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Alkaline Activation of Fly Ash: An Overview

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Abstract - *Thermal power stations use pulverized coal as fuel. They produce enormous quantities of fly ash as a by-product of combustion. A number of applications of fly ash have been investigated and adopted in various fields. Among the various uses of fly ash, its bulk utilization is possible only in civil engineering applications. The low hydration capacity of fly ash at initial period necessitated the introduction of activation techniques to enhance the fly ash activity towards improvement of initial concrete strength. This review paper discuss the various activation techniques and possible applications of activated fly ash .The paper also covers the effect of various properties of fly ash on activation. Activation of fly ash enhance several properties of fly ash such as improvement in strength, shrinkage characteristics, acid and fire resistance, cold weather resistance, great workability ,reduces CO2 emissions etc. The alkali activation of fly ash has become an important area of research because it is possible to use these materials to synthesize inexpensive and ecologically sound cement like construction materials.*

Key Words: Fly ash, Activation Techniques, Chemical Activation, Curing.

1 INTRODUCTION

Power stations, using coal like fuel are worldwide energy sources and consequently high quantities of fly ashes are nowadays generated. Simultaneously only a small part of these ashes is used (20-30%).Fly Ash is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. The recycling of fly ash has become an increasing concern in recent years due to increasing landfill costs and current interest in sustainable development.

Fly ash has several benefits to be used in construction field .It have several properties like, cold weather resistance, higher strength gains, can be used as an admixture, can substitute for Portland cement, considered as non-shrink material, produces denser concrete and a smoother surface with sharper detail, great workability, reduces crack problems, permeability and bleeding, reduces heat of hydration, produces lower water/cement ratio for similar slumps when compared to no fly ash mixes, reduces CO_2 emissions. Even in geotechnical field fly ash secured several applications such as it can be used as brick material, embankment fill, backfill material, soil stabilization, sub-base and pavement construction.

Fly ashes having high content of toxins/ heavy metals may be used deposited under expert advice. The environment ministry's expert panel opinioned that the interface between the water and fly ash at the bottom of fly ash filled void results in leaching of heavy metals into groundwater system as evident by high levels of trace elements particularly heavy metals in ground water samples collected from sites located close to the ash filled voids. It also found out that there is reduction in recharging of groundwater due to fly ash filled mine voids. Ash-filled voids cannot support tree species because of poor root system development which in turn results in uprooting of trees even by low velocity winds. Further according to a recent study by the Centre for Science and Environment (CSE), an NGO working on environmental issues, fly ash disposal remains a major problem with only about 50-60% of the total fly ash generated by the power sector being utilized. Around 173 millions tones of fly ash was produced across India in 2013-14.. As per estimates, about a billion tons of this toxic ash lie dumped in these ponds, polluting land, air and water. By 2021-22, the thermal power sector is estimated to produce 300 million tons of fly ash a year and with that, utilization of all the fly ash being generated is going to become even tougher.

For promoting the usage of fly ash as one of the leading construction material or geo-material, it is advisable to improve its engineering properties by stabilizing it with suitable stabilizer. Typically fly ash doesn't possess strength itself, usually we used lime (CaO) and ordinary Portland cement (OPC) as additive for stabilizing fly ash. But a major issue with OPC is that its manufacturing processes are energy demanding and emit a large quantity of carbon di-oxide (CO_2).Fly ash can be activated to enhance its properties, so that more applications of fly ash can be introduced. There by bulk and safe disposal of fly ash can be secured in an economical and environmental friendly way. Activation techniques are the method of enhancing activity of pozzolanic materials in order to improve the hydration capacity.

1.1 Fly ash and Its Geo-Engineering Properties

R.R. Singh, Er. Nitin Goyal et.al.(2015) revealed that the fly ash is available in ample quantity and there exist plenty of complications linked with disposal of fly ash and leaching issues to ground water with heavy metal. On the far side fly ash has considerable geotechnical, a chemical and physical property which can be substituted on soil and thereby avoiding depletion of natural geo material and problems like disposal and environmental pollution. Fly ash can be used as an embankment material, this paper has been attempted to promote the use of fly ash as an embankment material in Highway Engineering.

Singh and Sharan (2013) explained that strength characteristics of compacted pond ash depends on compactive energy and degree of saturation. Here the (fly ash / pond ash) sample was compacted to compactive energy ranging from 357 kJ/m^3 to 3488 kJ/m^3 out. Conventional compaction tests was used to determine the optimum moisture content and maximum dry densities corresponding to different compactive energies. Pond ash can be replaced with the natural earth materials in geotechnical constructions since properties of pond ash are similar to conventional earth materials.

Norimasa Yoshimotoa, Masayuki Hyodo et al (2012) The advantages of the use of granulated coal ash are the suppression of leaching of heavy metals and outdoor curing possibilities. The particle strength of granulated coal ash can be understood easily since is produced artificially. It is possible to control the particle strength, which is impossible in natural sands. The present research was carried out in order to investigate the possibility of putting such advantages to good use. The crushing characteristics of each individual grain was evaluated by Single particle crushing tests . From the study it is observed the single particle crushing strength of granulated coal ash did not depend on particle size. The compression characteristics of granulated coal ash is that it compressed very easily because the crushing strength of a single particle was low. Therefore, the yield stress of granulated coal ash was smaller than that of natural sands. They concluded that crushing strength can be a used as the parameter in evaluating the shear characteristic of granulated coal ash.

