

# Review on Utilisation of Waste Products in Concrete

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**ABSTRACT:** Necessity of alternate materials to replace the common constituents of concrete has become inevitable to make the construction industry sustainable. Many by products of Industry like Fly Ash, Silica Fume, Meta Kaolin, Rice Husk Ash, etc., replacing the components of concrete contribute towards sustainability in construction technology. The technique of replacement of materials in concrete done through various research works is highlighted in this paper.

**KEYWORDS:** Durability, Strength, Microstructure, Permeability.

## I. INTRODUCTION

Studies on concrete using various IBPs investigate the strength, durability, environmental impact and other sustainability aspects. fly ash, furnace slag, silica fume, cement kiln dust, wood ash, rice husk ash, palm oil fuel ash, sugarcane bagasse etc. is studied to replace the cement in concrete. Research on fly ash, granulated blast furnace slag, waste foundry sand, furnace bottom ash, coal bottom ash, fine recycled aggregate, crushed fine stone. etc. replacing sand is also done by many for its use in cement concrete. Studies on Electric arc furnace slag, Blast furnace slag, recycled aggregate etc., substituting coarse aggregates are also done by researchers. CEWEP reports "The use of bottom ash as an aggregate in asphalt and concrete is still in the early stages. For use as an aggregate, the bottom ash is sieved, separated into coarse and fine fractions, coated with bitumen and added to asphalt instead of stone chippings"(Confederation of European Waste-to-Energy Plants, 2009). I. M. Martins, J. C. Marques, (2010), reported that about 44% of coal bottom ash is used in the construction sector, but its application as addition in concrete is very low. Literature on Research works done in the area of utilisation of industrial by products (IBP), in the construction sector, is reviewed in this paper.

## II. LITERATURE REVIEW

### II. A. Fine Aggregate Replacement

Some of the research works done on concrete by replacing aggregate using materials like bottom ash, electric arc furnace slag, blast furnace slag, foundry sand, rice husk ash, recycled aggregate, ceramic waste, GRP wastes are reviewed in this section

L. B. Andrade, J. C. Rocha, M. cheriaf (2009) [22] studied the influence of bottom ash as fine aggregate in concrete. Chemical composition of the bottom ash used, is reported to have only 2.07 % calcium content which is very low compared to the 89.5 % SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> altogether and hence it is regarded as belonging to type F Fly ash. They studied various characteristics namely workability, density, bleeding, setting time, heat of hydration, and plastic shrinkage, by conducting tests on concrete proportioned in two ways called equivalent volume replacement and non equivalent volume replacement. Equivalent volume replacement includes corrected bottom ash quantity according to the moisture content in aggregate while non equivalent volume replacement added bottom ash quantity without correcting for moisture content in aggregate. Two ways of adding bottom ash to concrete is said to have influenced the mechanical properties. Non equivalent volume replacement is reported to have (a) maintained the mechanical properties as that for natural sand concrete (b) bleeding water loss similar to reference concrete (c) accelerated setting (d) higher heat evolution with increased bottom ash content at higher replacement level (e) higher plastic shrinkage.

M. Etxeberria, C. Pacheco, J.M. Meneses, I. Berridi (2010) [16] did research on concretes made with (a) chemical foundry sand and green foundry sand as substitution for sand, (b) Electric arc furnace slag and blast furnace slag used as substitution for coarse aggregates, in 25%, 50% and 100% replacement. Tests were done by them under different temperature conditions with the different combination of aggregates to evaluate compressive strength, splitting tensile strengths, modulus of elasticity, Change in length, and Sorptivity under high temperature exposure. Chemical foundry sand is mentioned to give most workable concrete and more amount of slag as coarse aggregate reduced the workability. With higher w/c, mechanical properties of CFS and GFS are stated as more adequate. Length change on using the metallurgical industrial by products is reported as similar to conventional concrete and has lower capillary porosity leading to a higher residual compressive strength after high temperature exposure.

