International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue: 2 Volume No.9 March - April – 2025
DOI:10.46647/ijetms.2025.v09i02.030 ISSN: 2581-4621

# Performance of Sustainable Concrete with Industrial Waste Product – A Review

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**Abstract**
In modern infrastructures all over the world, concrete is most consumed construction material and plays important role in shaping civilization, its consumption is next to that of water. It is used for various types of structures due to its structural stability and strength.The materials used in concrete are obtained from natural resources. Continuous use of these materials on a large scale leads to their depletion causing strain on the environment. Huge amount of waste products yield from the manufacturing industries are gaining attention as a substitute for cement and natural aggregates in concrete. Ground Granulated Blast Furnace Slag a fine mineral residue, a waste product from steel and iron industry can be utilized in concrete by partially replacing cement which leads to reduced cement content. Pond ash as material is siliceous or aluminous with less pozzolanic properties than fly ash, waste product of thermal power plants, is one such suitable material, that can be adopted as fine aggregate in concrete, replacing natural sand partially or fully. Encouraging the usage of such waste materials as a constituents in concrete to address the issues related to its disposal, environmental and ecological problems, is a social responsibility of researchers, thus contributing to 3Rs – Reduce, Reuse and Recycle, there by promoting sustainable construction. Thus, partial replacement of cement with ground granulated blast furnace slag and natural aggregate with pond ash is a sustainable approach. This paper reviews the effects of utilization industrial wastes on different concrete properties.
**Keywords:** Ground Granulated Blast Furnace Slag, Pond Ash, Sustainable Concrete.

## 1. INTRODUCTION (12 pt)

There is a vast demand for materials in the construction sector due to the fast-growing needs of infrastructure. The consumption of concrete in the world is next to water as concrete is most used material all over the world.. Conventional concrete is a mixture of cement, fine aggregate, coarse aggregate, and water. Compare to all other ingredients, coarse and fine aggregates occupy 75 to 80 % of the total volume of concrete out of that 25 to 30 % is engaged by the fine aggregate and affect the fresh and hardened properties of concrete. Cement is also a major ingredient of the concrete which acts as binding material. The fast and huge infrastructural developments in India demand an enormous quantity of cement and fine aggregates. The commonly used waste products for replacement of cement, fine aggregate and coarse aggregate in concrete are Rice Husk Ash, Coal Ash, Blast Furnace Slag, Phosphor, Red Mud Gypsum, Silica Fume, Fumed Silica, Crushed Glass, Eggshells Palm Oil Shell Aggregate for Lightweight Aggregate Concrete, Crushed Ceramic, Glass, Waste Wood and crushed concrete aggregate will make a green environment and such concrete can be called “Green Concrete”. GGBS a waste material has similar properties like cement and will make cement production less by addition of it in concrete. GGBS is the best replacement of cement in concrete at some percentage. In India, The generation of coal ash is increasing every year and it is about 170mt for the year 2011-12 and is expected to be above 1000mt for the year 2031-32. The ash generated from power plants contains about 20 percent Pond ash and 80 percent fly ash. Utilization of fly ash has shown an increase in percentage value in India, still, sufficient efforts must

DOI:10.46647/ijetms.2025.v09i02.030 ISSN: 2581-4621

be made to fulfill the promise of utilization of 100% of fly ash. Thus by saving the environment concrete can be made more ecological and the pollution-free world. The property of these materials is very good for concrete strength properties.

### 1.1. Ground Granulated Blast Furnace Slag (GGBS)

It is a byproduct of the iron manufacturing industry obtained through quenching of molten slag. The molten slag rapidly solidifies in a glassy granulate on cooling. The glassy granulate is further dried and altered into fine powder through grinding to achieve the required particle size. It has same property as cement composition like CaO 30% to50%, SiO2 28% to 38%, Al2O3 8% to 24% and MgO 1to18%. It is a supplementary cementing material that can be partially replaced with cement in concrete, producing low carbon concrete, reducing the CO2 emissions, improving properties of concrete, and resulting in cost savings and energy savings. Therefore, the use of GGBS is also a greener approach. Concrete is mostly used in construction works because of its long service life. The durability of concrete plays an important role in achieving such a long service life, as it is responsible for keeping the concrete away from any kind of deterioration. The durability of concrete can be reduced by some degradation mechanisms such as freeze-thaw damage, alkali-aggregate reactions, sulfate attack, and abrasion. The durability of concrete is improved, as it reduces the permeability, lowers the rate of heat evolution, refines the pore structure, and gives more resistance to sulfate attack. Molten slag is being generated in large quantities from iron and steel industries. It becomes a solid waste on cooling and the disposal of such waste can cause dire environmental problems. So it’s a much greener approach to convert this solid waste into powdered form and utilize it by partially replacing cement. (Sodhi, 2017).

