© 2018 IJSRSET | Volume 4 | Issue 10 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology
DOI : https://doi.org/10.32628/IJSRSET196270

# A Review on Utilization of Fly- Ash and Pond-Ash as a Partial Replacement of Cement in Concrete Mix Design

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## ABSTRACT

Now-a-days energy planners are aiming to increase the use of renewable energy sources and nuclear to meet the electricity generation. But till now coal-based power plants are the major source of electricity generation. Disadvantages of coal-based thermal power plants is disposal problem of fly ash and pond ash. It was earlier considered as a total waste and environmental hazard thus its use was limited, but now its useful properties have been known as raw material for various application in construction field. Fly ash from the thermal plants is available in large quantities in fine and coarse form. Fine fly ash is used in construction industry in some amount and coarse fly ash is subsequently disposed over land in slurry forms. In India around 180 MT fly is produced and only around 45% of that is being utilized in different sectors. Balance fly ash is being disposed over land. It needs one acre of land for ash disposal to produce 1MW electricity from coal. Fly ash and pond ash utilization helps to reduce the consumption of natural resources. The fly ash became available in coal based thermal power station in the year 1930 in USA. For its gainful utilization, scientist started research activities and in the year 1937, R.E. Davis and his associates at university of California published research details on use of fly ash in cement concrete. This research had laid foundation for its specification, testing & usages. This study reports the potential use of pond-ash and fly-ash as cement in concrete mixes. In this present study of concrete produced using fly ash, pond ash and OPC 53 grade will be carried. An attempt will be made to investigate characteristics of OPC concrete with combined fly ash and pond ash mixed concrete for Compressive Strength test, Split Tensile Strength test, Flexural Strength test and Durability tests. This paper deals with the review of literature for fly-ash and pond-ash as partial replacement of cement in concrete.

**Keywords:** Fly Ash, Pond Ash, Concrete, Compression, Flexural, Split tensile strength, Durability.

## I. INTRODUCTION

For any country electricity is the key to develop in the world. In many countries, coal is the major source for the production of electricity. In the process of electricity production huge amount of ashes get produced. These ashes are available as a by-product of coal-based power stations. It is a fine powder (fly-ash) resulting from the combustion of coal, by the flue gases of the boiler and collected in the electrostatic precipitators. Use of such waste as a resource material is an old practice of our civilization.

Any country's economic & industrial growth depends on the availability of power. In India also, coal is a major source of fuel for power generation. About 60% power is produced using coal as fuel. Indian coal is having low calorific value (3000-3500 Kcal.) & very

high ash content (40-45%) resulting in huge quantity of ash is generated in the coal based thermal power stations. During 2005-06 about 115 million tonne of ash has been generated in 125 such power stations. With the present growth in power sector, it is expected that ash generation will reach to 200 million tonne per annum by 2019.

Now-a-days energy planners are planning to increase the use of renewable energy sources and nuclear to meet the electricity demand in world but thermal power plants are the major sources of electricity production. The major disadvantages of thermal power plants are the disposal problem of different ashes. Ashes from these thermal power plants are available in large quantities type like fly ash and pond ash. Fine ash is used in construction industry in some amount and course ash is disposed over land in slurry forms. Only around 45% of fly ash is used in different sectors. Remaining fly ash is being disposed over land and around one acre of land is used for fly ash disposal to produce 1MW electricity from coal. Ashes utilization helps to reduce the consumption of natural resources.

To produce electricity approximately 180 MT Ash (fly ash and pond ash) is generated as a by-product material. The problem is the disposal of the ashes and its dumping. The problem after the production of electricity is it ash generated which produces air pollution, land pollution and availability of land for dumping which is very costlier. The research has to be carried out to find specific experimental data on the characteristic strength of concrete used fly ash and pond ash as cement replacement partially in concrete. If the experimental result is positive then the fly ash and pond ash can be used for partial replacement of cement in concrete which will reduce the cost of the concrete. Alternative materials will be generated and also the dumping problem and other environmental problem will be resolved.

Any coal based thermal power station may have the following four kinds of ash:

### A. Fly Ash:

This kind of ash is extracted from flue gases through Electrostatic Precipitator in dry form. This ash is fine material & possesses good pozzolanic property.

### B. Bottom Ash:

This kind of ash is collected in the bottom of boiler furnace. It is comparatively coarse material and contains higher unburnt carbon. It possesses zero or little pozzolanic property.

### C. Pond Ash:

When fly ash and bottom ash or both mixed together in any proportion with the large quantity of water to make it in slurry form and deposited in ponds where in water gets drained away. The deposited ash is called as pond ash.

### D. Mound Ash:

Fly ash and bottom ash or both mixed in any proportion and deposited in dry form in the shape of a mound is termed as mound ash.

### Environmental Benefits of Fly Ash Use in Concrete:

Use of ashes in concrete imparts several environmental benefits and it is Eco-friendly. It saves the cement requirement for the same strength thus saving of raw materials such as limestone and coal required for manufacture of cement.

