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SLUDGE AND FLY ASH AS A REPLACEMENT OF CONSTRUCTION MATERIAL

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ABSTRACT

The waste by humans being is increasing day by day, this increased waste. Thus, increasing concern for environmental protection, growing cost of waste disposal, depleting natural resources, growing economical constraints have put the metallurgical industries under tremendous pressure to find ways and means for waste utilization and also to reduce waste generation. The use of waste like fly ash and water treatment waste or sludge (primary treatment) is replaced by building materials , cement by flyash and fine aggregate by sludge. The study of 28 day unconfined compressive strength of 50:50(lime sludge: fly ash) composite is found 2278 KN/m2 to be greater than 60:40 composite.which is beneficial without effecting the basic property of concrete.

Keywords: *Sludge, Fly Ash etc.*

I. INTRODUCTION

India is the second most populous country, which has about 17% of the world population and 26% of the land area. Rapid industrialization last few decades has led to the depletion of precious natural resources in India and pollutes resources continuously. Further the rapid industrial developments have, also led to the generation of huge quantities of hazardous wastes, which have further aggravated the environmental problems in the country by depleting and polluting natural resources. Waste like fly ash, sludge can be used as conventional material in construction work.

II. LITERATURE REVIEW

The world is currently witnessing a rapid increase in sludge production, and this is expected to continue up to early part of next century. It is expected to see the production volume of sludge to increase as the total water demand is expected to increase from 690 BCM to 873 BCM by 2030 and to 950 BCM by 2060.Feasibility studies on the use of sludge to produce cement, mortar, concrete, building blocks, etc. as a means of ultimate sludge disposal has been initiated. The application of sludge can significantly reduce the sludge disposal cost component of water treatment. The recycling of residues can reduce environmental impacts, increase the useful life of the mineral raw materials used, and lower final production cost.

On one hand, the management of such a large volume of fly ash and sludge and mitigation of its likely impact on environment as well as demand on land for disposal is a mammoth task, both have been proved to be a useful material for a number of applications with potential to conserve valuable minerals, substitute materials inter-alia protection of environment. Thus, there lies a challenge to convert the threat to an opportunity.

III. REUSE OF FLY ASH

Tarun R Naik carried out research on reuse of fly ash in year 2008.Hecategorized the conventional coal combustion by-products utilization options into three classes of applications: Low Technology Applications; Medium Technology Applications; and, High Technology Applications.

The applications for conventional coal combustion by-products are enumerated as follows:

1. Fills and Embankments

As a borrow material, fly ash is utilized in the construction of both structural and non-structural fills. Structural fills containing fly ash are used for the support of buildings and other structures, while non-structural fills made with fly ash are used for development of parks, parking lots, playgrounds, etc. The inclusion of fly ash in construction fills and embankments not only provides economical alternatives to natural soils and rocks due to its availability in urban areas but also it improves their properties such as shear strength, pozzolanic properties, ease of handling, moisture insensitivity, etc.

2. Backfills

Fly ash is used as a backfill material for bridge abutments, buildings, retaining walls, trenches, excavations, etc. This is primarily because of favorable properties of this material, such as light weight, high shear strength, self-hardening properties, etc.

3. Pavement Base and Sub-base Courses

For construction of base and sub-base courses for pavements, fly ash is used in either with a combination with lime or Portland cement, and aggregate; a combination with cement and lime; or a combination with the on-site soils, with or without the addition of lime .In general, the behavior of the fly ash and the stabilizer mixture is similar to that of a fine-grained soil cement mixture, but pozzolanic reaction of the fly ash results in an increase in strength and impermeability with time. This enhances the durability of the base or sub-base course.

4. Subgrade Stabilization

A subgrade is a surface which acts as a foundation for pavements, floor slabs, embankments, or other structures. Fly ash alone or in combination with lime, is used to stabilize the subgrade in order to reduce plasticity, enhance strength, and improve workability of weak soils.The subgrade stabilization is needed in the construction of roadways, parking areas, railroad beds, building foundations, airport runways, etc.

5. Landfill Cover

Fly ash is an excellent cover material for landfills due to its several favorable properties such as compactability, shrinkage, and cementing behavior. It can be used in place of silts or clays for daily, intermediate, and final covers. The use of fly ash cover becomes economically attractive where other soils are scarce.

6. Soil Improvement

Addition of fly ash to soil results in improvements of infiltration characteristics, moisture-holding capabilities, and plant nutrients (trace elements).

7. Blended Cement

Many research has been done to find use of fly ash in cement, concrete, and other cementitious composites. Which proves beneficial.

In order to save a significant amount of energy and cost in cement manufacturing, fly ash is utilized as a component of blended cements. Fly ash is used as either a raw material in the production of the cement clinker, interground with the clinker or blended with the finished cement. Fly ash can be substituted for up to 8% of the clinker in manufacture of cement.

