DURABILITY OF CONCRETE MADE WITH WASTE FOUNDRY SAND: A REVIEW

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Abstract: Concrete is one of the most vital and common materials used in the construction field. The current area of research in the concrete was introducing waste foundry sand (WFS) in the ordinary concrete. Waste foundry sand is the by-product of metal casting industries which causes environmental problems because of its improper disposal. An experimental investigation was carried out on concrete containing waste foundry sand (WFS) in the range of 0%, 10%, 20%, 30%, and 40% by weight for M-40 grade concrete. Concrete was produced, tested and compared with conventional concrete in plastic state as well as in harden state for workability, compressive strength & split tensile strength. These tests were carried out on standard cube, cylinder for 7 , 28 and 91 days to determine the properties of concrete. Key words: Industrial Waste, Waste Foundry Sand (WFS), Eco friendly, Compressive Strength, Split Tensile Strength and Workability.

Introduction:

Foundry sand is the sand with uniform physical characteristics and it is high quality silica sand. It is a waste product of ferrous and nonferrous metal casting industries, at which the sand is used as a moulding material due to its thermal conductivity properties. The used foundry sand consists higher qualities than the regular sand used in filling construction sites. The sands are used to form the outer shape of the mould cavity. Basically, these sands depend upon a small amount of bentonite clay which is act as the binder material. Some chemical binders are also used by the foundries to form sand "cores". The internal passages for the molten metal is formed by sands cores inserted into the mould cavity. The casting is separated from the moulding after the metal has solidified. Moulding sands are recycled and reused multiple times in the casting process. Then a point comes where this sand can't be recycled to form moulds in casting process. Then this sand is replaced by the new sand and the process goes on again and again.

Literature view:

In recent studies it observed that with addition of WFS increases the water demand of fresh concrete when added as regular sand replacement (for the same slump values).

Prabhu et al. found no significant loss in workability up to 10% replacement but beyond this replacement level it started affecting the workability. This decrease in workability is probably due to the presence of water absorbing finer particles i.e. clay-type fine materials, ashes and impurities etc. in WFS, which are responsible for decreasing the fluidity of the fresh concrete and increasing the water demand. Increase in water demand results into increases the demand of superplasticizer.

Khatib et al. replaced fine aggregates in normal concrete by WFS in variable proportions (0%, 20%, 40%, 60%, 80% and 100%), reported a systematic loss in slump value from 200mm to zero. The slump value at 20%, 40%, 60% was 80%, 50% and 20% of slump value of concrete mix respectably.

Aggarwal and Siddique reported that there is an increase in water demand of concrete when WFS and bottom ash (BA) were added to concrete as partial replacement of ordinary sand, in equal proportions. Up to 60% replacement was studied and increase in water content by 4%, 6%, 10%, 16%, 22% and 36% of the initial value was required to maintain the slump level of all the mixes constant at 30 mm. Considerable loss in slump was observed with elapsed time as compared to the control concrete attributable to the generation of higher surface of hydration products due to higher fineness of WFA. A delay in initial and final setting times was observed, because very fine carbon particles existed in WFS and/or there was a loss of the link between aggregate and cement paste, causing a delay on cement hydration.

Sahmaran et al. explored the possibility of producing SCC with fly ash and WFS as a replacement of Portland cement with fly ash at different replacement levels. The replacement of fine aggregates with WFS was up to 100% by volume, wherein, they concluded that the SCC mix meets the EFNARC limits and no visible segregation or bleeding was observed in the SCC mix but beyond 50% replacement level of WFS the superplasticizer requirements were increased to achieve required slump flow etc.