In the manufacturing of one tonne of cement, about 1 tonne of $CO_2$ is emitted and goes to atmosphere. Less requirement of cement means less emission of $CO_2$ result in reduction in green -house gas emission.

Due to low calorific value and high ash content in Indian Coal, thermal power plants in India are producing huge quantity of ashes. This huge quantity is being stored / disposed off in ash pond areas. The ash ponds acquire large areas of agricultural land. Use of ashes reduces area requirement for pond, thus saving of good agricultural land.

## II. PREVIOUS RESEARCH REVIEW BASED ON FLY-ASH AND POND-ASH

**Amit Mittal et al.** conducted studies on concrete mixes with 300 to 500 kg/cum at 20%, 30%, 40% and 50% replacement levels. They reviewed that spherical shape of fly ash increase the workability of concrete or reduce unit water content. It indicates that as the cement content increases, the reduction in its strength at later ages reduces. The reduction in compressive strength with increase in fly ash content is more in mixes with lower cementitious content as compared to the mixes with higher cementitious content.

Coin-Concrete Innovation Centre. (2010) team has focused on the use of ASTM Class F fly ash in concrete, as a part of blended cement or used directly into concrete mixer. One of the important advantages with fly ash concrete is the resistance to alkali aggregate reaction (AAR). Increasing AAR because of fly ash or increased fly ash content is not registered by many authors in this literature study and they noted the lower early strength because of the slow pozzolanic reaction and less reactive cement content. To increase the strength of high-volume fly ash more reactive cement or finer fly ash may be used. A possible solution is changing the demand for 28 days strength to 90 days. The fineness seems to be important for the pozzolanic properties of the fly ash. An advantage with fly ash blended cement as CEM II A/V is a finer fly ash due to grinding of clinker and fly ash. But use of fine ASTM Class F / EN 197-1 Type V direct into the concrete should be possible.

**Semsi Yazici et al. (2012)** conducted studies on fly ashes with three different fineness were used instead of cement of 0%, 5%, 10%, and 15% and ten different types of concrete mixture were produced. They concluded that compressive and splitting tensile strength of concretes increase as fineness of fly ash increases. The highest values of the compressive and splitting tensile strengths of the concretes produced with fly ash additives are obtained with 5% replacement rates of the fly ashes. it was seen that as the replacement rate increased, compressive and splitting tensile strengths decreased.

**Michael Thomas** concluded the use of good quality fly ash with a high fineness and low carbon content reduces the water demand of concrete and consequently the use of fly ash should permit the concrete to be produced at a lower water content when compared to a Portland cement concrete of the same workability. Although the exact amount of water reduction varies widely with the nature of the fly ash and other parameters of the mix, a gross approximation is that each 10% of fly ash should allow a water reduction of at least 3%. A well-proportioned fly ash concrete mixture will have improved workability when compared with a Portland cement concrete of the same slump. This means that, at a given slump, fly ash concrete flows and consolidates better than a conventional Portland cement concrete when vibrated. The use of fly ash also improves the cohesiveness and reduces segregation of concrete. The spherical particle shape lubricates the mix rendering it easier to pump and reducing wear on equipment. It should be emphasized that these benefits will only be realized in well-proportioned concrete. Long-term strength Increased and Consider extending testing out to 56 days.

**M. N. Balakrishna et al. (2013)** stated the Portland cement and Fly ashes are interacting particulate materials. Hence it is possible to account for its combined interaction by Generalized Abrams law instead of water/cement ratio, water/cementitious

material (Cement + Fly ash) ratio. Since the strength development rate is not at the same rate hence it is not possible to expect same strength development at same age. In order to obtain the same strength ratios both in the case of Portland cement and Fly ash cement concrete mixes, the water/cement and water/cementitious material ratios can be readjusted. For each of the mixes, appropriate strength data of trial mixes are to be used. By appropriate reductions in water/cementitious material ratios, the strength development at a particular age can be matched in turn such reductions would result in identical residual porosities. This investigation indicates that, the grade of cement is as important as the characteristics of Fly ashes (fineness and unburnt carbon content) to have optimal strength development with age.

**Arumugam K et al. (2011)** stated that the study is to investigate the possibility of using pond ash in varying percentage as fine aggregate substitute in cement concrete. They concluded that while the pond ash is used the workability is reduced. With the addition of pond ash there is reduction in slump value of fresh concrete. The unit weight of concrete gets reduced through the addition of pond ash as replacement of fine aggregate since it has lesser specific gravity than fine aggregate for obtaining the required workability, super plasticizers are added while preparing the concrete. The split tensile strength and flexural strength of concrete with pond ash increases up to the addition of 20% sand replacement. The compressive strength of concrete with pond ash increases with increased curing period.