IV. Low-Strength, Structural Grade, and High-Strength Concretes

In general, inclusion of fly ash in concrete provides economical, ecological and technical benefits. The technical benefits include the improvement in properties of fresh and hardened concrete. In general, adding of fly ash as a partial replacement of cement in concrete mixtures improves workability, pumpability, cohesiveness, and causes reduction in water requirements, bleeding and segregation of fresh concrete. It also enhances strength and durability of hardened concrete due

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to both pore and grain refinements resulting from pozzolanic reaction of fly ash. The Strength and durability properties of concrete up to an appropriate level of cement replacement by fly ash are either equivalent or superior to no-fly ash concrete. More recent studies have shown that high-volume fly ash concrete having more than 50% cement replacement with either Class C or Class F fly ash can be proportioned to meet strength requirements for structural applications .

V. Paving Concrete

This concrete is proportioned to obtain lower slump compared to structural grade as well as high strength concretes. Recent studies have revealed that concrete containing large amounts of fly ash (for cement replacement in excess of 50% by weight) can be proportioned to meet strength and durability requirements for highway paving work .

VI. FIBRE REINFORCED FLY ASH

In 2006, Praveen Kumar and ShalendraPratap Singh did studies on fibre reinforced fly ash sub-bases in rural roads. Polypropylene fiber manufactured from high-density polypropylene and polyethylene. It is totally resistant to sea water, acids, alkalis, and chemicals. It has high breaking strength and abrasion resistance as it is less prone to wear and tear. It was found that strength at failure enhances with fiber reinforcement. It increases with increase in fiber content, at aspect ratio 100, it increased from 162 to 243 kPa with increment in fiber content 0.1–0.4% for fly ash.

The stress–strain behavior of fly ash under static load condition improved considerably due to increase in fiber content and increase in soil content. At a confining pressure70 kPa and aspect ratio 80, deviator stress increased from 184 kPa in the case of unreinforced sample of fly ash to 422 kPa when the sample was reinforced with 0.5% fiber content.

VII. REUSE OF LIME SLUDGE

In 2009, J. Flores et.al did research on potential reuse of water treatment sludge in cement mortar. The material generated by spray drying sludge is a readily handled powder which had a rounded form and a particle size similar to that observed in Portland cement. Atomized sludge contained 12–14% organic matter, 2–4% moisture, muscovite (25.9%), quartz (11.6%), calcite (16.7%), dolomite (3.1%)and seraphinite (4.6%), anortoclase (2.3%) and 35% amorphous material. The heavy metal content (except vanadium) in this atomized sludge was much lower than in sewage sludge ash. He further studied the proportion of $SiO_2+Al_2O_3$, i.e., the most active components in the pozzolanic reaction, was similar to the mean value reported in the literature for SSA, although the sludge structure was essentially crystalline and exhibited no activity in the Fretting trial or when it was tested for alkali activation.

The partial replacement of cement by sludge led to substantial retardation of hydration rates, even in the 90/10 samples. Replacement of larger proportions of cement significantly altered initial hydration, lengthening the induction period by over 12 hour, and silicate hydration was perceptibly retarded. A reaction between the fatty acids and the Ca^{2+} and OH^- ions in the medium, would inhibit portlandite nucleation. The mortars made with Portland cement mixed with 10 to 30% atomized sludge exhibited a substantial decline in slump and lower mechanical strength than the control cement, with 28-day strength activity index values of 30 to 50%. Setting was also altered in the blended cements with respect to the control.

1. Sludge in Bricks

The water treatment residual was characterized; the ceramic bodies were prepared and sintered to imply into building bricks and artificial aggregates. The sintering temperature requirement by the water treatment residual was higher than normally practiced in brick works due to the higher Al_2O_3 and lower SiO_2 content. The excavation waste soil, practically clay, was blended with water treatment residual to improve the brick quality. Under the commonly practiced brick-making condition, up to 13% of water treatment residual could be added to produce first grade brick. Test results of specific gravity, water absorption, and compressive strength of the artificial aggregates confirmed its applicability in constructions as various degrees of light-weight aggregates.

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Incineration was not required before the sintering process of WTR due to its low organic contents. The WTR resembled the brick clay in its chemical composition and, hence, sintering property. A higher sintering temperature was required by the WTR to achieve a qualified brick property due to its lower silica and higher alumina contents. Within the sintering temperature range, the aggregates fell in the light-weight category. The concretes strength indicated that only the artificial aggregates prepared by sintering at 1,100°C were comparable to those using other commercially available light-weight aggregate.

2. Lime Sludge in Construction

According to Martin, J. (2009)[6], beneficial utilization of Lime Sludge in transportation presents an opportunity to achieve sustainable utilization of a precious natural resource. Chemical analyses indicate Lime Sludge has similar chemical components as commercial hydrated lime.