Physical properties

Foundry sand is sub-angular to round in shape. Alike regular sand, WFS also mainly consists of silica but its silica content has been found lower than regular sand. Depending upon the industry sector from which it originates, type of casting process, type of additives used for moulding, number of times the sand is recycled, and type and amount of binder used, its physical and chemical characteristics may vary. About 85–90% of its particles are smaller than 100 mm. It is principally made up of sand which is evident from the particle size (0.05–2 mm) of WFS, obtained from 39 foundries, ranging from 76.6% to 100%, with a median of 90.3%. Since it is basically fine aggregate, so it can be expected to be used in many applications as substitute of natural sand. However, is too fine to be used as complete replacement of regular sand. Fineness modulus of WFS has been found in the range of 0.9–1.6 compared to 2.3–3.1 for normal sand. As per the particle size distribution of the foundry sand, the size corresponding to 50% of passing (d50) was around 33 mm and average diameter of foundry sand particle was observed to be 28.8 mm. The grain size distribution of WFS is very uniform, with approximately 85–95 percent of the material between 0.6 mm and 0.15 mm sieve sizes. While 5–12 percent of foundry sand can be expected to be smaller than 0.075 mm The particle shape is typically sub angular to round and it does not meet the gradation requirements for fine aggregates as per ASTM C33. Hence, only partial replacement with coarser sand is recommended to meet the standard specifications of fine aggregate.

Author	Naik et al.	Guney et al.	Siddique et al.	Naik et al.	Singh and Siddique	Prabhu et al.
Specific gravity	2.79	2.45	2.61	1.97	2.18	2.24
Density (kg/m^3)	1784		1638	1538		1576
Fineness modulus	2.32		1.78	1.32	1.89	
Water absorption (%)	5		1.3	3.20	0..42	1.13
Water absorption (%)	1.08	24	18	54.90	8	8
Moisture content (%)		3.25			0.11	
Clay lumps and friable particles	0.40		0.90		0.80	

Chemical composition:

Depending upon type of metal, type of binder and combustible used, the chemical composition of waste foundry sand may vary and it further influences its performance. Sands obtained from a single foundry, however, may not likely show significant variation over time; besides, blended sands produced by consortia of foundries often produce sands with consistently same composition. Waste foundry sand is rich in silica content and is coated with thin film of burnt carbon, dust and residual binder such as bentonite, sea coal or chemicals or resins. Due to presence of silica content it is hydrophilic owing to which it attracts water to its surface. Generally, silica content of WFS is lower than regular sand because of the presence of additives. Chemical composition of WFS as reported by various researchers is given in Table. Waste foundry sands from different foundry processing stages exhibit different physical and chemical properties. XRD analysis on WFS finer than 75 mm confirmed the presence of quartz and carbonates (calcite and dolomite) as well as montmorillonite.

Differential thermal analysis performed on two green WFS, collected from same Italian foundry, depicted different amounts of carbonaceous additive, about 2.8% in WFS from mould disposal and 5.1% in WFS from aspiration process during mould crush. The waste foundry sand having more carbon content showed more water absorption (5.4%) than the other having lesser carbon content (3.3%).

Chemical Composition of Waste Foundry Sand as reported by different authors.

Constituents	American Foudrymen's society	Etxeberria et al.	Sahmaran et al.	Basar et al.	Singh and Siddique	Singh and Siddique	Thaarrini et al.
SiO_2	87.91	84.94	76.0	81.85	83.8	87.48	83.93
$Al2O_3$	4.70	5.21	4.45	10.41	0.81	4.93	0.021
Fe_2O_3	0.94	3.32	5.06	1.82	5.39	1.31	0.950
CaO	0.14	0.58	3.56	1.21	1.42	0.22	1.03
MgO	0.30	0.67	1.98	1.97	0.86	0.18	1.77
SO_3	0.09	0.29		0.84	0.21	0.07	0.057
MnO		0.08	0.46		0.047		
TiO_2	0.15	0.19	0.17		0.22		
K_2O	0.25	0.97	1.20	0.494	1.14		
P_2O_5		0.05	0.04				
Na_2O	0.19	0.50	0.38	0.764	0.87		
LOI	5.15	2.87	5.85	6.93		5.81	2.19

Mechanical Properties

Tests conducted on WFS to check its strength and durability such as low Micro-Deval abrasion and magnesium sulphate soundness loss (ASTM C88-05) have shown good results, indicating good durability. Abrasion loss was found below 2% whereas; Magnesium sulphate soundness loss was within 5–15% . Javed and Lovell reported relatively high soundness loss, which may be due to the samples of bound sand loss and not a breakdown of individual sand particles . The angle of shearing resistance or internal friction angle of WFS has been found comparable to shearing resistance of normal sands i.e. between 33_ and 40_.

