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Properties of Self-Compacting Concrete Incorporating Waste Foundry Sand

Yogeshwar Kashyap¹, Dr. Rajwinder Singh Bansal², Arun Verma³

Department of Civil Engineering, Ramgarhia Group of Institutes (Ramgarhia Institute of Engineering and Technology, Phagwara, India¹

Head of Department, Department of Civil Engineering, Ramgarhia Group of Institutes (Ramgarhia Institute of Engineering and Technology, Phagwara, India²

Assistant Professor, Department of Civil Engineering, Ramgarhia Group of Institutes (Ramgarhia Institute of Engineering and Technology, Phagwara, India³

ABSTRACT: The need of concrete is increasing every year as the population of humans are increasing as per their demands i.e. infrastructure developments and shifting composition etc. Due to rising demands and fight to produce good quality of concrete, construction industries have overused the natural materials used in concrete, leads us to extinction in natural materials and results in rising prices of materials. Thus, the environmental problems related with excessive extraction and mining from natural sources have been reported in many countries. Due to finite availability of natural materials, and involvement of economy, it has now become very important to look as for the alternative source for natural materials used in concrete i.e. gravels and natural sand. Waste foundry sand (WFS) is a propitious material that can be used as an alternative for the natural sand i.e. (fine aggregates) in concrete. The thesis demonstrates the potential of re-use for waste foundry sand i.e. industrial by-product as a substitute of a fine aggregate in concrete. The fine aggregates i.e. (natural sand) are replaced with WFS in six different substitution rates i.e. (2.5%, 5%, 7.5%, 10%, 12.5% and 15%). Several tests were performed to examine the mechanical properties i.e. (compressive strength, flexural strength and splitting tensile strength) as well as the durability of concrete i.e. (sulphate resistance). The results indicate that the compressive strength was increased from 3.93%–9.3%, splitting tensile strength increased from 4.8%–11.37%, flexural strength increased from 3.81% -12.27% for 2.5%-5% replacement levels of waste foundry sand with fine aggregates in concrete and after that there is a systematic decrement in strength as the percentage goes on increasing at curing age of 28 days. The strength in Sulphate resistance test was increased up to percentage level of 10% with natural sand as a fine aggregate in concrete and after that there is a systematic decrement in strength. From following results, it was concluded that 10% WFS replacement level of WFS with fine aggregate in concrete can be effectively used to make concrete and various application of concrete i.e. (concrete paver blocks) and beyond 10% WFS replacement level is not beneficial.

KEYWORDS: Waste foundry sand, materials, concrete, natural sand.

I. INTRODUCTION

Foundry sand is a by-product from the production of both ferrous and nonferrous metal castings. Foundry sands can have properties desirable for use in the technology of substituting fine aggregates in applications such as; structural fills or embankments, road base or sub base, hot mix asphalt (Odeyemi et al. 2015), flowable fills and manufacture of Portland cement (Goodhue et al. 2001, FIRST 2004). In foundry industries, the process of metal casting requires the use of high-quality silica sands mixed with bentonite clay and water to make the outside shell of the mould cavity into which molten metal is poured (Gedik et al. 2008). Since metal casting has to be done at high temperature, sands are chosen as the mould cavity material because they have desirable characteristics. These include readiness to bond with clay, and high refractory nature, ability to retain mould shape during packing and pouring, permeability for the gases liberated from the mould and solidifying metal as well as ability of the sand to be shaken out (Bakis et al. 2006).

Excess foundry sand is generated since varying amounts of fresh sand, water and clay must be continually added to maintain the desired characteristics. This results to a larger volume of sand than is required for the foundry process (Goodhue et al. 2001). The excess sand is considered as waste because after repeated use under heat, the particles



