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Review Paper on Stabilized Fly Ash-Lime Sludge Composite as a Base Course Layer for Pavements

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ABTRACT :

To meet the demand of energy and potable water, number of thermal power and water purification plants are installed, which consequently generates bulk amount of fly ash (FA) and lime sludge (LS), respectively. Large amount of these industrial by-products are sometimes disposed without any treatment, which inhabit substantial land and cause risk to the environment. Utilization of FA and LS is a major concern in today's world so as to ensure that nothing goes waste and society can witness a sustainable development

1. 1 Introduction :

PROBLEM BACKGROUND

Many thermal power and water purification plants are erected to meet the need for energy and drinkable water, respectively. This results in the production of large amounts of fly ash (FA) and lime sludge (LS). Sometimes, a large quantity of these industrial byproducts are disposed of carelessly, contaminating large areas of land and endangering the environment. In the modern world, making use of FA and LS is crucial to ensuring that nothing is wasted and that society can experience sustainable development.

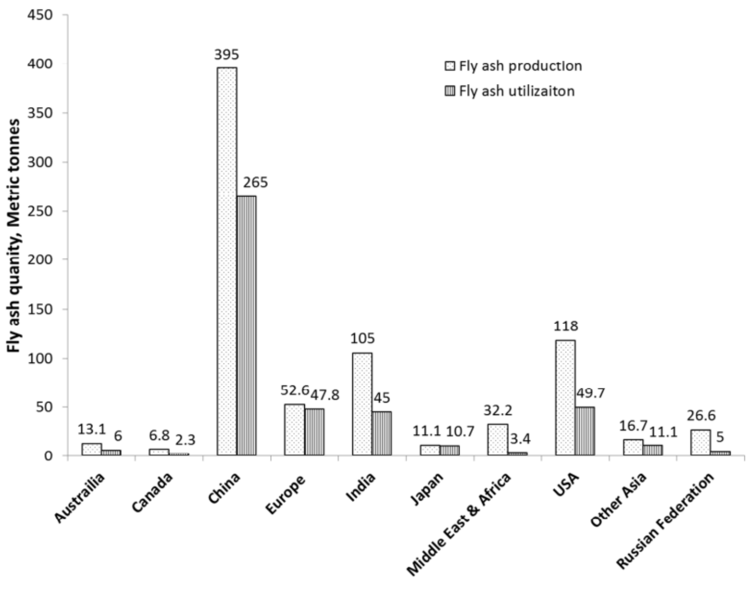

figure 1.1 Amount of fly ash production and utilization by countries in 2010

In India, thermal power production accounts for 70% of installed capacity for power generation, with coal accounting for roughly 60% of that total. Large amounts of fly ash are produced as a result of this capability, which is the culmination of more than 145 thermal power plants located around the country

. As seen in Figure 1.1, the scenario is essentially the same everywhere in the world. It is noteworthy that India uses comparatively less fly ash (43%) than China, which is the greatest producer and uses a considerable portion of its output (67%). According to the Fly Ash Association of India [2], only 53% of the 780 Metric Tonnes (MT) of fly ash produced globally was reportedly used in various purposes. Still, the utilisation rate is not particularly high. By 2020, all fly ash produced is anticipated to be used in a variety of application sectors, according to CEA .

Due to fly ash's advantageous physical, chemical, and other qualities, numerous researchers have previously proposed using fly ash in a variety of civil engineering construction projects. For instance, using Figure 1.2 as a guide, it has been investigated how to use fly ash in the production of cement and bricks , replace cement in mortar and concrete , build roads and embankments , use it as a light-weight aggregate , and use it in structural fills to reclaim low-lying areas. Furthermore, in order to cover all the major areas of fly ash application, specifications for pulverised fly ash for use as pozzolana in cement, mortar, and concrete were issued in 2003 . Similarly, fly ash was used to revise the Indian Code of Practice for both plain and reinforced concrete . Guidelines for the use of fly ash in various pavement layers and road embankments have also been incorporated by the Indian Road Congress . Fly ash use in the cement and building industries has significantly expanded since 1999. In 1999, PPC's portion of the world's total cement production was roughly 21.8%; by 2014, that percentage had risen to 67%. As of right now, PPC accounts for close to 90% of India's total cement output, and further efforts are needed to maximise the use of fly ash in other applications . However, it might be realised that in the future, concrete and cement by themselves wouldn't be able to use larger amounts of fly ash; therefore, alternative pathways would need to be developed.

