"A Review on Utilization of Waste Foundry Sand and Bottom Ash for Producing Economical and Sustainable Concrete"

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Abstract - *This paper deals with a state of art review on utilization of waste foundry sand and bottom ash in civil engineering practice. The over exploitation of non-renewable energy materials is becoming a threat and therefore it is necessary to seek the possibility of recycling them, once their durability is obsolete. Metal foundries uses large amounts of sand as part of the metal casting process. Foundries satisfyingly reclaim and reuse the sand many times in casting process. When the sand cannot be reused in the foundry, it is remove from the foundry and is called as "waste foundry sand." The constant depletion of sand beds at all major sources of availability is a major concern and thus efforts are taken in order to replace sand in construction activities. On other hand the government is currently implementing policies to increase the usage of coal as fuel for electricity generation. Since bottom ash has been classified as hazardous material that threatens the health and safety of human life, an innovative and sustainable solution has been introduced to reuse or recycle industrial waste such as coal bottom ash in concrete mixtures to create a greener and more sustainable world. Bottom ash has the potential to be used as concrete material to partial replacement of fine aggregates, coarse aggregates or both. Hence, this paper provides an overview of previous research which used bottom ash and foundry sand as fine aggregate replacement in conventional concrete. The workability, compressive strength, flexural strength, and sound absorption of bottom ash and foundry sand in concrete are reviewed.*

Key Words: Bottom ash, Waste foundry sand, partial Replacement, workability, compressive strength, flexural strength.

1. INTRODUCTION

Concrete is the most widely used man-made construction materials in the world. Slightly more than a ton of concrete is produced each year for every human being on the planet.

Fundamentally, concrete is economical, strong, and durable. Although concrete technology across the industry continues to rise to the demands of a changing market place. The construction industry recognizes that considerable improvements are essential in productivity, product performance, energy efficiency and environmental performance. The industry will need to face and overcome a number of institutional competitive and technical challenges. The consumption of all type of aggregates has been increasing in recent years in most countries at a rate far exceeding that suggested by the growth rate of their economy or of their construction industries. Artificially manufactured aggregates are more expensive to produce, and the available source of natural aggregates may be at a considerable distance from the point of use, in which case, the cost of transporting is a disadvantage. The other factors to be considered are the continued and expanding extraction of natural aggregates accompanied by serious environmental problems. Often it leads to irremediable deterioration of the country side. Quarrying of aggregates leads to disturbed surface area etc., but the aggregates from industrial wastes are not only adding extra aggregate sources to the natural and artificial aggregate but also prevent environmental pollution. Foundry industry use high quality specific size silica sand for their molding and casting process. This is high quality sand than the typical bank run or natural sand. Foundries successfully recycle and reuse the sand many times in foundry. When it can no longer be reused in the foundry, it is removed from the industry, and is termed as waste foundry sand (WFS**)**. It is also known as spent foundry sand (SFS) and used-foundry sand (UFS). Waste foundry sand are by-products which appears to possess the potential to partially replace regular sand as a fine aggregate in concretes, providing a recycling opportunity for them. If such types of materials can be substituted partly/fully for natural sand (fine aggregates) in concrete mixtures without sacrificing or even improving strength and durability, there are clear economic and environmental gains. Currently, very limited literature is available on the use of these byproducts in concrete. Waste foundry sand (WFS) is one of the major issues in the management of foundry waste. WFS are black in color 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).

Fig. 1: Waste foundry sand

Coal-based thermal power plants all over the world face serious problems in the handling and disposal of the ash produced. The utilization of fly ash is about 30% in various engineering requirements that is for low technical applications such as in construction of fills and embankments, backfills, pavement base and sub base course. Coal bottom ash is a coarse granular and incombustible by product from coal burning furnaces. It is composed of mainly silica, alumina and iron with small amounts of calcium, magnesium sulphate, etc. The appearance and particle size distribution of coal bottom ash is similar to that of river sand. Bottom ash based artificial lightweight aggregate offer potential for large scale utilization in the construction work. The other advantage of using bottom-ash is that it can be dust free, the sizes of bottom-ash can be controlled easily so that it meets the required grading.

Fig. 2: Bottom Ash

2. Properties of Waste foundry sand and Bottom ash

2.1. Physical properties of WFS

Waste foundry sand (WFS) is sub-angular to round in shape. Green sands are black or grey, whereas chemically bonded sands are of a medium tan or off-white colour. The specific gravity of foundry sand varies between 2.39 and 2.79. Waste foundry sand has a low absorption capacity and is non-plastic. Typical physical properties of waste foundry are given in Table 1.

