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ORIGINAL ARTICLE

Study the mechanical and durability characteristics of concrete utilizing waste foundry sand

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Abstract

Presently good quality natural river sand is not easily available, it is to be transported from a long distance. These resources are also consumed very rapidly. So there is a need to find alternative to natural river sand. The experimental work is mainly concern with the study of mechanical and durability properties like compressive strength, split tensile strength, Ultrasonic Pulse Velocity Test, flexural strength as well as permeability of concrete by partial replacement of natural river sand by waste foundry sand as a fine aggregate. Tests over carried out on cubes and beams to studies the mechanical properties and durability characteristic of concrete using waste foundry sand and compared with concrete with natural sand as fine aggregate. Natural river sand was replaced with six percentages (0%, 20%, 35%, 60%) of Waste Foundry Sand by weight. Splitting tensile strength test and flexural strength test were carried out to evaluate the strength properties of concrete at the age of 7, 28, 56 and 91 days. It has been found that workability decreases and Compressive strength, split tensile strength, flexural strength, ultrasonic pulse velocity of concrete specimens increases with increase in fine aggregate replacement by waste foundry sand, giving maximum strength at 35% replacement, it has been also observed that permeability of concrete goes on decreasing up 35% replacement after 35% there is slight increase in the permeability of concrete.

1. Introduction

Waste foundry sand is a by-result of ferrous and nonferrous metal throwing ventures. Foundries effectively reuse and reuse the sand commonly in a foundry. When the sand can at no time in the future be reused in the foundry, it is expelled from the foundry. It is named as waste foundry sand shown in Fig. 1. Because of the absence of landfilling space, and its steadily expanding cost, usage of waste material and by-items has turned into an appealing contrasting option to transfer. In India, roughly 2 million tons of waste foundry sand is delivered yearly, and in the United States, 6–10 million tons of waste foundry sand are disposed of annually. The car ventures and its parts are the significant generators of foundry sand. Foundries buy top-notch estimate particular silica sands for use in their trim and throwing operations. The crude sand is ordinarily higher than the regular bank run or characteristic sands utilized as a part of fill development locales. The sands frame the external state of the formed hole. These sands typically depend upon a little measure of bentonite dirt to go about as the folio material. Concoction covers are likewise used to make sand "centers." Contingent on the geometry of the throwing, sands centers is embedded into the shape cavity to frame inner entries for the liquid metal. Once the metal has cemented, the throwing

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is isolated from the trim and center sands in the shakeout procedure. In the throwing procedure, shaping sands are reused and reused in numerous circumstances. In the end, in any case, the reused sand debases to the point that it can at no time in the future be reused in the throwing procedure. By then, the old sand is uprooted from the cycle as a side effect, new sand is presented, and the cycle starts once more. Redirection of repercussion materials into valuable reuse will have a generous, positive effect on foundry enterprises. The transfer of foundry repercussions speaks to a huge cost for the foundry business, regardless of whether transfer happens in organization-possessed offices or in civil or exclusive landfills. With the diminishing in accessible landfill destinations, landfill transfer expenses are heightening because of the additional charges for transportation and landfill operation. Despite the fact that the transfer of overabundance foundry sand can be decreased by recovery of a more prominent rate of the sand before the transfer, new sands are required to supplement for shakeout misfortune, and sand that has debased past quality standard. Debased sand ought to be expelled from the throwing procedure to keep a decent restricting framework and guarantee to throw quality. An extreme answer for this issue is to valuably reuse foundry results. Controlled Low-Strength Material (CLSM) and Hot-Mix-Asphalt (HMA) are two developing markets that meet the fundamental financial and specialized capabilities to address a valuable reuse program. An assortment of specialized, financial, and natural contentions should be tended to before foundry results can concentrate on these applications. CLSM, in its easiest shape, is a premixed streaming soil-concrete that solidifies to frame a solid, firm geotechnical item. It can be intended for about any quality (0.3 - 8.3 Mpa), water-driven conductivity (10-2 - 10-6 cm/sec), rheological property (100 - 275 mm droop), or setting time (2 - 24 hours). Also, it can be blended, pumped, and put with standard solid gear. Waste foundry sand is essentially a fine mineral total. Over 80% of the particles by mass are thought by size between 0.15 – 0.70 mm, contrasted with 0.30 –4.75 mm for regular fine total. The AFS Grain Fineness Number (AFS GFN), a foundry industry parameter that was showing the normal grain estimate (greater, better), extends between 40 – 90 for the vast majority of the abundance foundry sands, contrasted with around 40 for regular fine total. Also, foundry sand is a uniform equidimensional sub-angular aggregate. These fundamental physical properties upgrade the stream consistency of CLSM; when abundant foundry sand is consolidated into CLSM blends, the reuse of foundry sand offers considerable ecological and monetary advantages. The cost and ecological effect of mining and digging virgin sand for CLSM, black-top, and cement are bit by bit rising. These increasing expenses of transportation, ecological direction, fuel and vitality in mining and digging, and the formative cost of virgin wellsprings of total are driving the requirement for the reuse of common assets. The utilization of CLSM and HMA containing foundry sand diminishes the requirement for mining or digging virgin granular total. There are no expenses of arranging foundry results to landfills, as shown in Fig. 2 just the delivery to nearby contractual workers. Both normal mineral assets and the urban condition are secured.