1. 2 Literature survey & background

The fine residue known as fly ash is made up of unburned particles that become solid while suspended in exhaust fumes. It is removed from boiler stack gases and collected using an electrostatic precipitator or mechanical techniques. It usually makes up 80% of the ash, with the remaining ash being referred to as bottom ash. The origin of the coal, the kind of plant, the burning process, the inorganic chemical composition of the coal, the degree of pulverisation, the types of emission control systems, the handling and collecting systems, etc., all affect the physical and chemical properties of ash. As a result, fly ash is categorised into various groups according to how similar its physical and chemical properties are. Fly ash is divided into two classes by ASTM [1]: Class C and Class F. Class C fly ash is cementitious by nature and exhibits significant reactivity with water even in the absence of lime addition due to its high calcium concentration (15–40% by weight). Class F fly ash is pozzolanic in nature and requires the addition of stabilisers like cement and lime since it includes lower percentages of calcium (1–12% by weight) and a preponderance of silicon and aluminium, which have little to no cementitious value level. In fly ash classified as Class F, the total oxide content is ≥70%, while in fly ash classified as Class C, the total oxide content is ≥50% ($SiO_2+Al_2O_3+Fe_2O_3$). Since Class F fly ashes make up the majority of fly ashes in India, they are pozzolanic in nature and require stabilisation before being used in any kind of construction application.

Comparably, another byproduct of water treatment plants is lime sludge, which has a high calcium carbonate content. To use lime sludge, a process of incineration is needed to turn it into lime (calcium oxide, CaO), which releases carbon dioxide (CO_2) into the atmosphere. Although this impure lime can be used for stabilisation, burning it is an expensive procedure that contributes to global warming. As a result, this is not the best way to dispose of lime sludge; instead, innovative options that allow for the direct use of collected lime sludge should be investigated. The use of lime sludge to increase lime kiln productivity was looked into and determined to be feasible by NCCBM [42]. Lime sludge integration is another suggestion made by CPCB [43] for cement production.

POZZOLANIC ACTIVITY OF CLASS F FLY ASH

Being pozzolanic in nature, Class F fly ash is readily stabilised using readily accessible stabilisers like cement and lime. Fly ash's strength, durability, permeability, compressibility, and erodibility can all be enhanced by the stabilisation process. A pozzolan is a siliceous or silico-aluminous substance that, by itself, has little to no cementitious properties. However, when moisture is present and the material reacts chemically with calcium hydroxide at room temperature, cementitious compounds are formed. The primary mechanism of pozzolanic activity is the reaction of pozzolan's reactive silica with calcium hydroxide, which results in the formation of calcium silicate hydrate (C-S-H). In fly ash-calcium hydroxide or fly ash-cement systems, the alumina in the pozzolan may also react, producing calcium aluminate hydrate (C-A-H), ettringite, gehlenite, and calcium monosulphoaluminate hydrate as byproducts. Therefore, a pozzolan's total reactive silica and alumina content serves as the primary indicator of its pozzolanic activity. Fly ash's pozzolanic activity is further influenced by a number of factors, including its fineness, amount of amorphous matter, amount of unburned carbon, and curing temperature. Walker and Pavia [44] found that when the size of the particles employed in the test samples rises, so does the pozzolanic activity.

Fly ash and lime have been examined by Rao and Asha [48], and it was found that these reactions are crucial in improving fly ash's mechanical qualities. They noticed that the fly ash-lime reaction accelerated at higher temperatures by tracking its kinetics at both normal and enhanced temperatures. After 28 days of curing, an elevated temperature yields 1.21-2.44 times more strength than a normal temperature. The study came to the conclusion that fly ash-lime reactions are endothermic in nature and thermodynamically preferred at fly ash contents of 50–70% and lime additions of 16–20%.

