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Effect of waste foundry sand (WFS) as partial replacement of sand on the strength, ultrasonic pulse velocity and permeability of concrete

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ABSTRACT

Ferrous and non ferrous metal casting industries produce several millions tons of byproduct in the world. In India, approximately 2 million tons of waste foundry sand is produced yearly. WFS is major byproduct of metal casting industry and successfully used as a land filling material for many years. But use of waste foundry sand (WFS) for land filling is becoming a problem due to rapid increase in disposal cost. In an effort to use the WFS in large volume, research has being carried out for its possible large scale utilization in making concrete as partial replacement of fine aggregate.

This experimental investigation was performed to evaluate the strength and durability properties of concrete mixtures, in which natural sand was partial replaced with (WFS). Natural sand was replaced with five percentage (0%, 5%, 10%, 15%, and 20%) of WFS by weight. A total of five concrete mix proportions (M-1, M-2, M-3, M-4 and M-5) with and without WFS were developed. Compression test and splitting tensile strength test were carried out to evaluate the strength properties of concrete at the age of 7, 28 and 91 days. Modulus of elasticity and ultrasonic pulse velocity test were conducted at the age of 28 and 91 days. In case of durability property, Rapid Chloride Permeability test was performed on all five mix proportion at the age of 28 and 91 days. Test result indicate a marginal increase in strength and durability properties of plain concrete by inclusion of WFS as a partial replacement of fine aggregate.

1. Introduction

Foundry industry produced a large amount of by-product material during casting process. The ferrous metal casts in foundry are cast iron and steel, non ferrous metal are aluminum, copper, brass and bronze. Over 70% of the total by-product material consists of sand because moulds consist usually of moulding sand, which is easily available, inexpensive, resistance to heat damage and easily bonded with binder and other organic material in mould. Foundry industry use high quality specific size silica sand for their moulding and casting process. This is high quality sand than the typical bank run or natural sand. Foundry successfully recycles and reuses the sand many times in foundry. When it can no longer be reused in the foundry, it is removed from the industry. The removing sand is termed as WFS. WFS are the major issue in the management of foundry waste. These WFS is black in colour and contain large amount of fines. The typical physical and chemical property of WFS is dependent upon the type of metal being poured, casting process, technology employed, type of furnaces (induction, electric arc and cupola) and type of finishing process (grinding, blast cleaning and coating).

Classifications of foundry sand mainly depend upon the type of binder and binder system used in metal casting. Some of the foundry sand which is use for metal casting is green sand and chemically bonded sand. Resin coated sand, cold box sand, hot box sand; Co_2 sands are some common type of chemically bonded sand. (Mould and core test handbook, American Foundry Society ISBN-087433-228-1)

Commonly clay bonded sand (green sand) is used for mould making and is mixture of silica sand (80–95%), bentonite clay (4–10%), carbonaceous additive (2–10%) and water (2–5%). Large portion of the aggregate is sand which can be either silica or olivine. There are many recipes for the proportion of clay, but they all strike different balance between mouldability, surface finish and ability of the hot molten metal to design. It still remains very cheapest way to cast metal because of easy availability. Other minor ingredients are flour, cereals, rice hulls, and starches. Silica sand is the bulk medium that resist the high temperature, bentonite clay bind the sand grain together, water activate the binding action of clay on sand and add plasticity. Carbonaceous additive prevent the fusing of sand on to the casting surface. Minor ingredients absorb moisture, improve the fluidity of sand. Green sand (clay bonded sand) also contains some chemical like Magnesium oxide (MgO), Potassium dioxide (K_2O), and Titanium dioxide (TiO_2). About 85% of green sand moulding used for cast iron in the world.

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Green sand is not green in colour, but green in the sense that it is used in a wet stage (akin to green wood).

Chemically bonded sand is used in both core making and mould making. In core making high strength is necessary to withstand against high temperature. Chemically bonded sand is mixing of silica sand and chemical binder (1–3%) for mould and core. When binder mixes with the silica sand, then catalyst start the reaction that cures the chemical resin and hardens the sand core or mould. There are various chemical binder system used in foundry industry, some of the binder are furfuryl alcohol, phenolic urethane, phenolic no bake-acid, phenolic resole-ester, sodium silicate, phosphate, alkyd (oil) urethane, shell liquid/powered and flake resins. Some of the most common chemically bonded sands are resins coated sand, hot box, cold box and Co_2 sand. Majority of binder used in the foundry are self setting chemical binder. The following sand binder or binder system in their sand mould process are Sodium silicate, phenolic urethanes, phenolic esters, phenolic hot box, phenolic nobake, furan nobake, furan warm box, sulphur dioxide, alkyd urethane and alkyd oil based core oil and epoxy So_2. Colour of the chemically bonded sand is light than clay bonded sand.