Table 1: Typical physical properties of waste foundry sand

Properties	**Javed and Lovell**	**Naik et al.**	**Guney et al.**	**Siddique et al.**
Specific gravity	2.39-2.55	2.79	2.45	2.61
Fineness modulus	-	2.32	-	1.78
Unit Weight (kg/m3)	-	1784	-	1638
Absorption (%)	0.45	5.0	-	1.3
Moisture content (%)	0.1-10.1	-	3.25	-
Clay lumps and friable particles	1- 44	0.4	-	0.9
Materials finer than 75µm (%)	-	1.08	*24*	*18*

2.2. Chemical properties of WFS

Table 2. Typical chemical composition of waste foundry sand

Constituent Value (%)	**American Foundry men's Society**	**Gune yet al.**	**Etxeberria et al.**	**Siddique et al.**
SiO_2	87.91	98	95.10	78.81
Al_2O_3	4.70	0.8	1.47	6.32
Fe_2O_3	0.94	0.25	0.49	4.83
CaO	0.14	0.035	0.19	1.88
MgO	0.30	0.023	0.19	1.95
SO_3	0.09	0.01	0.03	0.05
Na_2O	0.19	0.04	0.26	0.10
Constituent Value (%)	**American Foundry men's Society**	**Gune yet al.**	**Etxeberria et al.**	**Siddique et al.**
K_2O	0.25	0.04	0.68	-

TiO2	0.15	-	0.04	-
Mn2O3	0.02	-	-	-
SrO	0.03	-	-	-
LOI	5.15	-	1.32	2.15

2.3 Physical properties of CBA

The particles of coal bottom ash are angular, irregular and porous, and have a rough surface texture. The particle size ranges from fine gravel to fine sand. Bottom ash is lighter and more brittle compared to natural sand. The specific gravity of the bottom ash varies from 1.39 to 2.33. Bottom ash with a low specific gravity has a porous texture that readily degrades under loading or compaction. Table 3 shows the typical physical properties of coal bottom ash studied by different researchers.

Table 3. Typical physical properties of bottom ash

Physical Properties	Yuksel and Genc	Topcu and Bilir	Kim and Lee	Naik et al	Ghafoori and Bucholc
Specific gravity	1.39	1.39	1.87	2.09	2.47
Water absorption(%)	6.10	12.10	5.45	13.6	7.0
Fineness modulus	--	--	2.36	--	2.8

2.4 Chemical properties of CBA

Bottom ash is mainly composed of silica, alumina, and iron with small amounts of calcium, magnesium, sulfate, etc. The chemical composition of bottom ash varies depending on the type of coal used and the process of burning.

Table 4 shows the comparative study of the chemical composition of bottom ash, as reported in literature.

Table 4: Typical chemical properties of bottom ash

Chemical composition (%)	Yuksel and Genc	Andrade et al.	Bai et al.	Sani et al.
SiO2	57.90	56.0	61.80	54.80
Al2O3	22.60	26.70	17.80	28.50
Fe2O3	6.50	5.80	6.97	8.49
CaO	2.00	0.80	0.80	4.20
MgO	3.20	0.60	1.34	0.35
Na2O	0.086	0.20	0.95	0.08
K2O	0.604	2.60	2.00	0.45
TiO2	--	--	0.88	2.71
P2O5	--	--	0.20	0.28
SO3	--	--	0.79	--
LOI	2.40	4.60	3.61	2.46

3. Literature Review

Many authors have reported the use of used foundry sand in various civil engineering applications.

Bakis investigated the use of waste foundry sand (WFS) in asphalt concrete. Asphalt concrete mixtures were pre-pared with 0%, 4%, 7%, 10%, 14%, 17%, and 20% replacement of fine-aggregate with WFS. Grain size of the WFS ranged between 0.8 and30 mm. Tests were performed for the measurements of flow value sand Marshall Stability. The results showed that (i) replacement of10% aggregates with waste foundry sand was found to be most suitable for asphalt concrete mixtures; and (ii) waste foundry sand did not significantly affect the environment around the deposition.

