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## STRENGTH BEHAVIOUR OF CONCRETE USING FOUNDRY SAND AS AGGREGATE

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### ABSTRACT

The indiscriminate dumping of used foundry sand has led to environmental pollution and unwarranted occupation of space by this waste product. Since the trend all over the world now is the preservation of natural environment from pollutant. This paper has looked at the best and effective way of managing the waste foundry sand. Physical and chemical test were carried out on samples of foundry sand, to know its usefulness as alternative aggregate in concrete. Fine aggregate in concrete was partially replaced with foundry sand at 0%, 25%, 50%, 75%, and 100%. Compressive tests were carried out on sixty samples of concrete cubes of dimension 150 mm x 150 mm x 150 mm. each twelve samples was used for each aggregate composition. The pure aggregate gave a 28 days concrete strength of 20.79 N/mm<sup>2</sup>, while 25% foundry gave 19.62 N/mm<sup>2</sup>, other samples gave results that were very poor due to the presence of large clay particles. Foundry sand can be applied to fine aggregate in concrete up to 25% inclusion.

**Keywords:** Foundry sand, Clay particles, Concrete, Pollutant.

### INTRODUCTION

The recycling of waste materials for engineering purposes is gradually becoming popular, the use of materials such as snail shell, periwinkle, slag, slates, has become popular especially in concrete. Sada *et al* (2013), investigated the use of ground nut shell as partial replacement of fine aggregate in concrete, and concluded that the ground-nut shell can be use in lightweight concrete. A foundry is a manufacturing facility that produces metal castings by pouring molten metal into a preformed mould to yield the resulting hardened cast (Hein *et al*, 1975). Foundry sand is a high-quality silica sand that is used to form moulds for ferrous (iron and steel) and nonferrous (copper, aluminum, brass, etc.) metal castings. The raw sand is normally of higher quality than

typical bank run or natural sands used in construction (FHWA, 2004). The most common casting process used in the foundry industry is the sand cast system. Virtually all sand cast moulds for ferrous castings are of the green sand type. Green sand consists of high-quality silica sand, about 5-10 percent bentonite clay (as the binder), 2 to 5 percent water and about 5 percent sea coal (a carbonaceous mould additive to improve casting finish) (Winkler and BoI'Shakov, 2000). The term "green sand" is used because molten metal is poured into the mould when the sand is damp or "green"(Abichou et al 2004). The green sand process constitutes upwards of 90 percent of the molding materials used (AFS, 1991).

In addition to green sand moulds, chemically

bonded sand cast systems are also used. These systems involve the use of one or more organic binders (usually proprietary) in conjunction with catalysts and different hardening/setting procedures. Chemical binders include phenolic, furfuryl alcohol, and other inorganic binders (Winkler and Bol'Shakov, 2000). Foundry sand makes up about 97 percent of this mixture. Chemically bonded systems are most often used for "cores" (used to produce cavities that are not practical to produce by normal molding operations) and for moulds for nonferrous castings. Excess foundry sand is typically generated because varying amounts of the previously mentioned additives must continually be reintroduced to the foundry sand to maintain its desired properties, resulting in a larger volume of sand than is needed for the foundry process (Goodhue *et al*, 2001). In addition, heat and mechanical abrasion eventually render the sand unsuitable for use in casting moulds, and a portion of the sand is continuously removed and replaced with virgin sand. The spent sand is either recycled in a non-foundry application or land filling. Out of the 6 to 10 million tons of spent foundry sand generated annually, less than 15 percent is recycled (U.S EPA, 2007). The automotive industries and its parts are the major generators of foundry sand. Foundries purchase high quality size-specific silica sands for use in their moulding and casting operations. The basic processes in a typical foundry include core making, moulding, melting, pouring, cleaning and inspection. Core making and moulding usually produce 75% of the various by-products generated by foundries. The remaining is generated mainly by melting operations with minor contributions from cleaning and dust collectors. Typical amounts of total by-products materials from foundries range between 227 to 2270

kg (500 to 5000 pounds) per ton of produced metal castings (Hein *et al*, 1975).