With the exception of the early phases of cement hydration, Thongsanitgarn et al.'s research [49] showed that the fly ash-cement system's response mechanism is nearly identical to that of the fly ash-lime system. Cement releases $Ca(OH)_2$ during hydration, which then reacts with the amorphous silica found in fly ash. Tricalcium silicates ($3CaO.SiO_2$), dicalcium silicates ($2CaO.SiO_2$), tricalcium aluminate ($3CaO.Al_2O_3$), and tetra calcium alumino ferrite ($4CaO.Al_2O_3$ Fe_2O_3) are the main constituents of Portland cement. The acronyms for these compounds were C_3S, C_2S, C_3A, and C_4 AF.

STABILIZATION OF FLY ASH

Lav and Lav studied the microstructural development of cement and lime stabilized fly ash and it was observed that cement and lime-stabilized fly ash produced similar hydration products. Only weak calcium hydroxide (CH) and calcium carbonate (CaCO3) were identifiable by X-ray diffraction, thermogravimetric and differential thermal analysis. They reported that fly ash particles served as nucleation center for hydration and subsequently fills the voids of fly ash and thus contributed to stabilization. They also reported massive formation of ettringite and rose shaped calcium aluminate hydrate in lime stabilized fly ash. Cement stabilized fly ash attained UCS of 11 MPa and lime stabilized acquired 6.5 MPa respectively after 360 days of curing period

Ghosh and Subbarao [reported the shear strength characteristics of a low lime class F fly ash modified with lime (4%-10%) alone or in combination with gypsum (0.5% – 1%). It was observed that the addition of lime was effective to improve the shear strength characteristics and addition of gypsum further enhances the gain in shear strength at early curing periods (7 and 28 days). It was reported that fly ash stabilized with only lime requires longer curing period, 45 days and more, to gain considerable shear strength. The gain in unsoaked unconfined compressive strength of the fly ash was 2,853 and 3,567% at 28 and 90 days curing, respectively, for addition of 10% lime along with 1% gypsum to the fly ash. The effect of 24 h soaking showed reduction of strength varying from 30 to 2% depending on mix proportions and curing period.

Sivapullaiah and Moghal studied the effect of gypsum (1, 2.5%) on the strength development of two Class F fly ashes (Neyvelli fly ash, NFA and Muddanur fly ash, MFA) with different lime (1, 2.5, 5, 10%) contents after curing them up to 180 days under unsoaked and soaked conditions. It was observed that NFA mix 20 containing 2.5% lime and 1% gypsum contents gives maximum strength at any curing period. However, for MFA the strength gain at higher lime contents (10%) and with 1% gypsum was more than that achieved at 2.5% lime and 1% gypsum after 90 days. It was also reported that addition of 2.5% gypsum increases the strength of both the fly ashes far better than that at 1% gypsum. Thus, the strength of MFA at 5 and 10% lime contents with 2.5% gypsum was higher than that with 2.5% lime after curing for 28 days.

Aimin and Sarkar revealed that the principle underlying activation of gypsum is based on the ability of the sulfate ions to react with the alumina, the latter being one of the principal components in fly ash, which results in the dissociation of the glass structure. It has been suggested that the reaction between sulphate and fly ash also may lead to a dense hydrate structure and higher strength. The following reaction occurs when lime and gypsum is added to fly ash leads to formation of monosulphate which are responsible for strength gain.

Ghosh and Subbarao studied the physicochemical and microstructural developments of a low-lime fly ash modified with 6% and 10% lime and 1% gypsum. The strength of fly ash, stabilized with 10% lime and 1% gypsum, has reached a value of 6,307 kPa at 3 months' curing, i.e., 36.7 times the strength of untreated fly ash. The permeability has reduced to 10-7 cm/s due to the reduction in interconnectivity of the pore channels of the hydration products.

Kaniraj and Gayathri studied two Indian fly ashes stabilized with different content of cement for different curing period and revealed that the rate of increase in strength was high up to 14 days, and starts decreasing drastically between 28–90 days, and after 90 days no substantial change recorded in strength.