Isa, Turhan, Omer, (2007) [7] studied durability of concrete incorporating non-ground blast furnace slag and bottom ash as fine aggregate. Three series concrete were reported to be produced namely C Series (GBFS replacement), K Series (BA replacement) and CK series (GBFS+BA replacement). They produced concrete in each series with fly ash as mineral admixture and High Range water-reducing admixture and fine aggregate replacement of 10%, 20%, 30%, 40% and 50%. GGBFS or BA replaced concrete is reported to have increased durability in terms of abrasion resistance, drying-wetting effect, capillarity, high temperature effect and microstructure. Properties of the replaced by product and replacement level is stated to influence the performance. Isa, et al; [7] reported that the 90 days compressive strength showed that replacement ratios up to 40% give residual strength higher than the strength of reference concrete at temperature 800°C. K series is referred to show good performance in cracking and C series referred best in Freeze thaw resistance. Test results were reported as "Considering freeze -thaw resistance, the loss in strength for all series is below the loss in strength value for reference concrete. Drying-wetting effect accelerated the strength decreases for all three series of concrete. All replacement ratios except 10% have higher capillarity coefficients compared to reference group. Replacement of GBFS and/or BA did not decrease the surface abrasion in all series. A 20% replacement level is reported as ideal for the best performance. K series is the most porous concrete and C series has porosity like reference concrete till 30% replacement ratio."

H.K. Kim, J.G. Jang, Y.C. Choi, H.K. Lee (2014) [3] studied chloride resistance of high strength concrete having Bottom Ash. For various types of aggregates they have done Penetration test in steady state and rapid state, Thermal Analysis, Xray diffraction analysis, and Electron Probe microanalysis are the methods adopted by them to evaluate the Chloride diffusion, Total bound chloride concentrations in concrete, Crystalline phase of hydration products that can bind chloride and path of chloride penetration in concrete. They measured the Diffusion distance, Acid soluble chloride content, water soluble chloride content and studied the total and free chloride contents and relationship between the porosity in the concrete and the connectivity, which may affect the chloride penetration. Pore system in concrete with bottom ash is mentioned as not affected by its pozzolanic action. Steady state and rapid state measurements is reported not to show any difference in chloride penetration depths compared to conventional concrete. Total and free chloride contents in high strength concrete with bottom ash is claimed to be lower than control concrete. They inferred that BA as fine aggregate has no significant effect on diffusion length, but it reduced the amount of chloride diffusion.

Turhan Bilir (2012) [6] studied the effects of non-ground slag (NGGBS) and coal bottom ash (NCBA) as fine aggregate on concrete permeability properties. Permeability & Durability characteristics were studied by tests for rapid chloride permeability, freezing-thawing, drying-wetting, Microstructure. NGGBS and NCBA used singly or mutually between 30% and 50% replacement ratio is reported to give better durability and it can be used as fine aggregate replacement in chloride environment. Malkit Singh, Rafat Siddique (2014) [9], Studied compressive strength and durability aspects of concrete such as drying shrinkage, chloride ion penetrability, resistance to external attack of sulphate and sulphuric acid. Tests on compressive Strength, chloride ion penetration, SEM & XRD were done to evaluate sulphate attack, permeability, chloride penetration, and microstructure. Weight loss, reduction in compressive strength, drying shrinkage strain, expansion strains, water absorption, and permeable pore space were assessed to study dimensional stability, sulphate resistance, and drying shrinkage. 90 day compressive strength of bottom ash concrete is claimed to have crossed the 90 day compressive strength of control concrete. Resistance to chloride ion penetration, sulphate attack, dimensional stability is reported to be better for bottom ash concrete than control concrete.

Yogesh Aggarwal, R Siddique (2014) [11], studied microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates. Mechanical Properties, Durability characteristics were evaluated and analysed through tests on Compressive strength, splitting tensile strength, Flexural strength, rapid chloride penetration, de-icing salt surface scaling and microstructural aspects. Yogesh Aggarwal, R Siddique (2014) [11], found that increase in water content is necessary for required workability using bottom ash and waste foundry sand as partial replacement of fine aggregates. Mechanical behaviour of replaced concrete is reported to give greatest increase in case of 30% replacement and suggested a maximum of 50% replacement. Split tensile strength of 30% replacement of IBP is reported always higher than control concrete. Increase in strength from 28 days to 90 days is more for the IBP replaced concrete. Morphology of the formations due to hydration are stated as not changing for IBP additions except for 60% replacement.