### 1.2. Pond Ash

Pond ash is a by-product of Pulverized Coal Combustion (PCC) thermal power plant that originates from the burning of pulverized coal to produce electricity. Disposal of Pond ash requires a large amount of costly land and causes environmental health hazards, hence an alternative method is to develop for profitable and environmentally safe use of this waste material. Pond ash is one such alternative material which can be conveniently used to replace the natural material at an intermixing level which is limited by technical and other concern, in structural concrete, geotechnical, and highway constructions, encouraging the use of the huge amount of coal ash generated from TPP -Thermal Power Plants. Infrastructural needs are growing very fast worldwide and have led to the demand for a large number of materials for construction. A lot of research work is being carried out to use the alternative materials for constructions satisfying the strength and performance criteria of structures. Substitution of raw materials/constituents with alternatives is an important eco-efficiency driver and is in need of the hour. From the thermal power plant, the coal is burnt in a dry, bottom boiler, about 80 percent of the unburnt material or ash is entrained in the flue gas and is captured and recovered as fly ash. The remaining 20 percent of the ash is dry bottom ash, a dark gray, granular, porous, and material that is collected in a water-filled hopper at the bottom of the furnace. The lagoon bottom ash is usually combined with fly ash. This blended fly ash and bottom ash are referred to as Pond ash percent of all coal ash is handled wet and disposed of as Pond ash. This wet process of disposal demands thousands of hectares of land including agricultural and forest land. Though there is a considerable increase (from 3%in 1993 to30% in 2010 to 60% in 2018) in the use of coal ash, the utilization fraction rate needs to be increased to reduce grave environmental consequences. One of the important reasons being the caution of the World Bank to India that the disposal of coal ash requires 1000 square km. i.e. one meter square of land per person. **(Narmatha, 2017)**

## 2. LITERATURE REVIEW

Overall, this literature review highlights the research that fixates on the properties of concrete by partially replacing cement by GGBS in concrete and partial replacement of pond ash as fine aggregate in cement concrete and mortar. The following results are taken from various literature-

DOI:10.46647/ijetms.2025.v09i02.030 ISSN: 2581-4621

### 2.1 Study on Properties of Concrete by partially replacing Cement by GGBS-

**Rafat Siddique** studies strength of mortar by replacing cement with GGBS in cement paste and mortar. It presents comprehensive details of the physical, chemical properties, and hydration reactions. It also covers the workability, setting times, compressive strength, chloride, and sulphate resistance of cement paste and mortar. The use of GGBS accelerates the hydration of ordinary Portland cement at early hours of hydration. The consistency of cement decreased with an increase in GGBS content. The inclusion of GGBS enhances the compressive strength of the mortar.

**S. Arivalagan** investigated the effects on concrete by partially replacing the cement with GGBS at 20%, 30%, and 40% replacement levels. Test results showed an increase in compressive strength at 7 and 28 days at a 20% replacement level of cement by GGBS. Split tensile strength and flexural strength of the concrete also increased at 20% cement replacement. The increasing strength is due to the filler effect of GGBS. In the fresh concrete degree of workability of concrete also increased with increased GGBS percentage.

**Santosh Kumar Karri et. al.** investigated characteristics of M20 and M40 grade concrete with partial replacement of cement with ground granulated blast furnace slag (GGBS) by replacing cement at 30%, 40%, 50% replacement levels. It was observed that the concrete achieved maximum compressive strength at a 40% replacement level. But as the percentage replacement exceeded 40% replacement level, the values of compressive strength were found to be descended. Compressive strength at 30% replacement was found to be higher than that of 50% replacement in concrete. Split tensile strength and flexural strength results were also found to be highest at a 40% replacement level for both M20 and M40 grades.