Kumar and Raju made attempts to investigate the stabilization process with model test tracks over expansive subgrade in flexible pavements. Unstabilized fly ash and fly ash stabilized with cement and lime was laid as subbase over sand and expansive soil and cyclic plate load tests were carried out on the tracks. The maximum load carrying capacity was obtained for stabilized fly ash subbase compared to untreated fly ash subbase. For sand subgrade the total deformation decreased by 52.73% at 500 kPa for treated lime-cement fly ash subbase as compared to untreated fly ash subbase whereas for expansive soil subgrade the decrease was 65%. In case of field stretches, the total deformation at 500 kPa was decreased by 52.68 % on sand subgrade whereas 72.86% on expansive soil subgrade for treated lime- cement fly ash subbase when compared to untreated fly ash subbase

Ghosh studied the engineering properties of pond ash (slurry mix of fly ash and bottom ash) stabilized with lime and revealed that the bearing ratio of stabilized pond ash increases with increase in lime content up to 10%, however, the contribution of lime was more at the lower percentage (4%) levels in the pond ash as compare to high levels of (10% or more) lime addition. Addition of small percentages of phosphogypsum (0.5 and 1.0%) in lime stabilized pond ash, increases both soaked and unsoaked bearing ratio. Moreover, the soaked CBR values were less than the unsoaked values. For 10% lime and 1% gypsum content, the unsoaked bearing ratio was observed as 137%, 194% and 221% after 7, 28 and 45 days of curing respectively.

LIME SLUDGE AND ITS USES

Wang et al. [60] studied the effects of adding lime-sludge to a road sub-base aggregate and observed that addition of 0.5% to 1.0% sludge produced maximum improvement to the seven-day cured and freeze/thaw unconfined compressive strengths. The mix design suggested was 86% aggregate, 11% fly ash, 3% lime, and 0% to 3% sludge solids

Lim et alobserved the effect of addition of lime, fly ash, and loess into the water sludge and it was reported that the unconfined strength of the modified sludge by fly ash and loess satisfied the criteria for construction materials above 100 kPa. Addition of 15% lime and 10% loess to sludge represented the best results of all. From SEM, the microstructure of the lime-modified sludge was relatively dense. There was evidence that calcium compound was produced due to the inclusion of lime.

Baker studied the feasibility of using lime sludge as a soil modifier and suggested that it promises both performance and economic aspects. It was observed that approximately 35% lime sludge can be consumed for soil modification in transportation constructions. They also checked the practical and economic feasibility of using lime sludge and fly ash mixed in equal proportion (1:1) for embankment construction for highways

Yu et al. investigated the option of converting sewage sludge and water treatment sludge into ceramsite to achieve the sustainable disposal options in saving the natural resources of raw materials as well as the protection of environment. They claimed that the findings of this conversion can revolutionize handling of such kinds of sludge in the future for their reuse as low-cost raw materials, rather than as waste requiring costly disposal, in accordance with the concept of sustainable development.

Further, Yang et al. utilized sludge as the primary ingredient and mixed it with low-quality fly ash and waste glass powder to produce high-strength ceramsite. They recommended mix proportions as: silt–fly ash–glass powder = 60∶35∶5. The high-strength sludge ceramsite provided particle strength of 7.1 MPa, apparent density of 1,580 kg/m3 , and water absorption of 8.2%. It was reported that all properties were better than the requirements in the national standards.

Sales and De Souza studied the axial compression strength and water absorption of concretes and mortars produces with the joint addition of water treatment sludge and aggregates from recycled construction and demolish wastes. They observed that the sludge addition upto 30 % acts as a regulator of consistency and plasticity and, in suitable quantities, can even increase the compressive strength of concretes and mortars produced for a given application.

Matschei investigated the role of limestone, which mainly consists of calcite, and is a permitted additive to Portland cements often up to a 5 wt.% limit. They reported that most of the calcite added to the cement is reactive and affects the distribution of lime, alumina and sulfate and thereby alters the mineralogy of hydrated cement pastes. Calcite affects the mineralogical variant of the AFm phase(s). Calcite additions affect the amount of free calcium hydroxide as well as the balance between AFm and AFt phases, although C–S–H is unaffected in much of the range of compositions. Calculations of the specific volume of solids as a function of calcite addition suggest that the space-filling ability of the paste is optimized when the calcite content is adjusted to maximize the AFt content.