M.P.Kadam, Y.D. Patil (2014) [1] has studied the effect of coal bottom ash as sand replacement on the properties of concrete with different w/c ratio. Tests are mentioned to be done on samples with 0%, 10%, 20%, 30%, 40%, 50%,

60%, 70%, 80%, 90%, and 100% replacement by weight for M35 grade concrete. They have procured bottom ash from Eklahare thermal power plant Nashik city in Maharashtra and Ultra Tech 53 grade Cement was used for the study. Coarse aggregate size 10 mm and 20 mm and fine aggregates were used by them with the source of natural sand being river bed from Tapi river conforming to grading Zone –I of table 4 of IS 383. The mix proportion Cement: Sand: Coarse Aggregate(10 mm) : Coarse aggregate (20 mm): water is 1: 1.42: 1: 1.5: 0.45. From various tests done they found that for coal bottom ash replacement greater than 30%, compressive strength, split tensile strength, flexural strength, modulus of elasticity, and density decreased and water permeability increased.

H.K. KIM, J.H. JEON, H.K. LEE (2012) [29] investigations resulted in Mortar flow to be increased by 10–20% with the replacement by FBA aggregates. Specific compressive strength of the mortar with FBA aggregates was shown to be 5–11% higher than that of the mortar with normal fine aggregates. For the same porosity as mortar with normal aggregates, the water absorption was reported to be slower into the mortar with FBA aggregates. The dynamic modulus of elasticity was reported to be approximately 5–10 GPa lower when aggregates were replaced by FBA aggregates, although the compressive strength was unchanged. The mortar with FBA aggregates was commented as lighter than the mortar with NF aggregates regardless of the W/B because of the lighter specific gravity and porous structures of the FBA aggregates.

## II. B. Coarse Aggregate Replacement

C. Pellegrino, V. Gaddo (2009) [4] studied the concrete properties like compressive strength, tensile strength, elastic modulus, and durability characteristics using EAF slag as aggregate. Black EAF slag with high density and low water absorption is used by C.pellegrino et al; for their study which was tested for toxic compounds through the leaching tests and is reported to have toxic compounds within the limits of Italian standards. Fuller's ideal grading curve is found to be adopted by them. Medium class quick setting cement is adopted for the test. Concrete having 185 mm slump, w/c 0.52, is mentioned to be prepared by use of fluidifying agent 0.4 % and aerating additive 016% by weight of cement. Test results are reported to show that EAF slag is suitable to replace natural aggregates in conglomerates and for 2-4 mm sizes provided the EAF slag is properly seasoned before use. Durability of concrete is reported to be doubtful due to the interface porosity and free oxides hydration.

Research work by M. Etxeberria, C. Pacheco, J.M. Meneses, I. Berridi (2010) [16] on concretes made with (a) chemical foundry sand and green foundry sand as substitution for sand, (b) Electric arc furnace slag and blast furnace slag used as substitution for coarse aggregates, in 25%, 50% and 100% replacement reported that more amount of slag as coarse aggregate reduced the workability. EAF and BF slags replacing coarse aggregate are accounted as giving higher compressive strength when medium w/c is used. On using metallurgical industrial by products, a higher residual compressive strength after high temperature exposure is reported compared to conventional concrete due to lower capillary porosity.

H.K. KIM, H.K. LEE (2011) [26] studied the use of powerplant bottom ash as coarse aggregate in concrete. Investigation results are reported to show reduction in flow characteristics. Density of high strength concrete is reported to be less than 2000 kg/m<sup>3</sup> for 100 % BA coarse aggregate replacement. 28 day compressive strength is reported as not much affected whereas modulus of elasticity is considerably reduced. Flexural strength and modulus of rupture is stated to decrease with increase in % replacement.

## II. C. Cement Replacement

Vanchai Sata, Chai Jaturapitakkul, Kraiwood Kiattikomol (2007) [12] investigated the effects of IBPs used as Pozzolans on mechanical properties of high-strength concrete using coal combustion fly ash (FA), fluidized bed combustion fly ash (FB), ground rice husk ash (RHBA), ground palm oil fuel ash (POFA) replacing cement. It is reported that higher fineness of the materials contribute higher 28 day compressive strength, and split tensile strength and modulus of elasticity are not affected by these IBPs. Reduced super plasticizer requirement is also reported when these materials are used to replace cement. FB and RHBA are recommended as suitable pozzolanic materials to be used for replacing SF in producing high-strength concrete.

Guilherme Chagas Cordeiro, Romildo Dias Toledo Filho, Luís Marcelo Tavares, Eduardo de Moraes Rego Fairbairn (2009) [8] studied the effect of fineness of sugarcane bagasse ash to be used as a pozzolan in concrete. G. C. Cordeiro et al: quote "From a low pozzolanic activity of less than 50% of the as-received ash, values above 100% could be reached after prolonged grinding times". They have found that 10%, 15% and 20% replacement of cement by ultrafine ground ash improved the rheology and resistance to penetration of chloride ions without affecting the mechanical behaviour.