2. Literature review

Several researchers investigated the use of WFS in various civil applications. Javed and Lovell [1], Traeger [2], Kleven et al. [3], MOEE [4], AFS [5], Abichou et al. [6] Mast and Fox [7], Kirk [8] and Gunney et al. [9] have reported the use of WFS in highway applications. Nail et al. [10], Naik et al. [11], Tikalsky et al. [12] and Siddique et al. [13] have reported the use of WFS in controlled low strength material. Dungan et al. [14], Deng and Tikalsky [15] have used WFS in geotechnical field application. Braham A. [16] has reported the use of blended recycled foundry sand in hot mix asphalt. Ham RK and Boyle [17], Fero et al. [18], Engroff et al. [19], Siddique et al. [20] and Dungan et al. [21] have reported on leachate characteristic of used foundry sand. Seung-Whee and Woo-Keun [22], Naga and El-Maghraby [23], Pereiraa et al. [24] and Quaranta et al. [25] have reported the use of WFS in ceramic material and tile making process. El haggar and El Hatow [26] investigate the use of foundry sand with un-rejected plastic in the production of manhole cover. Periraa et al. [27] have reported the use of WFS for making refractory mortars. Colombo et al. [28], Ferraris et al. [29] and Geo and Drummond [30] investigated the use of WFS for the interization and reuse of waste materials by vitrification. Santurde et al. [31] investigated the technological behavior and recycling potential of WFS in clay brick.

Not much work has been reported on the use of WFS in concrete and concrete related product. Though some researchers has reported on this area, which are,

Khattib and ellies [32] investigated the properties (compressive strength and shrinkage) of concrete containing foundry sand as a partial replacement of natural sand. Natural sand replaced by three type of foundry sand white fine sand without the addition of clay and coal, the foundry sand (blended) and WFS. Thirteen concrete mixtures were made to investigate these properties. Replacement% of natural fine sand class M with foundry sand was 0%, 25%, 50% and 100%. Based on the teat results they concluded that, (a) the concrete made with WFS and white sand showed similar strength al all replacement%; (b) Strength of concrete was decreased due to increasing the replacement% of foundry sand; (c) Concrete incorporating white sand and WFS gives more strength than concrete made with blended foundry sand; (d) By increasing the replacement% of foundry sand length change of concrete was increased; (e) Drying shrinkage value was lower in concrete made with white sand and higher in concrete containing WFS and (f) Expansion was generally lower in concrete containing white sand as compared with the other two types (blended and spent) at a low sand replacement level of 25%.

Naik at el. [10] studied the effect of class F fly ash, coal combustion bottom ash and waste foundry sand on cast concrete product (brick, block and paving stone). Replacement level by mass for sand was 25% and 35%. Replacement level by mass, for Portland cement with fly ash was 25% and 35% for brick and block. For paving stone it was 15% and 25%. They investigated that (a) partial replacement of cement with FA consistently improved the strength and durability of concrete masonry units; (b) Block (25% FA and UFS) could be used for building exterior walls and (35% FA and UFS) could be used for building interior wall in cold region; (c) In warm region block and paving stone (contain 25%, 35% FA and UFS) could be used for building both interior and exterior wall and (d) up to 35% of sand in brick and block could be replaced with either BA or UFS for use where forest action is not a concern.

Naik at el. [11] investigated the use of high volume fly ash, bottom ash and waste foundry sand in manufacturing of precast moulded concrete product such as wet cast concrete brick and paving stone. ASTM class F fly ash was used as a partial replacement for 0%, 25% and 35% of Portland cement. Bottom ash combined with WFS replaced with 0%, 50% and 70% of natural sand. Test for compressive strength, freezing and thawing resistance drying shrinkage and abrasion resistance were conducted on wet cast concrete product. The result of this investigation showed that. (a) Difference in strength between control mix and mixtures incorporating by product decreased with an increase in age; (b) Wet cast brick unit that meet the minimum compressive strength requirement of ASTM for grade N brick (24 MPa) could be produced using concrete cylinder compressive strength as low as 14 MPa; (c) The compressive strength of paving stone continued to increased with age but fell short of ASTM C936 requirement (min 15 MPa) and (d) drying shrinkage increased with increasing amount of WFS, fly ash and bottom ash in concrete mixture however all brick met the drying shrinkage requirement of ASTM C55 (max 0.065%).

Siddique et al. [33] compressive strength, splitting tensile strength and MOE tests were carried out at the age of 28 and 56 days. Replacement% of natural fine sand with WFS was 10%, 20% and 30%. Based on test result they concluded that (a) compressive strength increased slightly with increase in WFS at all replacement%; (b) compressive strength increased by 4.2%, 5.2% and 9.8% at the age of 28 days when compared with ordinary concrete mix where as 1.0%, 5.18% and 14.3% increased at the age of 56 days; (c) splitting tensile strength increased with an increase in the WFS and (d) the MOE of wastet foundry sand concrete at all age was higher than the ordinary concrete. They also concluded that MOE of all concrete mixtures were increased with age.

Siddique at el. [34] determined the compressive strength, splitting tensile strength, flexural strength and modulus of elasticity of concrete containing WFS at 28, 56, 91 and 365 days. Fine aggregate were replaced with waste foundry sand with 10%, 20% and 30%. They concluded that. (a) Compressive strength, splitting tensile strength, flexure strength and MOE of concrete mixtures increased with increase in waste foundry sand content; (b) Mechanical properties of concrete mixtures increase with age for all the foundry sand content; (c) 8% to 19% compressive strength increased depending upon WFS% and testing age and (d) 6.5% to 14.5% splitting tensile strength, 7% to 12% flexure strength and 5% to 12% modulus of elasticity increased with age and waste foundry sand content.

Etxeberria at el. [35] investigated the properties of concrete using metallurgical industrial by product as aggregate. They used chemical foundry sand (QFS), green foundry sand (GFS) as a partial replacement of fine aggregate and blast furnace slag (BFS) as a partial replacement of coarse raw aggregate. Replacement% was 25%, 50% and 100% of fine and coarse aggregate. They conducted tests