Sand is used to make moulds for multiple reasons because it can easily withstand the heat of molten metal, it does not chemically react with the metal and it is permeable enough to allow gases to escape when the molten metal is poured. Sand is also the principal moulding material in the foundry shop where it is used for all types of casting, ferrous and non-ferrous alike (Olawale *et al*, 2011). Moulding sand is compacted and shaped according to the pattern that is going to be produced. This moulding sand is typically called "green" sand. Green sands are composed of three major ingredients: silica sand, clay, and water. Silica sand comprises the majority of the materials in a moulding (Jain, 2003). The sand used for metal casting can be repeatedly recycled, crushed down to a raw sand material and used again for casting (especially in foundries that use green sand). However, at a certain point, old foundry sand degrades and become unsuitable for further recycling within the foundry. At this point, it is discarded as a foundry by-product and new sand is used for the casting process and the cycle begins again (Siddique *et al*, 2009). Although there are other casting methods used, including die casting and permanent mould casting, sand casting is by far the most prevalent mould casting technique. Sand is used in two different ways in metal castings as a moulding material, which focuses the external shape of the cast part and as cores that form internal void spaces in products such as engine blocks. Since sand grains do not naturally adhere to each other so binders must be introduced to cause the sand to stick together and hold its shape during the introduction of molten metal into mould and cooling of casting. According to the United States department of Transport,

Foundry sand has been used in fills and embankments, road bases, hot mix asphalts, flow able fills and in the manufacture of some Portland cement type (FHWA 2004).

***Chemical composition of foundry sand***

Chemical composition of the foundry sand relates directly to the metal moulded at the foundry. Spent foundry sand consists primarily of silica sand, coated with a thin film of burnt carbon and residual binder (bentonite, sea coal, resins, etc.). Silica sand is hydrophilic and consequently attracts water to its surface. Depending on the binder and type of metal being cast, the pH of spent foundry sand can vary from approximately 4 to 8. It has been reported that some spent foundry sands can be corrosive to metals, (Emery, 1992) which can cause the deterioration of metal objects such as underground pipes, culverts, or reinforcing members. The presence of high acidity, pH of 5.5 or less, in soil is also considered a corrosive condition. Soil with a pH of 5.5 or less can react with the lime in concrete to form soluble reaction products that can easily leach out of the concrete. The result is a more porous, weaker concrete (Cal Trans, 2003).

Few peer-reviewed studies have been conducted to determine organic residues in spent foundry sand or the leachates produced from spent foundry sand. Laboratory studies indicate that organic compounds leach only at low concentrations (Winkler and Bol'Shakov, 2000). With the presence

of phenols in chemically bonded foundry sands, there is a possibility that leachate from stockpiles could result in phenol discharges (Emery, 1992), (Ham *et al*, 1989). Because of the high temperatures encountered during the molding process, residual organic compounds in spent foundry sands are found only in small quantities. Therefore, spent sand after casting typically does not contain organic contaminants above regulatory threshold levels; however, fresh casting mixtures and core sand that have not been in contact with hot metal may contain organic contaminants (Winkler and Bol'Shakov, 2000).

Foundry sand is one of the voluminous by-products from the foundry that are disposed off in landfills. This creates a serious solid waste management problem, mainly due to large amount of foundry sand produced worldwide. Space for waste storage on site is also limited, depending on production and the quantities generated. The waste may exceed the volume of storage facilities which can often constitute an obstacle to production. It is therefore necessary to investigate alternative outlet for the spent foundry sand, instead of land filling and stock piling. As foundry sand is basically a fine aggregate, it is reasonable to anticipate that it could be used in many of the application where natural sand are used. This would have additional advantage of natural aggregate been conserved due to substitution of primary natural sand with foundry sand, especially in concrete production.



**Figure 1: Foundry Sand Sample**

The construction industries rely heavily on conventional materials such as cement, granite and sand for the production of concrete. The high and increasing cost of these materials has greatly hindered the development of shelter and other infrastructural facilities in developing countries. There arises the need for engineering considerations for the use of cheaper and locally available materials to meet desired need to enhance self efficiency and lead to an overall reduction in construction cost for sustainable development (Olutoge, 2010).

## **MATERIALS AND EXPERIMENTAL METHOD**

### ***Sieve analysis***

The particle size distribution of the foundry sand was determined and compared with the particle size distribution of the natural sand. A sieve analysis test is a procedure to separate fine material from coarse material by means of a series of woven or perforated surfaces. The proportions of different size particles were recorded. A typical sieve analysis involves a nested column of sieves with

wire mesh cloth (screen). A representative weighed sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above, at the base is a round pan called the receiver.