UTILIZATION OF INDUSTRIAL BY-PRODUCTS IN PAVEMENT SECTOR

Kumar et al. performed study on four different local materials - fly ash, coarse sand, stone dust, and river bed material to use them in the subbase layer of flexible pavement. It was observed that the CBR of stone dust was the maximum 27 value of all, but its behaviour under dynamic load in triaxial tests was inferior to that of the other materials. Though fly ash had low CBR, it showed better stress-strain behaviour than stone dust. The results demonstrated that the river bed material was the best material for use in the subbase layer as it had good CBR, high E-value and resilient modulus, and low permanent strain values compared to other materials under study.

Lav and Lav studied the aggregate-free stabilized fly ash mixtures to be used as pavement base material. It was reported that along with cement content, layer thickness is also important parameter in controlling the design life of stabilized layers. The study suggested that since the strength of aggregate free stabilized fly ash is lower than the ones mixed with aggregate, cement content and layer thickness should not be less than 8% and 300 mm, respectively. Mixes having cement content less than 8% may be used as subbase materials instead of being used in pavement base.

Singh et al. performed detailed laboratory investigations on cement stabilized fly ash–(GBFS) mixes in order to find out its suitability for road embankments, and for base and sub-base courses of highway pavements. Various tests were conducted on cement stabilized fly ash–GBFS mixes and the cement content was varied from 0% to 8% at 2% intervals, whereas the slag content was varied as 0%, 10%, 20%, 30% and 40%. Test results showed that an increase of either cement or GBFS content in the mixture, results in increase of Maximum Dry Density (MDD) and decrease of Optimum Moisture Content (OMC) of the compacted mixture.

Shafique et al. conducted an experimental study to investigate the longterm performance of fly ash stabilized two fine-grained soil subbases. One low plasticity clay soil and another high plasticity expansive clay soil were stabilized with a Class C fly ash with content varying from 0%, 5%, 10%, and 20%, and compacted statically at the maximum dry density (standard Proctor) and at the optimum moisture content of the corresponding soil to prepare ten sets of replicates from each of the combinations. They reported that the strength of stabilized soils was at least three times higher than that of the unstabilized soils and hence fly ash was a competent material for soil stabilization.

USE OF FIBER REINFORCEMENT

Kaniraj and Havanagi examined the geotechnical characteristics of the cement (3%) stabilized fly ash-silt specimens containing 1% randomly oriented polyester fiber. It was reported that the 56 days UCS of cement stabilized fly ash-silt increases from 500 kPa to 1050 kPa upon 1% fiber addition. Fiber addition also changed their brittle behavior to ductile behavior.

Kaniraj and Gayathri [80] performed an experimental study to investigate the influence of randomly oriented Polyester fiber inclusions (1% by dry weight) on the geotechnical behavior of two Indian fly ashes. The raw fly ash specimens attained a distinct axial failure stress at an axial strain of about 1.5-2.5% which increased to 4- 4.5% with fiber addition and hence provide ductility to the specimen.

Kumar and Walia studied the effects of polyester fiber inclusions and lime stabilization on the geotechnical characteristics of fly ash-soil mixtures. Lime and fly ash were added to an expansive soil at ranges of 1–10% and 1–20%, respectively. Test specimens were subjected to compaction tests, unconfined compression tests and split tensile strength tests. Optimum composites with 15% fly ash and 8% lime were tested with 0, 0.5, 1.0, 1.5, and 2% plain and crimped polyester fibers by dry weight. It was observed that the addition of 1.5% of 6 mm plain fibers or 1.0% of 6 mm crimped fibers increased the unconfined compressive strength by approximately 74% as compared to that of same mixture without fibers. Also, with the addition of 1.5% of 6 mm crimped fibers or 1% of 12 mm plain fibers, the gain in split tensile strength was about 135% in comparison to that of the same mixture without fibers.

Kumar and Singh performed study on reinforced fly ash to investigate the composite as subbase material. The effect of polypropylene fiber (0.1-0.5%) reinforcement on conventional parameters of fly ash, such as, unconfined compressive strength, modulus of elasticity, shear strength and California bearing ratio was observed. It was found that the strength at failure enhanced with fiber reinforcement, at aspect ratio 100, it increased from 162 to 243 kPa with increment in fiber content 0.1–0.4% for fly ash. It was found that CBR of fly ash increased with increase in percentage of fiber content at a particular aspect ratio. But increments were more up to 0.3% fiber content, after that gain in CBR values were reduced for both cases soaked and unsoaked CBR. Based on the results it was concluded that fly ash is suitable in subbase, if it is reinforced with propylene fiber.