Figure 1: Waste Foundry Sand

Figure 2: Disposal of Waste Foundry Sand

1.1 Production of foundry industry in India and world

1.1.1 The World Scenario

There are around 35,000 foundries on the planet, with a yearly generation of 90 million tons. Regarding various foundries, China has the most noteworthy score (9374), trailed by India (6000) the most noteworthy score (9374), trailed by India (6000). The offer of Iron foundries is the most extreme i.e., very nearly 56%, trailed by steel with 14% and after that the nonferrous ones with 30%. The developing natural concerns and globalization of economies have prompted a conclusion of some8000 foundries in Europe. These nations have been mulling over to move their business to the low work cost focus i.e. the creating nations.

Table 1: Country v/s foundry production: scenario of world

Country	2009		2010		2011	
	Million tones	Rank	Million tones	Rank	Million tones	Rank
China	35.3	1	39.6	1	41.26	1
US	7.40	2	8.24	3	10.01	2
Japan	4.40	4	4.76	5	5.74	4
India	7.40	3	9.05	2	9.99	3
Germany	3.90	5	4.79	4	5.46	5
Brazil	2.30	7	3.24	7	3.34	7
Italy	1.67	9	1.97	9	2.21	9
France	1.74	10	1.96	10	2.04	10
Korea	2.10	8	2.23	8	2.34	8
Russia	4.20	6	4.20	6	4.3	6

1.1.2 Types of waste foundry sand

Clay bonded systems (Greensand) and chemically bonded systems are the two types of binder systems used in metal casting, depending on how the foundry sands are classed. Both types of sands have advantageous properties, but they differ in terms of physical and environmental qualities.

1.1.3 Clay bonded system (Green Sand)

Greensand is made out of normally happening materials which are mixed; amazing silica sand (85-95%), bentonite dirt (4-10%) as a fastener, a carbonaceous added substance (2-10%) to enhance the throwing surface complete and water (2-5%). Greensand is the most normally utilized reused foundry sand for helpful reuse. It is dark in shading because of carbon substance, has an earth substance that outcomes in rate of material that passes a 200 sifter and clings together because of dirt and water. In the measure of 4-10% by weight of base sand [1-3], Earth sort cover is utilized for making little, medium, and expansive molds. It is moderately modest and of low quality. The substance cover is typically utilized for little to medium size shape and centers and is generally more grounded with great disintegration resistance. The significant subdivisions of the earth family are montmorillonites (bentonites commonly utilized as a part of foundry), kaolinite, and illite. Inorganic-sort covers incorporate sodium silicate and Portland bonds, which are incombustible. They are naturally kind contrasted with natural fasteners and have minimal effort, low sand affectability, and low gas advancement. The sodium silicate, for the most part called water glass, alludes to a three-fixing framework: silica, sodium oxide, and water. The concrete-based holding framework is a blend of sand, 8-12% high-early-quality pressure-driven bond, and 4-6% water. Inorganic-sort fasteners create incredible hardness and quality by the setting activity of sodium silicate or Portland bond. Nonetheless, they introduce moderate cure attributes and once utilized, they are poor to separate or reuse [4-7], which balances their natural favorable position.