Management and risk evaluation

In foundry processes, sand from collapsed molds or cores can be reclaimed and then reused. Some new sand and binder is then added to maintain the quality of the casting and to make up for sand lost during normal operations

(Javed and Lovell, 1994). Foundry sand is produced by different foundry classes. The ferrous foundries (gray iron, ductile iron and steel) produce the most sand, and aluminium, copper, brass and bronze produce the rest. The sands from the brass, bronze and copper foundries are generally not reused. Little information is available regarding the amount of foundry sand that is used for purposes other than in-plant reclamation, but waste foundry sand has been used as a fine aggregate substitute in construction applications and as kiln feed in the manufacture of Portland cement. Most of the waste foundry sand from green sand operations is land-filled, sometimes being used as a supplemental cover.

Fiore and Zanetti (2007) studied the foundry sand reuse and recycling. They investigated the foundry sand of varying sizes. On the grounds of the gathered results, they concluded that residues may be divided into three categories according to the particle-size dimensions: below 0.1 mm, between 0.1 and 0.6 mm and above 0.6 mm. The fraction above 0.6 mm, mainly made of metallic iron, may be reused in the furnaces. The fraction between 0.1 mm and 0.6 mm may be reused in cores production, after a regeneration treatment. The fraction between 0.1 and 0.025 mm may be recycled as raw material for the concrete industry, and the below 0.025 mm fraction may be reused in green moulding operations. An economic evaluation of the proposed reuse and recycling solutions was performed.

Waste foundry sand in concrete

Several studies have been conducted on the use of WFS as partial and full replacement of fine aggregate in concrete. Although the sand used in foundries have very high percentage of silica but due to finer and unimodal particle size, the increase in WFS content in concrete beyond a certain level leads to negative effects on concrete. The presence of additives as impurities also causes negative effects on the properties in fresh state as well as hardened state of concrete.

Conclusion

The present work investigated the influence of UFS as a partial replacement of fine aggregate in the production of concrete. On the basis of the test results the following conclusions are drawn.

1. Compressive strength, splitting-tensile strength, flexural strength and modulus of elasticity of concrete mixtures increased with the increase in replacement of UFS up to 20 wt%.

2. Concrete mixes having UFS above 20 wt% showed higher durability properties like ultra sonic pulse velocity, rapid chloride penetration, water absorption and abrasion resistance than that of concrete mixes without the replacement.

3. The mechanical, durability and micro structural properties test results obtain with 20 wt% replacement of UFS were comparatively higher than the other mixes.

4. Experimental results shown that the UFS can be effectively utilized for replacing river sand in concrete without affecting the concrete properties.

5. Some studies have shown improvement in microstructure of concrete up to 50% WFS level. Large C-S-H gel formation was found up to 30% substitution. Beyond that C-S-H formation was low but number of pores was reduced, which increased strength. Concrete with 100% substitution have shown strength as nearly 50% of control concrete.

6. Shrinkage rate of WFS mixes was found higher at initial age of concrete but leveled out to other concretes after 28 days. Modulus of elasticity of concretes with WFS was found similar to compressive strength results. Upto 30% WFS level, improvements in modulus of elasticity have been reported.

7. Improvement in abrasion resistance of concrete with WFS is reported attributable to dense matrix due to addition of fine WFS.

8. Waste foundry sand addition had positive influence on sulphate resistance of concrete at up to 30% replacement ratio. At higher substitution the resistance degraded which is attributed to traces of SO3 present in WFS. Similarly beyond 30% substitution led to increase in carbonation depth in concrete with WFS which is attributed to poor workability which led to poor compaction.

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