Muntohar et al. performed laboratory evaluation of the effect of freezing – thawing cycles on strength and swell potential of fly ash and randomly oriented fiber stabilized expansive soil subbases. Results showed that adding fiber to the stabilized soil slightly increased the strength ratio from 0.11 to 0.13 by increasing the fiber content from 0.1 to 1.2%. The highest strength gain was obtained at 0.8% fiber content, and further addition of fibers tends to reduce both the unconfined compressive and tensile strengths, but the strength was still higher than the stabilized and unstabilized soils. It was reported thatthe inclusion of fibers in the stabilized soil contributed about 35–68% and 88–110% of the increase in the unconfined compressive and split-tensile strengths, respectively.

Parsons, R. L., Kneebone, E.assessed the field performance of fly ash stabilized sub grades of pavement to measure the level of improvement due to Class C fly ash and the degree to which improvements were beneficial. Dynamic cone penetrometer values were obtained for 12 sub grade fly ash treated roads and five sub- grade untreated roads from zero to nine years. Higher strengths were recorded for all sub-grade ash treated than for untreated soil below. No deterioration with period was observed for the sub grades evaluated. Fly ash treated laboratory and field investigations show that fly ash adds value to soil strength and stiffness and reduces plasticity and swelling potential.

Behak, L investigated the performance of the complete test segment of the low volume road of a base layer of soil lime. The test part was designed to take into account the soil type, the amount of lime content, the compacting properties of the stabilized soil and the results of the CBR laboratory tests. Two test sections of 50 m, consisting of a base layer with soil and 3 percent lime in one section and another 5 percent lime, were evaluated by visual observation and deflection measured by Benkelman beam. Despite a few structural complications, the average deflection values amended from 244 x 10^{-2} cm immediately after the section was constructed to 77 x 10^{-2} cm tested 4 months later. Research has concluded that use of soil lime blends for low-volume road base layers is a technical and economic alternative for a marked improvement in the rural road network.

Ambarish Ghosh carried out several laboratory tests on Class F pond ash alone and stabilized with changing percentages of lime 4, 6 and 10% and PG 0.5 and 1.0% to study the suitability of stabilized pond ash for road base and sub base construction. Light and heavy proctor compaction tests were conducted to detect the compaction characteristics of the stabilized pond ash. Bearing ratio tests were carried out on specimens, compacted with an optimum moisture content obtained from tests, cured for 7, 28 and 45 days. Bearing ratio tests undertaken on unsoaked and soaked condition. The test results highlight the influence of the lime content, the PG content and the curing period on the bearing ratio of the stabilized pond ash.

Manasseh Joel and Isaac O. Agbede experimented to improve the physical and strength properties of a reddish brown lateritic soil. 15 to 60% of sand by dry weight of the soil sample was used as a modifier for stabilization by 3 to 12% by dry weight of cement. Classification, compaction, California bearing ratio and unconfined compressive strength tests were conducted on specimens. The plasticity index decreased from 17% to 2.5% when treated with a mixture of 60% sand with 6% cement.

K.M.A Hossain and L. Mol This study demonstrated the use of cement kiln dust, volcanic ash and their combinations for CKD soil stabilization at 0, 2, 5 10, 15 and 20% and VA at 0, 5, 10, 15 and 20 %. In addition, another 4 combinations examined 5 % VA and 5% CKD, 10% VA and 2% CKD, 10% VA and 5% CKD. Experimental findings indicate that with changes from CKD 0 to 20 %, the maximum dry density decreased by 0 to 10% and increased by more over 10%. The OMC reduces and the amount of moisture content in CKD is higher than in VA.