1.1.4 Chemically bonded sands

Chemically reinforced sands are utilized both in the center making where high qualities are important to withstand the warmth of the liquid metal, and in shape making. Most concoction fastener frameworks comprise a natural cover initiated by an impetus, albeit a few utilize inorganic covers. Artificially reinforced sands are, for the most part light in shading and in the surface than earth fortified sands. Natural covers incorporate two noteworthy gatherings, sap and oil-based folios. They are burnable and are crushed by warmth [8, 9]. The sap is made by blending different extents of phenolic, furfuryl liquor (furan), urethane and formaldehyde. Going from 1.5 to 8% in light of base sand [10-12]. They are fluids or gums, characteristic or engineered, where the individual particles have the ability to polymerize or meld to frame long chains. This polymerizing response can be activated by certain synthetic reagents or warmth. The subsequent tie solidifies to frame an intense security with different materials [13] the oils in the measure of 0.5-3% can be either common oils, for example, linseed, perilla, Tung and dried out castor oils, or handled oils, for example, unsaturated mineral oils, engineered oil, and alkyd gum. Their instrument of solidifying is like tar, polymerization with or without warmth.

2. Result and discussion

2.1 Workability

Slump test are conducted to determine the workability of concrete at constant w/c ratio of 0.4 and the result of the test are listed in Table 2 and the variation of slump has been shown in Fig. 3.

Table 2: Slump value

S. No.	Mix. No.	Slump(mm)	W/C ratio
1	WFS00%	115	0.4
2	WFS20%	90	0.4
3	WFS35%	73	0.4
4	WFS60%	50	0.4

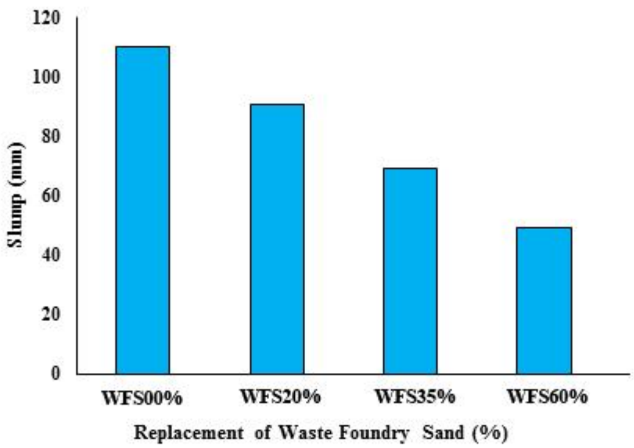

Figure 3: Variation of slump (mm)

As the waste foundry sand percentage increases 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 an increase in waste foundry sand content tends to become harsh, sticky and stiff. The presence of finer foundry sand particles in concrete lead to the increase in the water demand, as compared to the regular sand particles. The reduction in workability can be overcome by adding super plasticizer. Super plasticizer increases the workability of the concrete. Thus, the purpose of using a super plasticizer in a concrete mix is to allow a reduction in the water cement ratio while retaining the desired workability or, alternatively, to improve its workability at a given water cement ratio. The actual reduction in water depends on dose of admixtures, cement content, type of aggregate used, ratio of cement, fine and coarse aggregate etc.

2.2 Compressive Strength

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, 56 days and 91days are tabulated in Table 3. 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%, 35%, 60%. The concrete obtained by these replacement levels named as WFS 00 %, WFS 20%, WFS35%, and WFS60%.

Table 3: Compressive strength

S.No	Mix No.	Compressive Strength (Mpa)			
		7 Days	28 Days	56 Days	91 Days
1	WFS00%	25.3	31.80	36.55	40.11
2	WFS20%	26.8	32.66	36.70	42.33
3	WFS35%	26.9	33.40	37.22	44.00
4	WFS60%	24.5	31.05	34.88	38.66

Compressive strength of concrete mixtures made with and without Waste Foundry Sand (WFS) was determined at 7, 28, 56, and 91 days of curing. There was increase in the compressive strength of concrete mixtures with the inclusion of WFS as partial replacement of regular sand. At 28-day, control mixture WFS00% achieved a compressive strength of 31.88 MPa, whereas mixtures WFS20%, WFS30% and WFS60% achieved a compressive strength of 32.66, 33.40, and 31.05 MPa respectively; an increase of 1.7%,2.8% and 8% in comparison with the strength of control mixtureWFS00%. Compressive strength of concrete mixtures also increased with age. With age (from 28 to 91 days), percentage increase in compressive strength for control mixture WFS00%was between 14% and 26%, between 13.7% and 27.4% for mixture WFS20%, and between 11.7% and 29.2% for mixture WFS35%. Increase in the compressive strength of concrete mixes incorporating used-foundry sand indicated that foundry sand could be successfully used in making concrete as partial replacement of fine aggregate. The variation of compressive strength at 7 days, 28 days, 56 days and 91 days was analyzed. The ultrasonic pulse velocity is carried out according to IS 13311(Part 1): 1992UPV Test is a non-destructive method of testing of concrete quality, homogeneity and this concrete cubes can further have used to find compressive strength on this sample itself.