**Manjunatha M. et. al**. worked on the partial replacement of cement with GGBS at 15%, 30%, and 45% replacement level for M35 and M40 grade concrete. It was observed that the degree of workability of concrete was improved by partial replacement of cement with GGBS up to 45% for both M35 and M40 grade concrete. M40 grade concrete was found to be having better workability results than M35 grade concrete. The concrete containing 15%, 30%, and 45% GGBS for both M35 and M40 grade concrete achieved about 40% and 60% of their 28days strength at 3days and 7days respectively. While the Portland cement concrete achieved about 50% and 75% of its 28days strength at 3days and 7days respectively for M35 and M40 grade concrete. It showed concrete with GGBS showed slow early age strength gain.

**K.Ramadevi** performed experimental research on the properties of concrete by partially replacing fine aggregates with plastic PET (bottle) fibers. Concrete with 1%, 2%, 4%, and 6% PET bottle fibers for fine aggregate was produced and compared against the control mix with no replacement. Test results at 7 and 28 days showed that the compressive strength was increased up to 2% replacement of the fine aggregate with PET bottle fibers and it gradually decreased by 4% and 6% replacements. The split tensile strength was increased up to 2% replacement of the fine aggregate with PET bottle fibers and it gradually decreased by 4% and 6% replacements.

**Kumar et. al.,** studies when coarse aggregate is completely replaced with coconut shell (CS) an agricultural waste enhancing by utilizing a pozzolanic material Ground Granulated Blast-furnace Slag (GGBS) and its optimum for varying percentage of replacement 0%, 5%, 10% 15%, and 20%. For the optimum mix, the durability study and microstructural investigation, say SEM, XRD was examined. The result revealed that incorporating GGBS increases the strength of concrete to around 15% and proves to act as a pore filler.

### 2.2 Study on Properties of Concrete by partially replacing Fine Aggregate by Pond Ash

**A.K.Diwedi et.al.** has reported on sustainable management of Pond Ash. Due to an increase in the growth of industrial sectors the power requirement of the country is rapidly increasing. India depends on Thermal Power as its main source, thus increase in power requirement every year. To an estimated 85 thermal power plant whose installed power capacity 1,00,000 MW & coal consumption for the same is nearly 300 million MT every year. The coal reserves of the country are predominant of lower grades (average of 35% ash content), noncooking and as a result, more

DOI:10.46647/ijetms.2025.v09i02.030 ISSN: 2581-4621

than 110 million MT coal ash is being generated every year. The use of coal brings a huge amount of ash every year. The present majority of coal ash generated is being handled in wet form and disposed of in ash ponds, which is harmful to the environment. Thus the utilization of pond ash is necessary. This paper reviews and discusses the safe disposal of pond ash by using it as a building material in various construction works.

**A.K.Diwedi et.al.** carried an experimental investigation in view of sand becoming scarce and pond ash accumulation posing environmental problems, it is found that it is possible to replace some % of sand by pond ash as fine aggregate in concrete without compromising on strength and durability. For this, pond ash was collected from Ukai Thermal Power Plant which is a lot cheaper than sand and is checked for its strength and sand replacement capability. As per M20 Mix Design, concrete cubes of size 150 mm x 150 mm x 150 mm were cast by using different percentage of pond ash such as 0%, 10%, 20%, 30%, 40%, 50% and 60%. Satisfying results were obtained by replacing pond ash by sand. Based on the results it was found that pond ash can be used as a partial replacement for fine aggregate for M20 Mix.

**A. K. Dwivedi et. al** carried an experimental investigation on the effect of the addition of pond ash by partially replacing pond ash with cement and sand in the mortar. Pond ash of 0% to 40% (with an increase of 5%) by weight to cement and sand replacement was done respectively. The specimens were cast and cured under standard curing conditions for 3, 7, 28, and 90 days. In the case of pond ash mortar, the compressive strength containing 30 % replacement was higher than standards and mortar for 28 days curing period. The strength development was quite slow in case of all replacement after 3 and 7 days. Incorporating the 40 % pond ash decreased compressive strength after 28 and 90 days. Compressive strength for another case (Cement Replacement), was also increasing with time, but it was observed that the rate of strength gaining decreases with an increased rate of replacement incorporating pond ash percentage. For replacement up to 40%, it was observed that the dry density decreases with an increase in pond ash content in mortar. For series-II (cement replacement) the bulk densities for all replacement were gradually decreasing with an increasing percentage of pond ash content. Hence it was concluded that the bulk dry density reduces with an increase in percentage replacement of pond ash when compared with OPC mortar.