**Gaurav Patel et al. (2013**) Based on limited experiment Investigation, they concluded that Specific Gravity for Natural Sand is 2.65 and for Pond ash is 1.89. Pond Ash satisfied limit of Specific Gravity as per IS Code. Fineness Modulus for Natural Sand it is 2.79 and for Pond ash it is 1.23. Pond Ash satisfied limit of Fineness Modulus as per IS Code. Sieve Analysis for sand it is Zone II and for Pond ash it is Nearly IV. Water Absorption for Natural Sand it is 0.99 % and for Pond ash it is 20% So Pond Ash satisfied limit of Water Absorption as per IS Code. Bulk Density for Natural Sand it is 1759 Kg/m3 and for Pond ash it is 840 Kg/m3. Pond Ash satisfied limit of Bulk Density as per IS Code. Pond Ash satisfied limit of Chemical Composition as per IS Code.

**Prof. P. P. Bhangale et al. (2013)** Concluded that the density of concrete reduces with the increase in the percentage of pond ash the compressive strength of concrete with pond ash increases with increased curing period. The maximum compressive strength occurs at the same percent of CA/FA which have shown the best workability in the mixes with paste volumes, w/c ratios and different levels of replacement of fine aggregate with ponded ash. Mixes having higher fine aggregate percent shown strength comparable to maximum strength observed at later ages. However, mixes with lower fine aggregate percent shown lower strength at all ages. Such reduction in strength can be attributed to the formation of voids/pores due to lack of enough fines. Considering the compressive strength criteria and cost of concrete, the replacement of fine aggregate with pond ash is feasible and the variation of strength of ponded ash concrete in comparison to reference concrete lies within ± 10% up to the age of 28 days for various mixes. The compressive strength of concrete with pond ash reach higher value with 20% of replacement of fine aggregate by pond ash.

**Bharathi Ganesh et al. (2012)** The variation in the properties of samples of Pond Ash collected from different locations around the outlet point with respect to its physical properties were not much. This may be due to the fact that the variation in RTPS plant operations are controlled and are maintained least due to automation of its operation and also coal is taken from the same source. The results of characterization of Pond Ash sample are not very satisfactory when compared to natural sand, but confirm its suitability in concrete as fine aggregate in terms of its strength and durability studies conducted

on concrete with Pond Ash as fine aggregate in various replacement levels. Hence effective utilization of Pond Ash as constituent in various concrete constructions encourage the large-scale utilization of industrial waste, facilitating human habitation, replacing fast depleting natural resource, so as to contribute to sustainable construction and also helps in conserving the precious top soil required for growing food contributing to environmental and ecological benefits.

R. S. BANG based on the present study of NSPAC and CSPAC, following conclusions are drawn. It is observed that 25% PA content with NS as fine aggregate gives consistently higher compressive strength, flexural strength, and split tensile strength at 56-days of curing period and small drop of about 10% at 28-days curing period. But 25% PA content with CS as fine aggregate at 28-days curing period recorded higher strengths up to about 25%. In the present investigation with prolonged curing period, 50% replacement of PA as fine aggregate is found feasible. If small drop in the strength at 28 days may be up to 10% can be tolerated, then 25% PA can be utilized as fine aggregate with natural sand. In case of CSPAC, 25% PA replacement level show increase in strength at 28 days curing period and can be used with advantage as alternative to the natural sand.

According to Technical data of APNRL Plant, the Portland cement is the most expensive part of concrete formulation. It is found that fly-ash can replace 20% to 30% of the Portland cement in concrete without changing its long-term strength, this practice provides considerable economy. Its will be a wise decision to make full utilization of this by-products of thermal power plant in all possible way to mitigate pollution to the maximum.

## III. CONCLUSION

From reviewing the above research papers related to fly-ash and pond-ash relevant Conclusions can be made:

1. Use of fly ash improves the workability of concrete.
2. Shrinkage of fly ash concrete mix is similar to control concrete mix.
3. Fly ash concrete is more durable as compared to OPC concrete.
4. Density and air content of concrete mix are generally unaffected with the use of fly ash.
5. In general, the highest values of the compression and splitting tensile strengths of the concretes produced with fly ash additives are obtained with 5% replacement rates of the fly ashes. It was seen that as the replacement rate increased, compressive and splitting tensile strengths decreased.
6. As the fineness of fly-ash increase, the compressive strength increase.
7. The compressive strength of concrete with pond ash increases with increased curing period.
8. While the pond ash is used the workability is reduced. For obtaining the required workability, super plasticizers are added while preparing the concrete.
9. The split tensile strength of concrete with pond ash increases up to the addition of 20% ash sand replacement.
10. The flexural strength of concrete with pond ash increases up to the addition of 20% ash sand replacement.
11. Use of both fly-ash and pond-ash make concrete more economical.

Generally experimental investigation is carried out for higher grade like M 40 and M 45 grade concrete. Further investigation should be carried out regarding M 25 and M 30 grade concrete, which could be useful for flats and high-storey buildings.

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**Cite this article as :**

Harshkumar Patel, Dr. Yogesh Patel, "A Review on Utilization of Fly- Ash and Pond-Ash as a Partial Replacement of Cement in Concrete Mix Design", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), ISSN : 2456-3307, Volume 4 Issue 10, pp. 413-418, September-October 2018. Available at doi : https://doi.org/10.32628/IJSRSET196270
Journal URL : http://ijsrset.com/IJSRSET196270