Table 4: Ultrasonic Pulse Velocity

S.N	Mix. No	Ultrasonic Pulse Velocity (m/s)			Quality of Concrete
		28 Days	56 Days	91 Days	
1	WFS00%	4545	4550	4660	Excellent
2	WFS20%	4664	4680	4685	Excellent
3	WFS35%	4700	4780	4690	Excellent
4	WFS60%	4484	4400	4600	Good

Variation of ultrasonic pulse velocity with percentage replacement of waste foundry sand and with age of concrete has been shown in Fig 4.

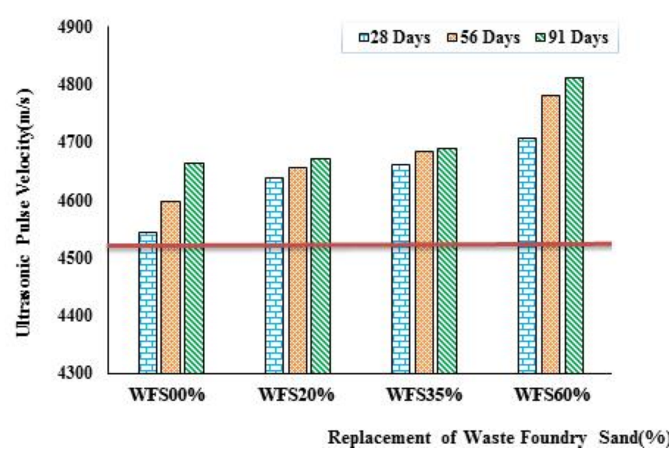

Figure 4: Variation of ultrasonic Pulse velocity with Replacement (%) of WFS

It can be concluded from the above charts that UPV value increased with the increase in waste foundry content in concrete mixtures and it also increases with age. UPV value for the concrete mixture containing WFS20%, WFS35% was found more than control concrete mixture WFS00%. Electronic wave velocity value varies between 4545 m/s to 4484 m/s at 28 days' maximum value were observed for WFS35% concrete mixture. As there is an increase in UPV value with the inclusion of WFS in the concrete mixture, it means that the quality of concrete in term of density, homogeneity, and lack of imperfections is good. Increase in the Ultrasonic Pulse Velocity may be due to the dense packing of the fine aggregate, coarse aggregate and Waste Foundry Sand. Through this investigation, it has been established that up to 35% use of WFS results in better-enhanced strength and more durable concrete. 4.6 Flexural Strength Beam specimens of dimension 100mm x 100mm x 500mm were tested for flexural strength. The tests were carried out confirming to IS: 516-1959(8). The specimens are tested under two-point loading. The average value of 3 specimens for each category at the age of 28, 56 days,91 days, shown in Table 5 and the load vs. deflection curve for WFS00%, WFS20%, WFS35%, WFS60% has been shown in Fig. 5-8.

Table 5: Flexural Strength

S.No	Mix.No.	Flexural Strength (MPa)		
		28 Days	56 Days	91Days
1	WFS00%	3.74	4.04	4.13
2	WFS20%	4.12	4.24	4.38
3	WFS35%	4.20	4.40	4.46
4	WFS60%	3.55	3.59	3.73

On the basis of Experimental results obtained it has been found that there is an increase of 6.7%, 7.2% and 10.6% in the flexural strength of concrete with the partial replacement of waste foundry sand up to 35%. However, for 60% replacement of WFS there was a slight decrease of 2.5% in the flexural strength compared to WFS00%. The above variation in strength may be attributed to the fineness of WFS as it is higher than natural fine aggregate. It reduces the porosity of concrete thereby increasing its density and strength. But the reduction in Flexural strength of concrete specimen with replacement percentage beyond 35% may be due to binders present in foundry sand, composed of the very fine powder of clay and carbon, which results in a weak bond between The load vs. Deflection Curve has been shown in Fig. 5-8.