Abd. El Aziz researched to identify the consequence of lime and silica fume on the engineering properties of clay soil. The investigation was carried out on samples with varying proportions of SF lime. The results of the lab show the lime silica fume mixture, a significant decrease in the swelling characteristics of the clay soils, a noticeable decrease in the plasticity index when subjected to an LSF unique blend of 11 to 15%. California Bearing Ratio value increase from 3.0 % to 17.0 %, when LSF blend introduced to 5 to 15%, similar cohesion and angle of internal friction increase. The author concluded that the merging of lime and silica fumes helps to improve the engineering properties of clay soil

Shailendra Singh n attempt has been made in this study to stabilize the soil using lime. Experimental tests were carried out with 4 % and 6 % lime content for liquid limit, plastic limit, OMC, MDD, bulk and dry density, C.B.R. test, grain size analysis and swelling pressure measurements. The analysis shows that the engineering properties of black cotton soil have substantially improved

Martin Jacob and K. Pandey A variety of laboratory experiments were performed by authors and the effects of hydrated lime on the engineering behaviour of highly plastic clay soil were evaluated. Tests were carried out with various amounts of hydrated lime. The plasticity index values of the clay soil decreased substantially and effectively with an increase in the lime content. The change in the plastic limit shows the granular nature of the clay particle due to lime. A significant decrease in swelling potential and pressure values was achieved with a rise of up to 4 per cent of lime.

Deepa G Nair et al Authors identified predictive validity of rice husk ash being pozzolanic product by the systemic analysis of the samples with reference to its reactivity; silica within RHA formed by burned rice husk inside a continuous air supply lab furnace were identified as a consequence of the incineration temperature, duration and cooling process. Ashes were analyzed to determine the optimal conditions for the extraction of reactive ash. The NMR spectra clearly indicates that the highest volume of silica is present in the fast-cooled RHA consequent from burn of a rice husk at 500°C at 12 hour

Aditya Kumar Anupam, Praveen Kumar and G D Ransinchung R N Investigated and presented the potential of flyash, bagasse ash and rice husk to be evaluated by 5 to 35% by soil weight for shrinkage, compaction and CBR behaviour. Shrinkage limit values increase for all mixtures and increased trend for RHA soil mixture was found from 16 % of natural soil to 33 % because free lime available causes flocculated clay particles to decrease the friction and replacements of particles. Optimum moisture content increases a trend by increasing the content of mixtures. Authors found that as comparison to other materials RHA blended soil indicates higher value due to the presence of silica and calcium oxide, more water is needed for chemical reactions.

E. A Basha et al The Authors observed soil properties such as plasticity behaviour, compaction, strength and special technique X ray diffraction on cement and RHA blended soil samples. The findings of this study suggest that cement and rice husk ash reduce plasticity behavior, cement stabilized soils achieve substantial declines. When cement content continues to increase, the MDD of cement-stabilized residual soil decreases slightly whereas the OMC is steadily increased with the conjunction of RHA and cement.

J.N. Jha et al tested and examined the effectiveness of rice husk ash as a pozzolanic to enhance soil lime treatment in order to test the effect of the different mixture proportions of lime and RHA on the different soil properties. The author concluded that the inclusion of RHA tends to increase not only the strength but also the of the lime stabilized soils.

K. Ganesan, Rajagopal, K. Thangover Authors investigated the mechanical properties of bagasse ash for the identification of pozzolanic quality. Initially, physical, chemical properties were evaluated and extensive concrete testing were carried out. Authors observed that raw ash produced more carbon content from the boiler at an uncontrolled temperature and bagasse burning under controlled temp. of 650°C for 1hr reduce the carbon content more than 50%. The carbon content of 650°C for 1 hour decreases by more than 50 percent.

Moses, G, Osinubi, K. J The others analyzed and confirmed the increase in strength of black cotton soil treated with cement and bagasse ash mixture when compacted at different energy levels The author concluded that the treatment of natural soil with cement and bagasse ash presented a 7 day UCS value of 839 kN/m2 at 8% OPC with 4% BA content and the durability of the specimen was justifiable on the basis of the 7 day soaking test results obtained from resistance to loss in the strength test. Authors recommended an optimal mix of 8% OPC and 4% BA for use as a sub base material.

Sharma and Shivapullaiah described the compaction behaviour and effects of fly ash and GGBS on the unconfined strength of the stabilized soil. The author concluded that the application of GGBS with and without fly ash and lime had a substantial effect on the geotechnical characteristics of the soil.