Common procedures for determining the optimal lime content for soil stabilization based on pH values are found not applicable for Lime Sludge. Instead, performance criteria based on unconfined compression tests need to be utilized. Lime Sludge was found to increase the soil deformation modulus and reduce the plastic behaviors. Wet mix and dry mix methods do not appear to significantly affect the strength of Lime Sludge modified soil. Considering of the economic factors associated with drying Lime Sludge, Lime Sludge can be introduced in the slurry format through the wet mix procedure. The existing testing data demonstrated the positive effects of Lime Sludge treatment in improving the soil mechanical performance properties as well as improving the durability under freeze-thaw cycles.

VIII. California Bearing Ratio Test

CBR test has been performed on Fly Ash and Lime Sludge in 50:50 proportion using cylindrical mould with 150mm diameter and 175mm height. The CBR values are calculated for penetration of 2.5mm and 5mm.Generally CBR at 2.5mm will be greater than at 5mm and in such a case/ the former shall be taken as CBR for design purpose . If CBR for 5mm exceeds that of 2.5mm , the test should be repeated . If identical result follow , the CBR corresponding to 5mm is taken.
Unconfined Compressive Test
Composition 1:
LS : BFA : Ca(OH)2 : GYPSUM
50 : 50 : 12 : 1
60 : 40 : 12 : 1
Lime Sludge , Fly Ash , Ca(OH)2 and gypsum of mass 108gm are properly mixed in above proportions in dry form and water content (OMC) of 24% ie. 24% by mass of water is added and mixed properly. Mouldof diameter 37mm and height 76 mm are used to prepare samples and samples are obtained via Extruder machine. The samples are kept in dessicator(Method of Curing) and finally in Humidity chamber at 270C and 95% humidity.
Composition 2 (Fibre Reinforced):
LS : BFA :Ca(OH)2 : GYPSUM : FIBRE
50 : 50 : 12 : 1 : 0.5
The composition has been prepared in the same way as above.

IX. Test results

The test has been performed according to IS 2720(Part 10)-1973. Above compositions have been tested for 7,28, 56 and 90days strength using UTM Machine .

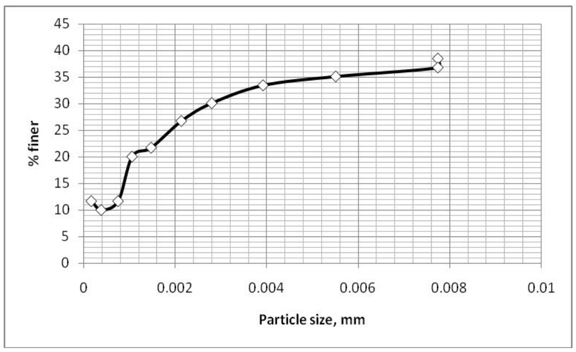
The 28 day unconfined compressive strength of 50:50(lime sludge: fly ash) composite is found to be greater than 60:40 composite , hence all the further studies have been done on 50:50 (lime sludge : fly ash) composite

UCS test have been done on fibre reinforced samples as well as samples without fibres. Although UCS value for fibre reinforced samples are found to be slightly less than others , however , the stress v/s strain curve of fibre reinforced samples is found to be smoother . Hence fibre reinforced samples shows greater ductility .

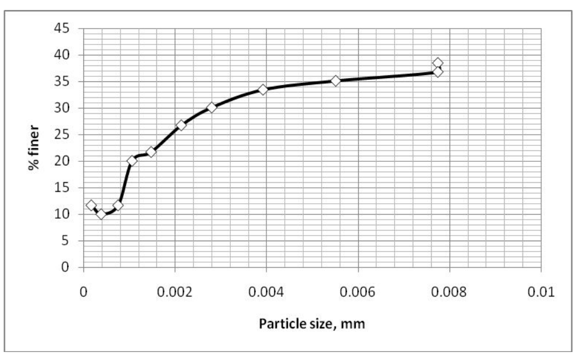
The pH of lime sludge and fly ash is found to be 8.11 and 8.805 respectively , hence both are alkaline in nature . Also the optimum moisture content of the composite is found to be 24 % , hence subsequent samples are prepared using this moisture content .

The permeability studies of the sludge and fly ash composite with varying percentage of china clay (10%, 15%,25%,30%,35%) shows decrease in the permeability. This composite can be effectively used as liner in ponds , landfills etc with further refinement and by using commercially available bentonite clay. The optimum quantity of clay is found to be 24% .

The C.B.R value of the lime sludge and Badarpur fly ash composite was found to be 13.16%[5]. As per IS 4332 California bearing ratio value for sub-grade should be in the range (10%-30%). which means it can be used in sub-grade applications.



Graph 1: Sieve Analysis of Lime Sludge (> 75 micron)



Graph 2: Hydrometer of Lime Sludge (< 75 micron)

X. Conclusion

This study investigated the use of water treatment sludge (lime sludge) and fly ash for natural material (soil, clay etc) and/or conventional material (cement) replacement in civil engineering applications.

The waste generated from thermal power plants and water treatment plants ie fly ash and lime sludge respectively, posing disposal problems are used as a composite which not only provide significant strength but also with the help of clay and fibers are effectively utilized for applications such as liners in landfills and providing high durability in sub-grade applications.

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