**Ghosh et.al.** has reported on the Physico-chemical characterization of pond ash samples collected from Kolaghat Thermal Power Plant. In experimentations, TS, VS, and FS, specific gravity, specific surface area were determined as per IS methods. Particle size distribution curves were obtained after sieve analysis and different values of % finer and grain size of all three samples were combined to plot particle size distribution graphs. SEM-EDS study was conducted (JEOL JSM5800 Scanning Electron Microscope with Oxford EDS detector) to determine the oxide components of the samples. After observing the SEM images of the pond ash samples it was concluded that the ash particles were mainly made up of irregular spherical, semi-spherical irregular grains, and fibrous matrix. EDS results show the presence of toxic elements like As and Cd and radioactive elements like Rn in trace amounts. All the pond ash samples had lime content of less than 7%. So the fly ash present in the pond ash samples can be classified as Class-F. Also, it can be concluded that pond ash sample 2 had the highest silt/clay component which may be the reason for its poor permeability.

**Rafat Siddique** has carried an experimental investigation in which fine aggregate (sand) was partially replaced with Class F fly ash. Fine aggregate (sand) was replaced with five percentages (10%, 20% 30%, 40%, and 50%) of Class F fly ash by weight. Tests were performed for properties of fresh concrete such as slump, unit weight, temperature, and air-content according to Indian Standard Specifications.

**Rafieizonooz et. al.,** The major aim of this research study was to investigate concrete by replacing sand with bottom ash waste and cement with fly ash. Concrete specimens were prepared incorporating 0, 20, 50, 75 and 100% of bottom ash replacing sand and 20% of coal fly ash by mass, as a substitute for ordinary Portland cement. The fresh properties of the experimental specimens were determined. From results, it was concluded that workability reduces when bottom ash content

DOI:10.46647/ijetms.2025.v09i02.030 ISSN: 2581-4621

increases by replacing sand. At the early age of 28 d, no significant effect was observed in the compressive, flexural, and tensile strengths of all concrete samples. After curing at 91 and 180 d ages, the compressive strength of both the experimental and control concrete samples increased significantly but remained almost similar. It is concluded that these experimental concrete mixes can be used in several structures (foundations, sub-bases, pavements, etc.) which will minimize the cost, energy, and environmental problems

**Abdulhameed Umar Abubakar et.al**. carried out an experimental investigation to study the effect of the use of coal bottom ash(CBA) and fly ash as a partial replacement of fine aggregates and cement for M35 grade of concrete respectively in the range of 0, 5, 10, 15 & 20% (equal percentages). From the results the workability of the fresh concrete i.e. slump and compacting factor decreases as the percentage replacement increases. M35 grade concrete at 7, 28, 56 & 90 days curing gets a compressive strength of 30N/mm2 for a curing period of 28 days. By the increase in the curing period, the strength of this particular concrete gets increased.

**P. P. Bhangale et.al**. studied the cost analysis by replacing fine aggregate with pond ash analysis and concluded that there is variation of the strength in pond ash concrete as compared to normal concrete and it lies within plus or minus 10% up to 28days curing for various mixes.

**Abhishek Sachdeva** et al. carried out an experimental investigation on use of coal bottom ash as a partial replacement of fine aggregates(10%, 20%, 30%, and 40%) in concrete in which controlled concrete of grade M40 was prepared. It was observed, a marginal decrease in the compressive strength up to 20% replacement level. Therefore, 20% of fine aggregates can be replaced with coal bottom ash, and concrete with good strength can be produced with coal bottom ash in concrete.

**Remya Raju et. al**. investigated the effect of the use of coal bottom ash as partial replacement of fine aggregates in various percentages (0–30%), on concrete properties. The workability of bottom ash concrete was decreased on the use of coal bottom ash in partial replacement of fine aggregate in concrete. On addition of micro-silica to bottom ash concrete workability decreases. Compressive strength was marginally reduced and there was no significant strength gain in concrete when the percentage of micro silica was more than 8%.