Reddy and Gourav (2011) in their study observed that a marginal increase in strength can be obtained by treating fly ash by lime or by using an additives like gypsum followed by steam curing at low temperature. The results showed yielding maximum strength is possible in normal curing conditions at optimum lime–fly ash ratio of about 0.75 and, 24 h of steam curing at 800 C .

Pandian (2004) found that angle of internal friction of fly ash is about 30 degrees therefore it is a freely draining material. Fly ash has a lower specific gravity, so it leads to lower unit weights causing lower earth pressures. He concluded that fly ash can be utilized in geotechnical applications if some modifications are incorporated in fly ash to enhance its properties by adding additives.

1.2 Activation of fly ash

Sanjukta Sahoo (2016) discusses the different techniques of activation adopted till now and their impacts on concrete strength and durability. It is stated that fly ash activation can be done by many activation techniques such as chemical, mechanical, thermal, mechano-chemical and physiochemical methods and many others. . The process description and the compressive strength of fly ash concrete at 7 and 28 days are presented for a comparative assessment.

Iwona Wilin ska and Barbara Pacewska (2018) In this paper, possibilities to activate binding mixtures containing high and very high amount of fly ash and low amount of Portland cement were discussed. Several activating methods were described, such as mechanical activation, exchanging of part of components of binder by more reactive fine-grained material, chemical activation by the use of alkaline activators as well as combined methods. Possibilities of using these methods were discussed in relation to amount of fly ash introduced as replacement of cement and kind of fly ash used. Usefulness of calorimetry and thermal analysis methods was also presented.

Sanjay Kumar, Rakesh Kumar (2011) Isothermal conduction calorimeter at ambient (27 8C) and elevated (60 8C) temperatures was used to study geopolymerisation of mechanically activated fly ash. It was observed that under both the conditions, mechanical activation enhanced the rate and decreased time of reaction. Improvement in strength properties is correlated with median particle size, and reactivity of fly ash. The characterisation of the geopolymer samples by SEM-EDS, XRD and FTIR revealed that mechanical activation leads to microstructure and structural variations which can be invoked to explain the variation in the properties.

Sandeep Mane and Barshin Mubashir (2012) Experimental study was conducted to evaluate the mechanical properties of mortar containing physical and chemical activated fly ash. Up to 50% by weight of cement was replaced with flyash. Additives such as sodium hydroxide (NaOH) and potassium hydroxide (KOH) were used at rate 2.5% of total binder weight In order to activate the hydration reactions were studied. Compression, flexural, and R-curve approach were used to study the both the strengthening and toughening mechanisms. Experimental data indicate that increasing the flyash content from 20% to 50% results in a favorable influence on compressive strength whereas the flexural and fracture properties remain virtually at the same level. Autoclave curing of high flyash mortar samples results in a considerable increase in the strength and ductility.

1.3 Alkali Treated Fly Ash /Other Binders

Fernandez- Jimenez et al. (2005) conducted a study to determine the relationship between the mineralogical and microstructural characteristics of alkaline activated fly ash mortars. The activation of fly ash provides a material with cementing features comparable than that of OPC. In the process of alkali activation of fly ashes, some alkaline activators are blended with fly ash and then it is cured. The glassy nature of constituent of the fly ash gets transformed to compacted cement. The experiments show that an alkaline alumina silicate gel is the product formed by the reaction which have a crystalline structure. The gel so formed is responsible for the exceptional mechanical-cementitious properties of the fly ash activated with alkali.

M Criado et al. (2007) used class F fly ash and conducted alkali activation and studied the effect of soluble silica content on the mechanical and microstructural development of the cementitious materials. Activation was done by various alkaline solutions with diverse soluble silica contents all with constant sodium oxide content. The result shows that high mechanical strength in the material is obtained with an increase in the soluble silica content at short curing times (8 hours). They also added that with slight increase in curing times (20 hours), the strength of alkali activated fly ash get increased with a lesser silica content .

A Fernandez- Jimenez et al. (2004) conducted a study on the microscopic level of a set of alkali-activated fly ash. The microstructural development of fly ash-based cementitious geo-polymers and thermally cured fly ash samples was governed. In activation process, the Alkaline activators are blended with fly ash and followed by curing for solidification of the resulting paste. By this process the glassy nature of fly ash get transformed to cement like nature. With the increasing in time the degree of reaction also keeps on increasing. First few hours of the thermal curing shows high degree of reaction.

Fernandez et al. (2004) conducted a micro level study on a set of fly ash samples activated by alkali and thermally cured. The morphology of fly ash particles was investigated that can very well suit to real life situation. The fly ash was mixed with alkali activators and the resultant paste was cured for solidifying. Here the constituent of the fly ash which are glassy in nature gets transformed to compacted cement. The work found a conceptual model to describe the alkaline activation process of fly ash. The results indicate that the amount of reaction keeps on increasing with time. But higher degree of reaction is attained during the first few hours of thermal curing.