I. Papayianni, E. Anastasiou (2010) studied industry based products namely high calcium fly ash and ladle furnace slag as binders and EAF slag as aggregate in concrete. Binder materials are reported to be tested for density, fineness, specific surface, setting time, expansion, pozzolanicity index and chemical properties. HCFA is claimed to show higher specific surface, shorter initial setting time and higher pozzolanicity index compared to LF slag. Durability aspects like fracture toughness, water penetration, freeze thaw resistance, porosity, microstructure along with mechanical properties like compressive strength, split tensile strength and flexural strength are reported to be done. Results are reported to suggest that 50% binder replacement by HCFA can produce high strength concrete greater than 70 MPa using EAF

aggregates and EAF aggregates increased the strength by 20%. For LF slag content as 30 % of the binder and EAF slag aggregate, 28 day compressive strength is claimed to be equal to that of conventional concrete. Resistance to freezing and thawing under de-icing salts is reported to have increased by using an air entraining admixture. Abrasion resistance and fracture toughness is mentioned to have increased by use of EAF slag as aggregate. HCFA/LF slag binder and EAF slag aggregate is claimed to have resulted in impermeable concrete.

B. carasco et al;(2014) evaluated plant biomass bottom ash as replacement for cement in building blocks and found that compressive strength is decreased due to increase in porosity. Chee Ban Cheah, Mahyuddin Ramli (2012)[30] studied the potential use of high calcium wood ash to replace cement in mortar production. 15 % HCWA replacement is reported to give higher compressive strength for mortar. 10 % replacement is mentioned as giving reduced shrinkage. Inclusion of more than 5% HCWA is reported as lowering the carbonation resistance.

### III. CONCLUSION

Industry Based Products like electric arc furnace slag, blast furnace slag, foundry sand, rice husk ash, recycled aggregate, fly ash, coal bottom ash, can be used as fine aggregate in concrete. Fluidized bed combustion fly ash, ground rice husk ash are suitable pozzolanic materials which can replace silica fume for high strength concrete. EAF slag and blast furnace slag are suitable to replace natural conglomerates in concrete. Use of industry based products to replace various components of conventional concrete can contribute towards sustainability in concrete technology.