Jay Patel et. al studied the effect on use of alccofine and fine fly ash by partially with cement and pond fly ash was replaced by fine aggregate in concrete. In mix G1, G2, G3 cement was partially replaced with alccofine (4%) and fine fly ash by (26%) and pond fly ash varies 10%, 20%, and 30% as replacement of F.A. Similarly in mix G4, G5, G6 alccofine (6%) and fine fly ash (24%) and pond fly ash same as 10%,20%,30%. According to the analysis, the highest flexural strength of concrete almost was linearly decreased as the replacement level of bottom ash was increased. According to analysis 4.84Mpa flexural strength for 6% alccofine and 10% pond ash usage was at 28 days. The Flexural strength of the cylinder shows that tensile strength up to the desired limits of 5.42 Mpa is not obtained. According to analysis 3.98 Mpa splitting tensile strength for 6% alccofine and 10 % pond ash usage at 28 days. The split tensile strength of the cylinder shows that split tensile strength up to the desired limits of 5.42 Mpa is not obtained.

**Shekhar Mahat et. al** carried experimental study on the use of Pond ash as Fine Aggregate (FA) in concrete. The properties of Pond Ash was compared to the standard sand and was added by weight as 10%, 20%, 30%, 40%, 50%, and 60% respectively as replacement of FA in concrete. The compressive strength of the concrete with 10% Pond ash replacement as Fine aggregate shows higher strength for 3,7 and 28 days of curing but the strength is higher for 20% replacement for 56 days of curing. The Flexural strength of the Pond ash replaced concrete decreases with an increase in the percentage of replacement.

**Ways S M et. al** carried experimental studies on the use of Pond ash as Fine Aggregate (FA) by 0%, 20%, 40%, 60%, 80%, and 100% by weight for M25 grade concrete, at fixed water-cement ratio 0.48. Results show that the hardened properties of concrete such as compressive strength, split tensile strength and flexural strength decreased as the percentage of replacement of pond ash increase up to 40% and decreases as replacement percentage increase more than 40% compared to

controlled concrete. In this slump was kept constant 100 ± 10 mm respectively and achieve the required slump Emceplast BV Plasticizer were used as directed by the manufacturer, for this work dosage was 0.21% to 0.25%. It was observed that up to 40% replacement of sand as pond ash, the Harden properties are approximately the same as that of the controlled concrete.
**Kumar Mukesh et. al** carried investigation studies to explore the possibility of the use of pond ash as a partial replacement of fine aggregate in concrete. Pond ash obtained from the thermal power station was used as a partial replacement of fine aggregate in M 25 grade of concrete. Replacement levels were 10%, 15%, 20%, 25%, and 30% by weight of fine aggregate. Specimens were tested for workability immediately after mixing and compressive strength after 7, 28, and 56 days curing. The result showed that pond ash (up to 20%) can effectively be used in PPC concrete without much compromising the compressive strength. .

## CONCLUSION

In this era of technological revolution, the waste i.e. Pond Ash from the various coal waste power plants is increasing due to the increasing demand that can be suitably utilized as a fine aggregate in cement concrete and mortar. Supplementary cementing material i.e. GGBS can be partially replaced with cement in concrete, producing low carbon concrete. There are some conclusions drawn based on these above studies

•The use of GGBS reduces permeability, lowers the rate of heat evolution, refines the pore structure, gives more resistance to sulfate attack, and improves the durability of concrete.
•Increase in GGBS content increases workability, reduces water/cement ratio leading to higher ultimate compressive strength.
•Pond Ash particles physically are porous, angular, irregular, rough-textured, well-graded, and lighter than the natural aggregate.
•The pond ash being more porous, hence absorbs more water than sand, therefore workability of pond ash concrete decreases with the increase in the percentage, some superplasticizer should be used in increasing dose as a percentage of pond ash is increased.
•From investigations, it is concluded that ponded fly ash can be conveniently used to replace fine aggregates to a significant extent in cement mortar & concrete.
•The Compressive strength, Split tensile strength and Flexural strength of the pond ash replaced concrete decreases with an increase in the percentage of Pond Ash replacement.
•The addition of pond ash results in a decrease in compressive strength at an early stage and an increase in compressive strength at a later stage.
•It is also concluded that these experimental concrete mixes can be used in several structures (foundations, sub-bases, pavements, etc.) which will minimize the cost, energy, and environmental problems.
•Reusing wastes in concrete help attaining the economy while contributing to the environment at the same time by avoiding waste disposal.

## ACKNOWLEDGEMENTS

Place Acknowledgments, including information on the source of any financial support received for the work being published. Place Acknowledgments, including information on the source of any financial support received for the work being published.

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