### ***Chemical Analysis***

Chemical analysis was carried out on the foundry sand to determine both heavy and light metals that are present in the foundry sand. Dried sample of Foundry sand were sieved to 0.5mm. The samples were put in a conical flask. 0.5ml of concentrated sulphuric acid, Perchloric acid and 10ml of concentrated nitric acid were added to the sample in the conical flask. The mixture was heated to make the samples to release their metals into the acid solution. The heated mixture was allowed to cool and filtered into plastic bottles by filter paper; it was mixed with 100ml of distilled water. The digested soil sample was tested by Atomic Absorption Spectrophotometer (Type: S4 AA system, NC 9423 400 30042, made by Thermo scien-

tific) to obtain the actual metals that were present in the Foundry sand.

#### **Preparation of Test Specimen**

Fine aggregate was replaced by foundry sand in the ratio: 0%, 25%, 50%, 75%, and 100%. Where the 0% represents the control sample which consists of only cement, fine aggregate and coarse aggregate in the ratio 1: 2: 4. Each sample has twelve cubes, making a total of 60 cubes. The foundry sand was obtained from some foundry industry in Otta, Ogun State, Nigeria.

The batching of concrete test samples was by weight in order to eliminate errors due to variation in the proportion of voids contained in a specified weight, in conformity with BS 8110 (1997), the mix proportion was 1:2:4 by weight of cement, fine aggregate, coarse aggregate and the water-cement ratio by weight of 0.65, crushed granite aggregate with maximum size of 12.5mm was mixed with the sand-cement mixture.

#### **Curing**

This was done according to BS 1881; part 111 (1983), the cubes were immersed inside water trough such that the cubes were completely covered with water. On each testing day, the test sample was brought out of the trough and allowed to dry a bit before the weight was determined.

#### **Cube test (compressive strength test)**

The crushing of the concrete cube was done in the Civil Engineering soil mechanics laboratory of the Federal University of

Agriculture, Abeokuta, using a compressive strength machine (CN370, 2000kN, made by Impact test equipment). The cubes were taken out from the water, allowed to drain and the weights of the cubes were measured. The weighed cubes were placed in the compressive strength machine in which the load was applied at the rate of 6.80KN/s and the crushing load at which the cubes failed were recorded. The crushing was done for 7, 14, 21 and 28 days. The results are showed in Figure 3.

## **RESULTS AND DISCUSSIONS**

#### **Sieve Analysis of foundry and Sharp sands**

The results for the particle size distribution of foundry sand and natural sharp sand are shown in Figure 2. It indicates the different amount of foundry sand that passes through and retained on each sieve size. The percentage passing through sieve size 4.75mm, 2.36mm and 150µm falls within coarse, medium and fine sands while that of 1.18mm, 600µm and 300µm are within the silt and clay range. It can be observed that foundry sand contains 80.20% fine sand, 12.98% medium sand and 7.12% coarse sand. The fineness modulus is lower than the minimum requirement this is due to the very high fine sand in foundry sand which reduces the concrete strength. The result also shows that sharp sand contains 32.78% fine sand, 62.06% medium sand and 5.16% coarse sand. The fineness modulus is within the range Specified by ASTHO and Unified soil classification standards for fine aggregate in concrete.