become degraded and cannot be used for the moulding process (ReTAP 1996). However, the fact that this sand can no longer be used for moulding does not render it completely useless, as it can find use in non-foundry applications. These include embankments/structural fills, road base/sub base, hot mix asphalt (HMA), flowable fills, soil/horticultural, cement and concrete products as well as traction control (FIRST 2004) Since making of road bases is one of the non-foundry applications of Waste Foundry Sand (WFS), its reuse as aggregate in making concrete paving blocks has been identified for the present study. Concrete paver blocks are commonly installed as the base course of rigid pavements, footpaths, passenger waiting shades, bus stops, industrial parks and public places in the urban areas. Radhikesh et al. (2010) define concrete paving blocks as precast solid products made out of cement concrete, in various sizes and such shapes as rectangular, square, and round blocks of different dimensions with designs for interlocking of adjacent paving blocks. Aggregates form about 70-80% of the concrete constituents in the construction of both rigid and flexible pavements (Roberts et al. 1996, Waziri et al. 2011). Evidently, the proportion of aggregates in concrete is the highest of all the constituents. Therefore, abundant supply of aggregates is required for concrete applications, thus the need to explore the use of industrial waste products, including WFS as additional sources of fine aggregates. More so, the reuse of WFS has not been employed in Kenya yet. The selected industries, from which the present

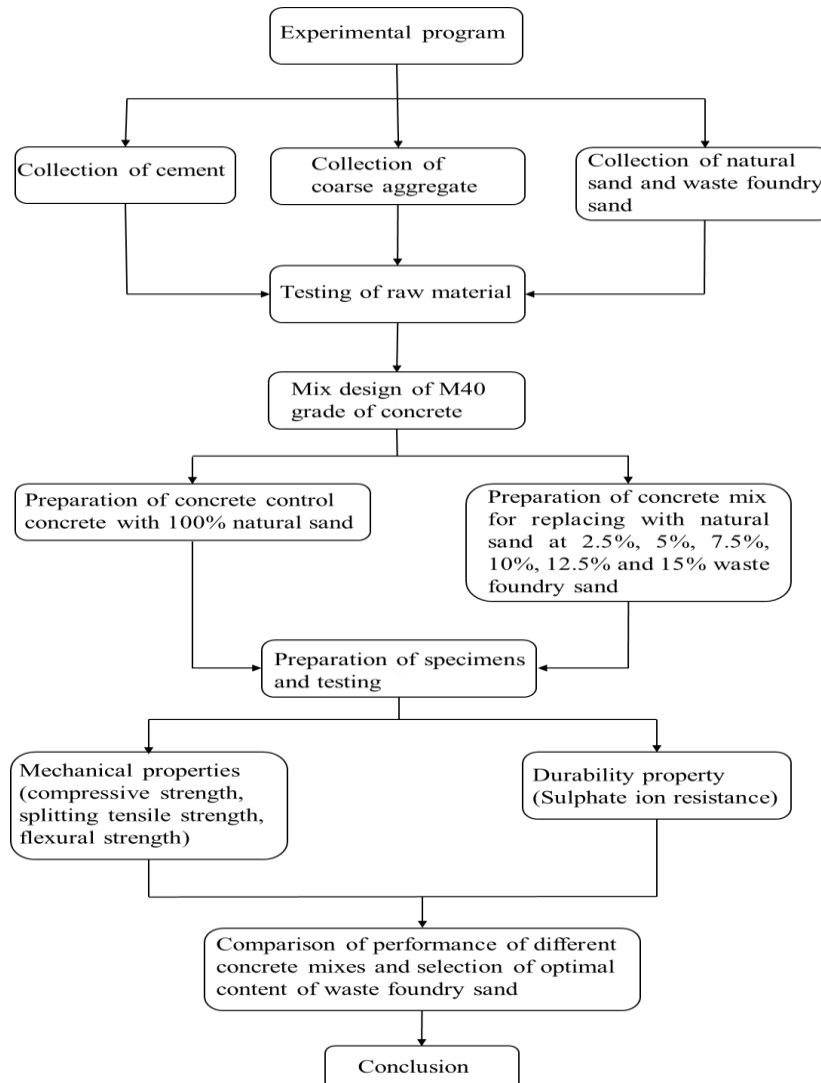
II. SIGNIFICANCE OF THE STUDY

This study seeks to evaluate the use of waste foundry sand which is an industrial byproduct that needs to be recovered with urgency. Foundry sand can be resourceful as a substitute or supplement for natural sand which is becoming scarce by the day. There is a high demand for pavements in urban areas but the availability of sand for their construction is limited. Therefore, the results of this study can be of benefit to the construction industry because the use of WFS as fine aggregate will offer a cheaper and convenient alternative as the material source will be close to the construction site in urban areas, where most foundry industries are located. This will in turn help reduce the negative impacts related to energy use, resource exploitation and environmental pollution. With the understanding that there is a rapid increase in the Kenyan population and the world at large, there is a consequent need for Moreland and better infrastructure. Therefore, the use of the existing resources needs more prudent planning so as to avoid a scenario where the future generations are not able to meet their needs. So, the practice of resource conservation has to start now.