Eknath investigated the comparative study of the properties of fresh & hardened concrete containing ferrous & non-ferrous foundry waste sand replaced with four (0%, 10%, 20% and 30%) percentage by weight of fine aggregate & tests were performed for M20 grade concrete. Result showed that (i) addition of both foundry sand gives low slump mainly due to the presence of very fine binders; (ii) Compressive strength at 7 days of both ferrous & nonferrous mixtures increases and maximum increase was observed with 20% WFS of both types of sand, at 28 days 30% addition of ferrous WFS & 10% addition of nonferrous WFS gives same strength as ordinary concrete and goes on decreasing for higher percentages of replacement; (iii) Split tensile strength gives maximum values with 20% WFS for both types of sand; (iv) water absorption is minimum with 20% ferrous WFS & with 10% nonferrous WFS. They alsoreported that both ferrous & nonferrous WFS can be suitably used in making structural grade concrete.

P. Aggarwal et al. studied various strength properties for various percentages of replacement of sand with bottom ash, results indicated that workability of concrete decreased with the increase in bottom ash content. The density of concrete decreased with the increase in bottom ash content due to the low specific gravity of bottom ash as compared to fine aggregates. He discovered Compressive strength, of fine aggregates replaced bottom ash concrete specimens were lower than control concrete specimens at all the ages. The strength difference between bottom ash concrete specimens and control concrete specimens became less discrete after 28 days. Compressive strength of fine aggregate replaced bottom ash concrete continues to aggrandize with age for all the bottom ash contents. Mix containing 30% and 40% bottom ash, at 90 days, attains the compressive strength equivalent to 108% and 105% of compressive strength of normal concrete at 28 days. The span required to attain the required strength is more for bottom ash concrete.

Kumbhar investigated the various mechanical properties of concrete containing used foundry sand(UFS). Concrete was produced by replacing natural sand with UFS in various percentages (10%, 20%, 30% and 40%). Based on the test results they concluded that (i) workability goes on reducing with increase in UFS content; (ii) At 28-days, Compressive strength, splitting tensile strength and flexural tensile strength for different replacement levels of UFS is increased whereas flexural tensile strength goes on reducing for UFS content more than 20%; (iii) At 28-days, the modulus of elasticity values increases with replacement of UFS up to 20%. They also concluded that the UFS can be utilized as a replacement to regular sand in concrete up to about 20%.

The American Coal Ash Association (ACAA) has lead a survey on the applications of bottom ash and it is found that usually bottom ash can be used for several construction purposes such as transportation, construction, agriculture and so on. It can also be used as soil modification, structural fillers, road base material and etc. Therefore, this paper aims to review previous research that has been carried out on the effect of bottom ash in concrete as sound absorption material. From the previous research, it had found that the presence of bottom ash in the concrete mixture can be either a partial or total replacement of fine aggregates has effect on the workability, compressive strength, flexural strength and sound absorption in concrete were reviewed to ensure either it is suitable to be replaced with natural aggregate (fine or coarse) in concrete as sound absorption material and also to verify the quality of bottom ash by confirming desired properties of the product.

Han-Young investigated two types of Foundry Sands like clay bonded sand (CLW) and silicate bonded sand (COW) as a fine aggregate for concrete and basic properties such as air contents, setting time, bleeding, workability and slump loss of the fresh concrete with WFS were tested and compared with those of the concrete mixed without WFS. Also compressive strength and tensile strength of hardened concrete of 28 days were measured. The results showed that (i) flow value and compressive strength of mortar is very rapidly decreased with increasing the replacement ratio of COW and CLW; (ii) Bleeding of concrete with COW, CLW are decreased according to increasing replacement ratio of COW and CLW; (iii) concrete mixed with COW of 30%, compressive and tensile strengths of concrete are higher than those of any other concrete without COW, whereas concrete mixed with CLW, compressive and tensile strengths of concrete are a bit smaller than that of control concrete.

4. CONCLUSIONS

1) Bottom ash when used as Light weight aggregates performs well in tune with natural light weight aggregates because of its lightweight.

2) Bottom ash gives better results with high degree of thermal insulation and material saving.

3) Compressive strength increased due to replacement of fine aggregate with waste foundry sand and bottom ash.

4) M20 grade concrete mix obtained increase in 28-day compressive strength from 25.0MPa to 30.20MPa on 35% replacement of fine aggregate with WFS, whereas it increase was from 36.6MPa to 42.8MPa for M30 grade of concrete mix. Maximum strength was achieved with 35% replacement of fine aggregate with WFS.

5) For 20 % replacement of bottom ash concrete gives maximum compressive strength, split tensile strength.

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