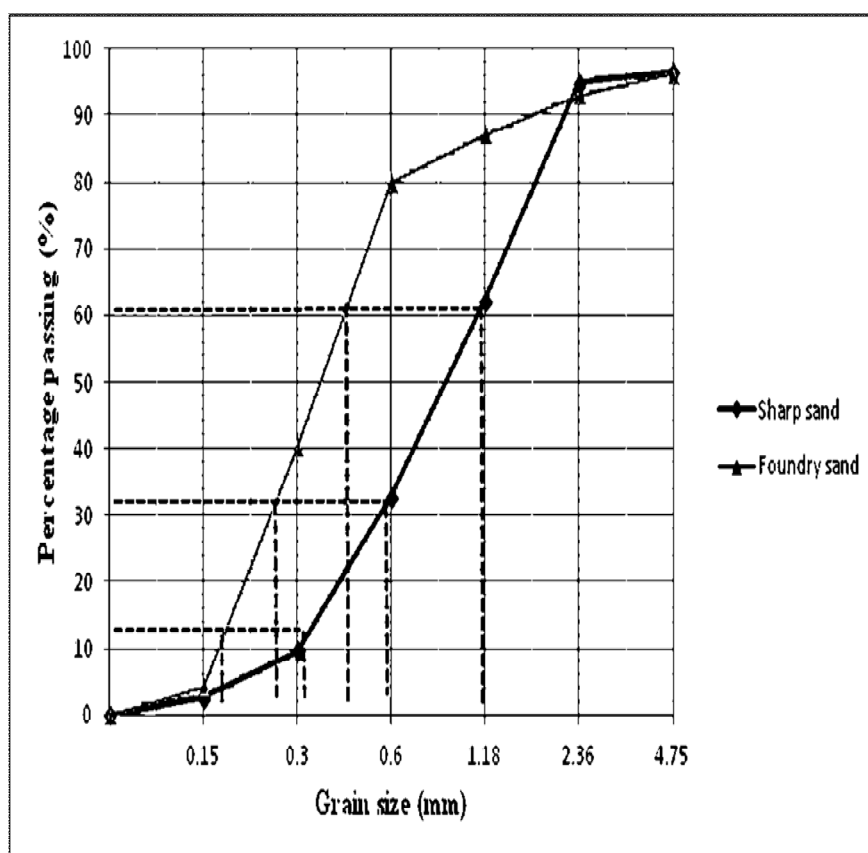


Figure 2: Particle Size Distribution of Foundry and Sharp Sand

### Chemical Analysis Results

It can be observed From Table 1, that Foundry sand contains high concentration of Iron while Calcium, Manganese and Zinc were present in low concentration. Copper, Chromium and Cadmium were not detected in the foundry sand sample. Lead, Sodium and Potassium were also present in the Sample. The table also showed that Sharp sand contains high concentration of Iron

while Calcium, Manganese and Zinc were present in low concentration. Copper, Chromium and Cadmium were not detected in the sharp sand sample. Lead, Sodium and Potassium were also present in the Sample. The concentration of all the metals present in foundry sand is generally higher than that of sharp sand; this confirms the pollution of the natural sand with heavy metals through the activities of the foundry industry.

**Table 1: Chemical Composition of Foundry Sand and Sharp Sand**

Constituents	Symbol	Foundry sand (mg/l)	Sharp sand (mg/l)
Lead	Pb	322.50	75.50
Zinc	Zn	37.50	9.50
Copper	Cu	Not detected	Not detected
Manganese	Mn	10.00	56.00
Iron	Fe	9063.00	1900.00
Sodium	Na	592.50	276.50
Chromium	Cr	Not detected	Not detected
Potassium	K	598.50	395.00
Cadmium	Cd	Not detected	Not detected
Calcium	Ca	5.00	11.50
Magnesium	Mg	130.00	30.00

**Compressive strength of sand samples**

The development of compressive strength of concrete with days is showed in Figure 3. It indicates the different amount of foundry sand that were added as it affects the strength of the concrete. The increase in strength was substantial as the curing days increases, while the concrete compressive strength decreases as the percentage of foundry sand increases. The compressive strength of the concrete specimens is reciprocal to the percentage of foundry sand added. The 0% foundry sand attained the maximum strength; the reduction in strength of concrete as a result of increment in the addition of foundry sand could be attributed to the fact that foundry sand is poorly graded and contains clay used as a binder. The fact that poorly graded soil contain more void, as the percentage of foundry sand increases there is a corresponding increase in void which lower the density of the concrete. As a result, compressive

strength will also decrease with increase in voids.

Furthermore, it was observed that the mixture with 25% of foundry sand is higher than the compressive strength of 100% foundry sand. The compressive strength of mixture with 0% foundry sand is slightly higher than mixture with 25% foundry sand.

Figure 3, showed the compressive strength ratio at 7, 14, 21 and 28 days with respect to percentage replacement of sharp sand with foundry sand. Compressive strength at 7days for 0%, 25%, 50%, 75 % and 100% was 10 N/mm<sup>2</sup>, 9.97 N/mm<sup>2</sup>, 7.50 N/mm<sup>2</sup>, 6.60 N/mm<sup>2</sup>, and 4.94 N/mm<sup>2</sup> respectively. At 14days for 0%, 25%, 50%, 75% and 100%, the compressive strength were, 13.00 N/mm<sup>2</sup>, 12.00 N/mm<sup>2</sup>, 9.50 N/mm<sup>2</sup>, 8.08 N/mm<sup>2</sup>, and 6.51 N/mm<sup>2</sup> respectively. The result at 21days for 0%, 25%, 50%, 75% and 100% were 18.05 N/mm<sup>2</sup>, 16.52 N/mm<sup>2</sup>,