III. OBJECTIVES OF THE STUDY

- To determine the chemical composition of waste foundry sand generated from selected foundry industries in Nairobi.
- To assess the physical properties of waste foundry sand from various foundry industries in Nairobi.
- To evaluate the optimum percentage replacement of waste foundry sand as fine aggregate in concrete for paving blocks.

IV. METHODOLOGY



The effect of using waste foundry sand containing concrete was investigated at various percentages as partial replacement with fine aggregates. Also, effect on durability and mechanical properties in concrete containing waste foundry sand.

- **CEMENT** - Portland pozzolana cement (PCC) was used which was conformed as per IS 1489-Part- 1, the various physical properties of cement are initial and final setting time, specific gravity, standard consistency, and fineness which are evaluated by the following procedure given in IS 1489-Part- 1.



Fig a) Portland pozzolana cement (PCC)

- **NATURAL SAND-** The material was locally available with 4.75 mm is the nominal maximum size of the fine aggregates. The fine aggregates were tested as per BIS: 383–1970. Specific gravity, fineness modulus, water absorption and sieve analysis were determined by BIS: 383–1970.



Fig (b): Natural sand

- **COARSE AGGREGATES-** The material was locally available with 4.75 mm is the nominal maximum size of the fine aggregates. The fine aggregates were tested as per BIS: 383–1970[83]. Specific gravity and water absorption were determined by BIS: 383–1970[83].



Fig (c) Coarse aggregates

- **WASTE FOUNDRY SAND-** The Waste foundry sand was collected in bags from caste iron foundry in Batala, Jalandhar (Punjab). Waste foundry sand was tested according to BIS: 383–1970[83]. Specific gravity, fineness modulus, water absorption and sieve analysis were determined by BIS: 383– 1970[83].



Fig (d) Waste foundry sand

SUPER PLASTICIZER- Super plasticizer is also defined as water reducer and these are used in making or production for high grade concrete. Super plasticizers reduce 30% of water content in concrete and it decelerate the curing time of concrete. They effectively improve the performance of fresh past of concrete.



Fig (e) Super plasticizer

- **MAGNESIUM SULPHATE**- The magnesium sulphate powder was collected from nearby chemist shop. It is the admixture which is based on polycarboxylic ether.



Fig (f) Magnesium sulphate

- **WATER**- Water is very important material that helps in achieving the required strength in concrete. In the essential process of hydration, it requires almost $3/10^{\text{th}}$ of its water weight. If water is not properly used in concrete as per required in design, it can negatively affect the structure made by concrete. If water is used in less amount it can affect the workability which can further affect the mechanical and durability properties in concrete and if it is used in more amount it can cause bleeding and segregation in the structure of concrete. Water ranging between 6-9 is fit for drinking and can be used in concrete.

- **MIX PROPORTION**- Control mixture (M-1) of concrete was designed according to Standard Specifications BIS: 10262-1982[84] and BIS 456-2000 to have 40 MPa compressive strength of 28 days of curing ages. Additional concrete mixtures (M-2, M-3, M-4, M-5, M-6 and M-7) were designed by replacing waste foundry sand at several percentages (2.5%, 5%, 7.5%, 10%, 12.5% and 15%) by weight with fine aggregates. The water cement ratio is kept constant for all designed concrete mixtures. The mix proportion for all concrete mixtures are given in table no.1