Nanda H S et al Authors reported laboratory studies by using ground granulated blast furnace slag to strengthen lithomargic soil with 1 to 6% lime and amount of slag used ranges from 10 to 50% by dry soil weight. The results obtained indicate that 30% of the optimum slag seems to have a peak unconfined compressive strength of 30 days after curing. It is also noted that the UCS value of soil and GGBS mixtures increases as well as the curing time through the GGBS percentage increase. It is also observed that 30% of GGBS is effective, raising its strength from 108 kPA of raw soil to 336.35 kPA for 30 days of curing.

Dayalan J examined the use of GGBS and Fly Ash by 5, 10, 15 and 20 % by dry weight of soil to evaluate soil stabilization. The efficiency of the stabilized soil samples were evaluated using different tests such as specific gravity, Atterberg limits, standard proctor test and California Bearing Ratio (CBR) at optimum moisture content. The findings showed that the optimum value of fly ash was 15 % and that GGBS was 20 % for soil stabilization based on the CBR value.

Anil Kumar Sharma and P.V Sivapullaiah Experimented to investigate the behaviour of GGBS and Flyash blends to enhance the properties of 80 % BC soil and 20 % sodium bentonite. Specific soil properties of 0, 10, 20, 30, 40 % GGBS, flyash blend and 1 % lime addition for the same proportion. Authors noted that the addition of binder or lime-binder mixture liquid limit decreased from 78 % to 54 % and 56 %, respectively, the very same plastic limit was 45 % to 32 % and 49 % to 41 % for 40 % binder. Shrinkage limit increases with content of the binder. UCS testing was done for the curing period 7, 14, 28 days for soil and binder.

V. S. Aigbodion, S. B. Hassan, T. Ause, G.B. Nyior Experimented and given knowledge to characterize the bagasse in order to discover the suitability of the metallurgical and material industries. The author noted that the XRD examination of ash exposes that Quartz, Cliftonite, Moissanite and Titanium oxide are the main compounds, and that carbon and silica have the highest percentage of all compounds and elements. The SEM / EDAX data shows the appearance of prismatic, spherical and fibrous structures, which are also comparable to the XRD analysis.

S. B. Hassan, T. Ause, G.B. Nyior explored bagasse ash as a product using a variety of techniques to find its applicability in various fields. The particle size distributions of bagasse ash have been calculated using the (AFS) specification. The diffraction patterns of the ash sample were assessed through an X ray diffraction examination, a microscopic analysis by a scanning electron microscope (SEM) complemented by EDAX. Results show that the presence of oxides and carbon in ash has been shown to be ideal for refectory and ceramic products such as insulation, membrane filters and structural ceramics; fine particulate size characteristics imply that bagasse ash can be used as sand moulding during casting operations

1.3 Conclusion :

The study on the utilization of stabilized fly ash-lime sludge composite as a pavement base course layer provides valuable insights into the potential of using industrial by-products in road construction. The following key conclusions can be drawn from the research:

1. Improved Engineering Properties: The stabilization of fly ash with lime sludge enhances the material's engineering properties, such as strength, durability, and load-bearing capacity. This makes the composite suitable for use in pavement base courses, offering a viable alternative to traditional materials like crushed stone or gravel.
2. Environmental Benefits: Utilizing fly ash and lime sludge, both industrial waste products, in pavement construction promotes environmental sustainability. This approach reduces the need for natural resources and helps in the effective management of waste, reducing the environmental footprint of construction activities.
3. Cost-Effectiveness: The use of stabilized fly ash-lime sludge composite can lead to cost savings in road construction projects. The availability and low cost of these materials, coupled with their adequate performance, can lower the overall expenses associated with pavement construction and maintenance.
4. Feasibility and Practicality: The study demonstrates that it is feasible to use fly ash-lime sludge composites in real-world pavement applications. The material's ability to meet the required standards and its performance under traffic loads indicate that it can be effectively integrated into existing construction practices.
5. Long-Term Performance: The research suggests that the stabilized composite can provide long-term performance in pavement base layers. However, continued monitoring and further research are recommended to assess the material's durability over extended periods and under varying environmental conditions.

In conclusion, the stabilized fly ash-lime sludge composite shows great promise as an alternative material for pavement base courses. Its adoption could lead to more sustainable, cost-effective, and efficient road construction practices, contributing positively to both the environment and the economy.

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