11.52 N/mm<sup>2</sup>, 10.08 N/mm<sup>2</sup>, and 9.34 N/mm<sup>2</sup> respectively. While 20.79 N/mm<sup>2</sup>, 19.62 N/mm<sup>2</sup>, 14.57 N/mm<sup>2</sup>, 11.97 N/mm<sup>2</sup>, and 10.23 N/mm<sup>2</sup>, were the compressive strength at 0%, 25%, 50%, 75%, and 100% at 28 days respectively. This implies that the Compressive strength at various percentage of foundry sand replacement

increases with age but lower when compare with the compressive strength of the ordinary mix, the trend of these results confirms that the presence of high fine sand in the foundry sand reduces the bonding strength within the concrete matrix, hence the reduction in strength.

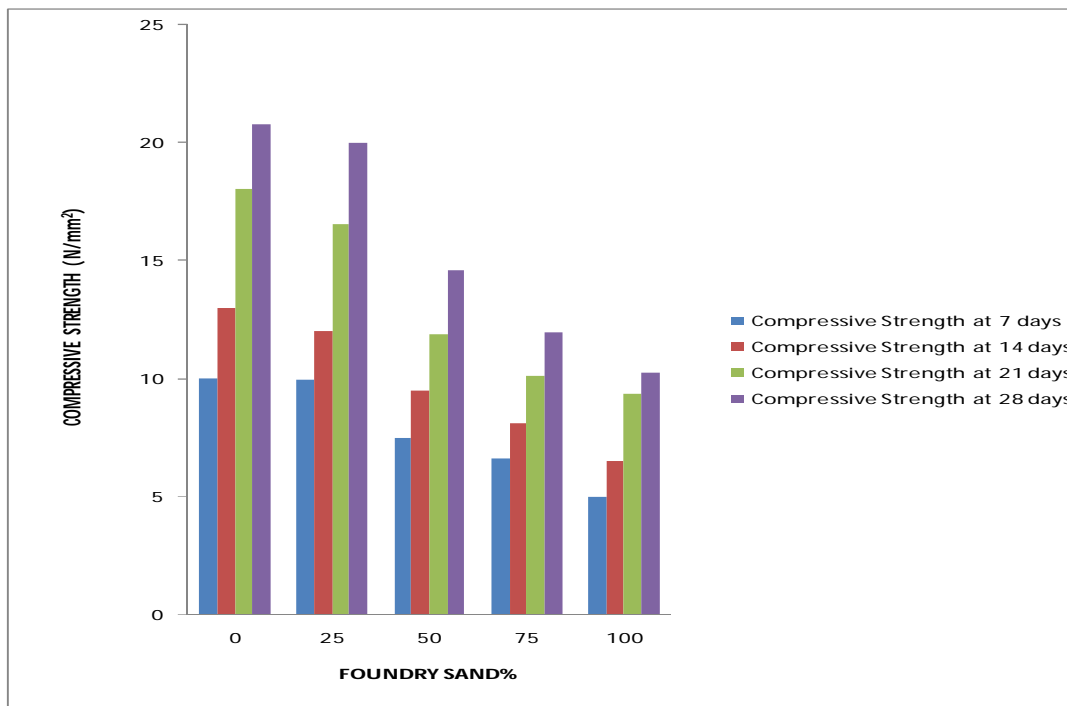


Figure 3: Compressive Strength Test Variation With Days

### CONCLUSIONS

From the results of the tests carried out, foundry sand is uniform but poorly graded, which indicated that it contains more void space. The compressive strength of concrete decreases as the percentage of foundry sand increases, an increase in strength was observed with increase in age for each replacement level of fine aggregate with foundry sand. The 25% foundry sand is the ideal percentage of foundry sand, which is in the boundary limit of the production of

high strength concrete. The 50%, 75% and 100% foundry sand replacement produced low strength concrete, which indicates that the compressive strength of foundry sand concrete samples is dependent on the amount of foundry sand aggregate in the sample, and the low strength can be attributed to the presence of clay materials in the foundry sand. The fineness modulus of foundry sand is not within the allowed limit provided by ASTM C33, which also contributed to the low strength observed. The



heavy and light metals present in foundry sand and sharp sand is the same but differ quantitatively but this has no effect on the compressive strength of concrete produced from foundry sand. Foundry sand can be safely used as partial replacement of fine aggregate in concrete at 25% level without any problem, and this will help solve the problem of inadequate disposal methods that are currently in use at the various foundry industries.

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