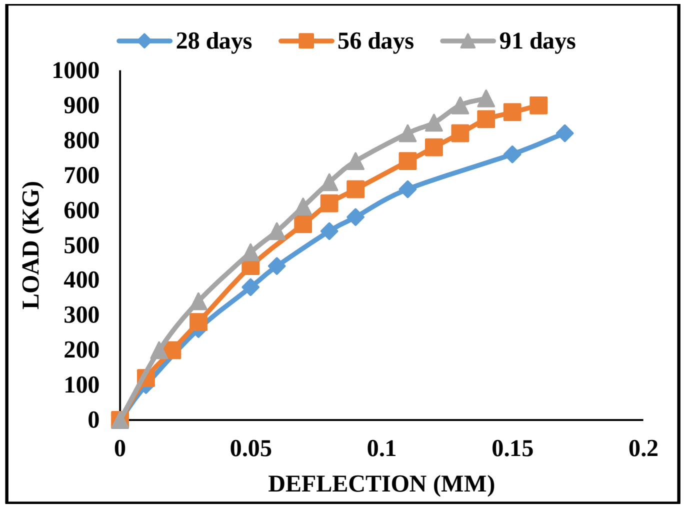

Figure 5: Load vs. Deflection curve for WFS00%

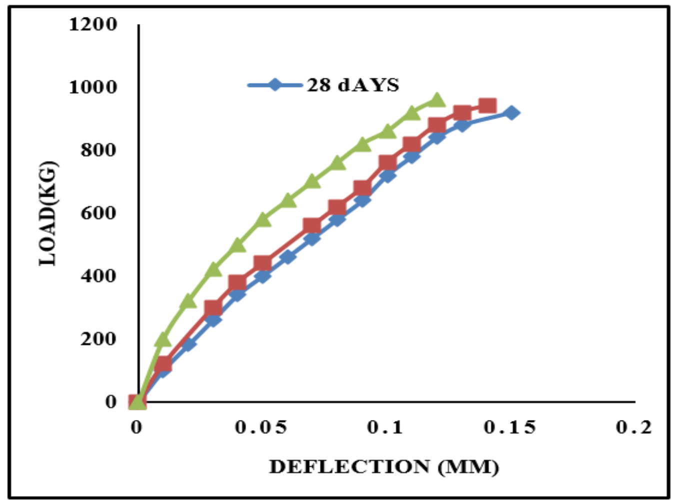

Figure 6: Load vs. Deflection curve for WFS20%

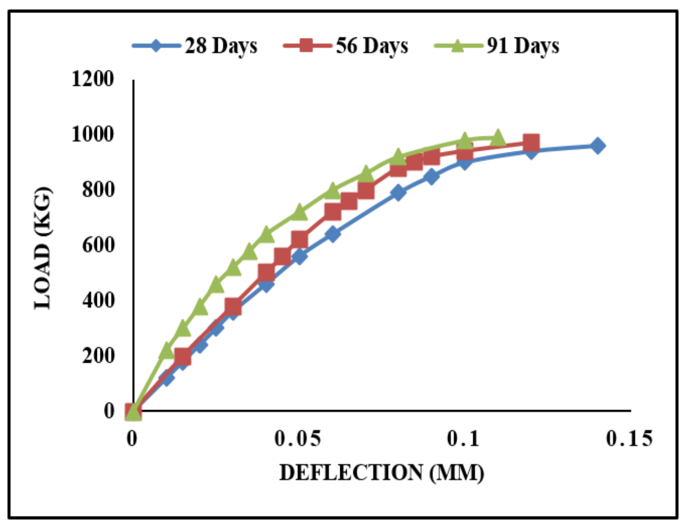

Figure 7: Load vs. Deflection curve for WFS35%

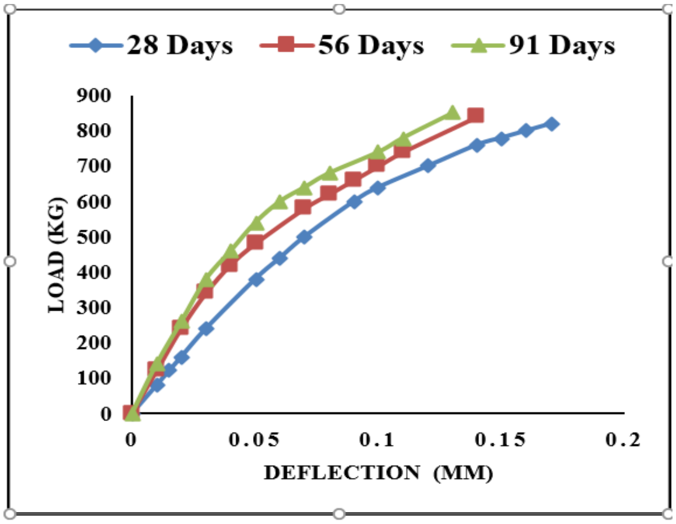

Figure 8: Load vs. Deflection curve for WFS35%

From above graph, it has been found that flexural strength also increases with age of concrete. The increase in strength parameters may be due to the 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 the reduction in Flexural strength of concrete specimen with replacement percentage beyond 35% is attributed to binders present in foundry sand, composed of the very fine powder of clay and carbon, which results in a weak bond between cement paste and aggregate