Fig (g) Addition of waste foundry sand in concrete mix

Table 1: Mix design of concrete mix for M40 grade containing waste foundry sand

Mix no.	M-1	M-2	M-3	M-4	M-5	M-6	M-7
Cement (kg/m^3)	398.57	398.57	398.57	398.57	398.57	398.57	398.57
Waste foundry sand (%)	0	2.5	5	7.5	10	12.5	15
Waste foundry sand (kg/m^3)	0	21.16	42.34	63.51	84.68	105.85	127.02
Sand (kg/m^3)	850	828.75	807.5	786.25	765	743.75	722.5
W/C	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Water (kg/m^3)	139.5	139.5	139.5	139.5	139.5	139.5	139.5
Coarse aggregates (kg/m^3)	1081.836	1081.836	1081.836	1081.836	1081.836	1081.836	1081.836



V. TESTING PROCEDURE

After curing ages of required time period, the samples were taken out from curing tank and then the surface of each samples are wiped off. All samples tests for compressive strength and flexural strength were performed as per Indian Standard Specifications BIS: 516–1959[85] in which cubes and beams size was kept 150x150x150mm and 100x100x500mm. All samples tests for split tensile strength were performed as per Indian Standard Specifications BIS: 5816– 1999[86] in which cylinders size were kept 150x300mm and Sulphate resistance test for samples were performed as per ASTM C452-06 in which cubes size were kept 150x150x150 mm. The compressive, splitting and flexural testing of samples was done after 7, 28 and 56 days of curing age and sulphate ion resistance testing for samples was done after 14 and 28 days of curing age.

In this work the sulphate resistance test was conducted by immersing samples in 7% of magnesium sulphate for 14 and 28 days of curing age. The samples before immersion in magnesium sulphate was kept 28 days of curing age at normal temperature in water and then compressive strength is conducted on these samples.

VI. RESULT AND DISCUSSION

The present investigation is on the study of effective use of waste foundry sand as a partial replacement by regular sand as a fine aggregate in concrete. Mechanical i.e. (compressive strength, splitting tensile strength and flexural strength) and durability properties i.e. sulphate resistance) of concrete were checked by replacing waste foundry sand at several percentages i.e. (0%, 2.5%, 5%, 7.5%, 10%, 12.5% and 15%) with natural sand in concrete. Test results in this investigation indicates that industrial by-product i.e. waste foundry sand is suitable and can be used in concrete as a substitute for regular sand in concrete

VII. CONCLUSION

The reuse of waste foundry sand as a substitute with fine aggregates for production of concrete up to certain percentage in this research is based on to evaluate the mechanical and durability properties of concrete. The extensive tests are carried out on seven mix and following conclusion based on these tests have been made.

- a. The inclusion of waste foundry sand with fine aggregates in concrete enhance the strength properties with increasing content of WFS up to certain replacement level and further the strength properties also improved with the increase in curing age.
- b. Compressive strength of concrete increased from 3.93%–9.3% and after that there is a systematic decrease in strength, splitting tensile strength of concrete increased from 4.8 %– 11.37% and after that there is systematic decrease in strength, flexural strength of concrete increased from 3.81%–12.27% and after that there is systematic decrease in strength at 28 day of curing age.
- c. The maximum strength was observed at 5% WFS of inclusion with fine aggregates in concrete at all curing ages in mechanical properties i.e. (compressive strength, splitting tensile strength and flexural strength). The increment in strength can be observed because WFS contains silica content in high amount which helps in the formation of C-S-H gel and this is due to the packing behavior of matrix particles.
- d. The sulphate resistance test was done on concrete mixture containing waste foundry sand and observed that 10% of WFS replacement level gives the maximum compressive strength value
- e. i.e. 51.73 MPa for 28 days of curing age. The increment in strength is because of the waste foundry sand that increases the strength of magnesium sulphate due to presence of traces of Sulphur (SO_3) in it which causes deterioration in concrete and enhances the ettringite formation.
- f. The maximum values were observed for 5% of WFS replacement level containing concrete for all tests of mechanical properties and 10% of WFS replacement level in concrete level gives the maximum value for the sulphate resistance test in concrete.
- g. From following observation, it was observed that 10% of waste foundry sand replacement level can be successfully used to make concrete and in various applications of concrete like concrete paver blocks, whereas beyond this replacement level is not beneficial.

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