F Purteas et al. (2003) series of experiments are conducted to find the mineralogical and microstructural characteristics of alkali activated fly ash/ slag mixtures cured at different temperatures . The tests such as by XRD, FTIR, MASNMR, SEM/EDX, atomic absorption and ion chromatography are governed. NaOH was used as an activator in this work which is the chemical agent. X-ray diffraction analysis does not detect slag consisted largely of a glassy phase and crystalline phases. According to the results mechanical strengths were almost same in both curing conditions. The results shows that at 28 days the mechanical strengths are higher in the pastes which were cured at 22 c than those obtained at 65 c.

Puertas et al. (2000) conducted a study on activation of fly ash and slag pastes added with NaOH solution and the nature of reaction products was evaluated. The process parameters such as alkali concentration, curing temperature and fly ash / slag ratios are studied. Blended cements and concretes can be manufactured by fly ashes and Blast furnace slags which are renowned construction materials. Low heat of hydration, high sulphate content and water-sea resistance are the basic characteristics of Blast furnace slag cements. They stated that fly ashes can be used as pozzolanic material to improve physical, chemical and mechanical properties of fly ash blended cements and concrete. The conclusion of the results shows that with increase in slag content in the pastes, compressive strength increases and NaOH concentration develops the strength.

1.4. Geo Material Using Fly Ash

Messina, Ferone, et al (2018) stated that alkaline activation can be used for the production of sustainable precast elements based on geopolymeric binders. In this work, three mineral admixtures, namely blast furnace slag, silica fume and metakaolin, were used to synthesize binary alkali activated binders. Silica fume exhibited an increasing detrimental effect which includes the formation of agglomerates/partial foaming with early age curing temperature. Blast furnace slag and meta-kaolin Rperformed well to be effective admixtures without higher curing temperatures. Alkaline activation represents a powerful tool for the recovery of a wide range of natural and industrial residues not only concerning coal fly ash or waste (“weathered”) fly ash.

Nuno Cristelo Stephanie Glendinning et al (2012) evaluated the effectiveness of activation of low-calcium fly ash using alkaline on the improvement of residual granitic soils which is to be used on rammed-earth construction. Results revealed that there is an optimum value for the activator/solids ratio and the alkali concentration.The decrease in the Na2O:ash ratio results in an increase in strength. Application of sodium chloride or the super plasticiser shows no improvement, while the calcium produced only a short term increase in strength.

Angel Palomo and Ana Fernández-Jiménez (2011) defined that alkaline activation is a chemical process in which a powdery fly ash is mixed with an alkaline activator to produce a fast setting and hardening paste within a reasonably short period of time. The strength, shrinkage, acid and fire resistance of the resulting materials depend on the nature of the alumino Silicate used and the activation process variables. The alkaline activation of fly ash is consequently of great interest in the context of new and environmentally friendly binders with properties similar to or that improve on the characteristics of conventional materials. This paper briefly discusses a number of new applications for alkaline activated fly ash: i) in the precast industry for the manufacture of railway sleepers; (ii) for the production of lightweight materials; and (iii) as protective coatings on non-fire-resistant materials.

T. Bakharev (2005). This paper reports the results of the study of the influence of elevated temperature curing on phase composition, microstructure and strength development in geopolymer materials prepared using Class F fly ash and sodium silicate and sodium hydroxide solutions. The study obtained results such that long pre-curing at room temperature before application of heat was beneficial for strength development in all studied materials, as strength comparable to 1 month of curing at elevated temperature can develop in this case only after 24 h of heat curing. Long pre-curing at room temperature is beneficial for strength development of geo-polymeric materials utilising fly ash and cured at elevated temperature as it allows shortening the time of heat treatment for achievement of high strength. The main product of reaction in the geo-polymeric materials was amorphous alkali alumina silicate gel. Fly ash samples formed with sodium hydroxide activator had more stable strength properties than fly ash samples formed with sodium silicate.

2. CONCLUSION

Activation of fly ash helps to develop an improved strength and durable building material. Through this, bulk volume of fly ash can be utilized in an economical and eco-friendly manner. Activation of fly ash can be done by several methods like chemical activation, mechanical activation, physio-chemical, mechano- chemical activation etc. Alkaline activation could enhance several properties like improvement in density and strength, durability, shrinkage characteristics, acid and fire resistance, cold weather resistance, great workability, reduces CO_2 emissions etc. Alkali activated fly ash has several applications such as embankment and backfill material, brick production, waste stabilization and solidification, raw feed for cement clinkers, mine reclamation, stabilization of soft soils. Fly ash has properties similar to conventional earth material. Stabilized fly ash can be used for several geotechnical works. Physical, chemical and engineering properties are needed to be determined prior to any use. Activation of fly ash is an effective method to improve its properties as well as to solve the disposal issues. Fly ash can be activated by alkalis, admixtures, binders.

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