2.3 Permeability

Water permeability test has been done at the various replacement of waste foundry sand at 28 days, 56 days, and 91 days. The results of the test are tabulated in Table 6 below.

Table 6: Coefficient of permeability

S.No.	Mix No.	Coefficient of Permeability K x 10^{-9} (m/s)		
		28 Days	56 Days	91 Days
1	WFS00%	8.24	4.28	3.66
2	WFS20%	6.78	3.87	3.32
3	WFS35%	6.17	3.68	3.11
4	WFS60%	9.37	5.55	5.00

The graph showing variation of permeability with percentage replacement of waste foundry sand at 28 days, 56 days, and 91 days has been drawn and shown in Fig. 9.

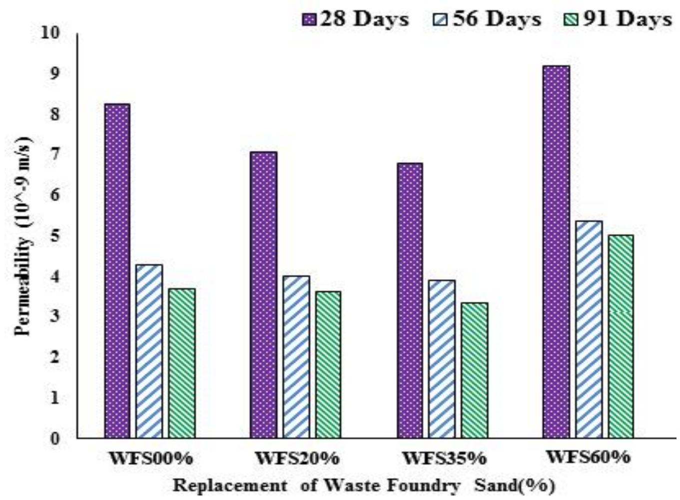

Figure 9: Variation of Coefficient of Permeability with % replacement of WFS

References

[1] Abichou T, Benson C. Database on Beneficial Reuse of Foundry Byproducts, Recycled Materials in Geotechnical Applications Geotech. ASCE, Spec.Publ. 79, 1992, 210 – 223.

[2] BIS: 10262-1982. Recommended guidelines for concrete mix design, Bureau of Indian Standards, New Delhi, India

[3] BIS: 1199-1959. Indian standard methods of sampling and analysis of concrete, Bureau of Indian Standards, New Delhi, India

[4] BIS: 3085 –1965, "Method of test for Permeability of Cement Mortar and Concrete" Bureau of Indian Standards, New Delhi, India

[5] BIS: 383-1970. Specifications for coarse and fine aggregates from natural sources for concrete, Bureau of Indian Standards, New Delhi, India

[6] BIS: 516-1959. Indian standard code of practice – methods of test for strength of concrete, Bureau of Indian Standards, New Delhi, India

[7] BIS: 5816-1999. Splitting tensile strength of concrete – test method, Bureau of Indian standards. New Delhi, India

[8] Eknath P. Salokhe D., "Application of foundry waste sand in the manufacture of concrete", IOSR-JMCE, ISSN: 2278-1684, 2005, 43-48.

[9] Fiore S, Zanetti MC. Foundry wastes reuse and recycling in concrete production.American Journal of Environmental Sciences3(3): 2007; 135–42.

[10] Guney, Yucel S, Yasin D; Yalcin M; TuncanA.Re-usage of waste foundry sand in high-strength concrete. Waste Management, Vol. 30, 2010, 1705–1713

[11] Johnny B, Taher L, Ellie F, "Utilization of recycled and waste materials in various construction applications", American Journal of Environmental Science, 9 (1), 2013, 14-24,

[12] IREDA-CII Report 2004

[13] Khatib JM, Ellis DJ. Mechanical properties of concrete containing foundry sand. ACI Special Publication;(SP-200). 2001. 733–48

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