### REFERENCES

- [1] M. P. Kadam, Y. D. Patil., 2014. "The Effect of sieved Coal Bottom Ash as a Sand Substitute on the Properties of Concrete with Percentage Variation in Cement", American Journal of Civil Engineering and Architecture, Vol. 2, No. 5, 160-166.
- [2] Siddique, R., 2010. "Utilization of coal combustion by-products in sustainable construction materials" Resources, Conservation and Recycling, 54, 1060-1066.
- [3] H.K. Kim, J.G. Jang, Y.C. Choi, H.K. Lee., 2014. "Improved chloride resistance of high-strength concrete amended with coal bottom ash for internal curing" Construction and Building Materials 71, 334-343.
- [4] Carlo Pellegrino, Vittorio Gaddo., 2009. "Mechanical and durability characteristics of concrete containing EAF slag as aggregate" Cement & Concrete Composites 31, 663-671
- [5] Joo Young Park., 2014. "Assessing determinants of industrial waste reuse: The case of coal ash in the United States" Resources, Conservation and Recycling 92, 116-127
- [6] Turhan Bilir, 2012. "Effects of non-ground slag and bottom ash as fine aggregate on concrete permeability properties" Construction and Building Materials 26, 730-734.
- [7] ISA, TURHAN, OMER., 2007. "Durability of concrete incorporating non-ground blast furnace slag and bottom ash as fine aggregate" Building and Environment 42, 2651-2659.
- [8] Guilherme Chagas Cordeiro, Romildo Dias Toledo Filho, Luís Marcelo Tavares, Eduardo de Moraes Rego Fairbairn., 2009. "Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete" Cement and Concrete Research 39, 110-115
- [9] Malkit Singh, Rafat Siddique., 2014. "Compressive strength, drying shrinkage and chemical resistance of concrete incorporating coal bottom ash as partial or total replacement of sand" Construction and Building Materials 68, 39-48.
- [10] Joo Young Park, Marian R. Chertow., 2014. "Establishing and testing the reuse potential indicator for managing wastes as resources" Journal of Environmental Management 137, 45-53
- [11] Yogesh Aggarwal, R. Siddique., 2014. "Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates" Construction And Building Materials 54, 210-223.
- [12] Vanchai Sata, Chai Jaturapitakkul, Kraiwood Kiattikomol., 2007. "Influence of pozzolan from various by-product materials on mechanical properties of high-strength concrete" Construction and Building Materials 21, 1589-1598.
- [13] I. Papayianni, E. Anastasiou., 2010. "Production of high-strength concrete using high volume of industrial by-products" Construction and Building Materials 24, 1412-1417
- [14] Kittipong Kunchariyakun, Suwimol Asavapisit, Kwannate Sombatsompop., 2015. "Properties of autoclaved aerated concrete incorporating rice husk ash as partial replacement for fine aggregate" Cement & Concrete Composites 55, 11-16.
- [15] Harald S. Mullera, Raphael Breinera, Jack S. Moffatta, Michael Haist., 2014. "Design and properties of sustainable concrete" 2nd International Conference on Sustainable Civil Engineering Structures and Construction Materials
- [16] M. Etxeberria, C. Pacheco, J.M. Meneses, I. Berridi., 2010. "Properties of concrete using metallurgical industrial by-products as aggregates" Construction and Building Materials 24, 1594-1600
- [17] M.L. Berndt., 2009. "Properties of sustainable concrete containing fly ash, slag and recycled concrete aggregate" Construction and Building Materials 23, 2606-2613
- [18] RAFAT SIDDIQUE., 2014. "Utilization of industrial by-products in concrete" Procedia Engineering 95, 335 - 347; 2nd International Conference on Sustainable Civil Engineering Structures and Construction Materials
- [19] E. Menendez, A.M. Alvaro, M.T. Hernandez, J.L. Parra., 2014. "New methodology for assessing the environmental burden of cement mortars with partial replacement of coal bottom ash and fly ash" Journal of Environmental Management 133, 275-283
- [20] Milagre Martins, I.M. Gonçalves, A. Marques, J.C., 2010. "Durability and Strength Properties of Concrete Containing Coal Bottom Ash" RILEM Publications SARL 9, 275 - 283, International RILEM Conference on Material Science
- [21] ISA Yu Ksel, TURHAN., 2007. "Usage of industrial by-products to produce plain concrete elements" Construction and Building Materials 21, 686-694
- [22] L.B. ANDRADE, J.C. ROCHA, M. CHERIAF., 2009. "Influence of coal bottom ash as fine aggregate on fresh properties of concrete" Construction and Building Materials 23, 609-614.
- [23] Adhunik Power and Natural Resources Ltd. (2012) report on "Technical data and potential use of fly ash, bottom ash, and pond ash of APNRL plant"
- [24] Malkit Singh, Rafat Siddique, 2014. "Strength properties and micro-structural properties of concrete containing coal bottom ash as partial replacement of fine aggregate" Construction and Building Materials 50, 246-256.
- [25] Turhan Bilir., 2012. "Effects of non-ground slag and bottom ash as fine aggregate on concrete permeability properties" Construction and Building Materials 26, 730-734.
- [26] H.K. Kim, H.K. Lee., 2011. "Use of power plant bottom ash as fine and coarse aggregates in high-strength concrete" Construction and Building Materials 25, 1115-1122.

- [27] M.P.Kadam ,Y.D. Patil., 2014. “ Effect Of Coal Bottom Ash As Sand Replacement On The Properties Of Concrete With Different W/C” International Journal of Advanced Technology in Civil Engineering.
- [28] Kou Shi-Cong, Poon Chi-Sun., 2009. “Properties of concrete prepared with crushed fine stone, furnace bottom ash and fine recycled aggregate as fine aggregates” Construction and Building Materials 23, 2877–2886.
- [29] H.K. KIM, J.H. JEON, H.K. LEE., 2012. “Flow, water absorption, and mechanical characteristics of normal-and high-strength mortar incorporating fine bottom ash aggregates” Construction and Building Materials 26 , 249–256.
- [30] Chee Ban Chea, mahyuddin Ramli, 2012. “Mechanical strength, durability and drying shrinkage of structural mortar containing HCWA as partial replacement of cement” Construction and Building Materials 30 , 320–329.
- [31] www.Cewep.eu, Confederation of European Waste-to-Energy Plants, 2009