 and next highest is for Mix3, and lowest is for Mix1.The results of porosity and water absorption are in agreement with each other i.e., porosity and water absorption is highest for Mix2 and next highest is for Mix3 and lowest for Mix1.

Table8: Results of water absorption for three different es of concrete.

Sl.no	Mix combination	Avg.% of water absorption
1.	Mix 1	1.547%
2.	Mix 2	2.149%
3.	Mix 3	1.958%

4.3.3 Permeability test: The test is carried out according to German Standard DIN- 1048.From the Table 9 average depth of penetration is higher for Mix2 and lowers for Mix3. Higher depth of penetration for Mix2 is due to higher porosity of concrete compared to the Mix1 as indicated in the Table 9.

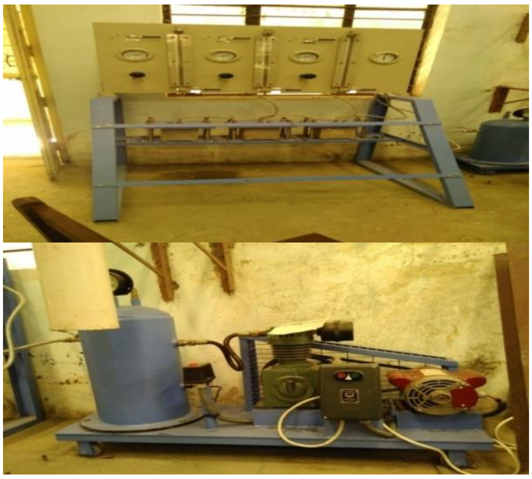

Fig 3: permeability test set up

Table 9: Results of permeability test for three different types of concrete.

SL NO	Mix combination	Avg. depth of penetration in cm
1.	Mix1	2.86
2.	Mix2	4.38
3.	Mix3	1.85

4.3.4 Heating and cooling test: The specimens are cast and cured for 28 days, after curing the specimens are subjected to heating and cooling for a period of 20days (20cycles) to check the durability. The specimens are heated at normal atmospheric temperature in day time and cooled during the night time. This process is continued for 20 days and strength of the specimens is checked at the end of 20 days.Results are presented in the following Table 10.Table10 reveals the results of compressive strength due to heating and cooling effect. Heating and cooling effect has not much influence on all the mix combination, but Mix2 has resulted in higher strength compared to Mix1, this increase in strength may be due to enhanced hydration, due to the temperature.

Table10: Results of Heating and Cooling test

Sl.no	Mix combination	Avg. comp. Strength in N/mm^2
1.	Mix1	39.676
2.	Mix2	33.572
3.	Mix3	26.595

4.3.5 Alternate wetting and drying test: The specimens were cast and cured for 28 days, after curing the specimens are subjected to alternate wetting and drying for a period of 20 days to check the durability. The specimens are kept for wetting in curing tank for 1 day and next day it is allowed to dry, again the procedure is repeated, after 20 days cycle the strength of specimens are tested to check the effect of alternate wetting and drying on concrete.Results are given in the following Table 11.Table 11 indicates effect of alternate wetting and drying on compressive strength of all three mixes. Here also the influence of wetting and drying is marginal for Mix1 and Mix2 but Mix3 has resulted in quite higher strength compared to the other concrete, this is due to continued hydration during wetting process and water absorption of foundry waste sand is also less.

Table11: Weights of different concrete after immersion in Sulphate solution.

Sl.no	Mix combination	Weight before immersion in Magnesium sulphate solution in Kg	Weight after immersion for 28 days in Magnesium sulphate solution in Kg	Avg. comp. strength in N/mm^2	Avg. 28days comp. Strength in N/mm^2
1.	Mix1	8.440	8.325	40.548	42.292
2.	Mix2	8.695	8.550	24.852	27.758

3.	Mix3	8.625	8.475	37.496	28.049

Sl.no	Mix combination	Avg. comp. Strength in N/mm^2
1.	Mix1	39.894
2.	Mix2	28.212
3.	Mix3	38.676

4.3.6 Sulphate attack on concrete: Sulphate attack test is carried out as per Leonardo journal of science ISSN 1583-0233.From Table12 it is clear that marginal decrease in weight of the sample were observed for all the three mixes. Due to sulphate attack marginal decrease in strength was observed for Mix1.Decrease in strength for Mix2 is low and is less than target mean strength ($26.6N/mm^2$)it is due to more porosity&permeability but however it is acceptable for M20 grade concrete based on acceptance criteria ($24N/mm^2$).The behavior of Mix3 is totally different, it has resulted in quite higher strength compared to Mix1, and it is due to the formation of ettringite (tri calcium alumino sulphate).

V. Conclusion

1. From the result of sieve analysis of burnt black sand and weathered sand, both sand belongs to ZONE III.

2. water absorbtion of weathered sand is more as compared to burnt black sand and local sand hence worakability reduced.

3. Porosity and water absorption decreases in the order of concrete containing weathered sand, concrete containing burnt black sand and control mix.

4. Concrete containing weathered sand and burnt black sand has resulted in lower strength at 28 days of curing compared to control mix this is due to higher water absorption of foundry waste sand. At 56 days age of concrete (moist cured for 28 days and exposed to ambient temperature for 28 days) control concrete and concrete containing burnt black sand has recorded nearly the same strength but concrete containing weathered sand has recorded lower strength.All the three concrete for both the ages have satisfied the requirement of M20 grade concrete.

5. The effect of heat curing on compressive strength of control mix and concrete containing burnt black sand registered nearly the same strength but concrete containing weathered has recorded lower strength compared to control mix, this is due to higher water absorption of weathered sand.

6. Permeability is measured in terms of depth of penetration of water in concrete, Concrete containing weathered sand is more permeable which is clear from higher porosity result in 4^{th} conclusion and lower compressive strength in 5^{th} conclusion.

7.Heating and cooling effect has not much influence on concrete using locally available sand and burnt black sand, but increase in strength was observed for concrete containing weathered sand.

8. Effect of alternate wetting and drying is marginal for concrete using locally available sand and weathered sand.But concrete using black sand has resulted in higher strength, it is due to enhanced hydration and low water absorption of black sand.

9. Decrease in strength is observed due to sulphate attack on concrete using locally available sand and weathered sand but for concrete containing burnt black sand increase in strength was observed.

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