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Comprehensive Review on Gauging Engineering Properties of Red Mud-Fly Ash-Marble Dust Amalgamation

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ABSTRACT

The maximum dry unit weight increases with the increase in the percentage of red mud and also the optimum moisture content does. The similar trend is followed with the addition of marble dust. After the limited addition of red mud/marble dust to the fly ash the maximum dry unit weight noticed to be decreased. By keeping this in view the optimum/reference mix is fixed as 70 %red mud+ 30 % fly Ash+ 8 % marble dust. Waste transformation is the powerful term used as part of effective solid waste management technique. Under this preview, the definitive objective should be to convert completely waste material produced into useful engineering material. Civil engineers around the world are in search of utilization of Red mud, Fly ash and Marble dust, which are required both for cost effective solutions for roads and for preservation of scarce natural resources. At the end, we found that large scale utilization of this waste material is possible in these fields. Also, in order to utilise these waste materials, there has been a growing interest among the researchers to study their engineering properties for civil engineering application. In this context, red mud-fly ash-marble dust mix holds promise for civil engineering application.

INTRODUCTION

The electricity generation in the country like India will remain predominantly coal-based for a couple of coming decades leading to generation of tonnes of fly ash. Fly ash is waste by-product from thermal power plants which use coal as a fuel. It is estimated that about 100 million tons of fly ash is being produced from different thermal power plants in India consuming several thousand hectares of valuable land for its disposal causing severe health and environmental hazards. Electricity production from coal based thermal power plants are major source of fly ash production. For the total installed capacity of 80548 MW, the country's total coal demand in 2010-12 was 730 Mt. Total fly ash generated during the year was 131.09 Mt and the ash utilized was 73.13 Mt. The percentage ash utilization during the said year was 55.79%. The forecast estimates the increase in coal demand by the year 2031-32 is approximately 2000 Mt. Fly ash is an effective agent for chemical and/or mechanical stabilization of soils. Moreover, the consistency and abundance of fly ash in many areas present unique opportunities for use in structural fills and other highway applications.

Red mud is a solid waste residue of the digestion of bauxite ores with caustic soda for alumina production. Its disposal remains a worldwide issue in terms of environmental concerns. Enormous quantity of red mud is generated worldwide every year posing a very serious and alarming environmental problem. Depending on the raw material processed, 1–2.5 tons of red mud is generated per ton of alumina produced . In India, about 4.71 million tons/annum of red mud is produced which is 6.25% of world's total digestion with sodium hydroxide at elevated temperature and pressure .During the past decades, extensive work has been done by a lot of researchers to develop various economic ways for the utilization of red mud. This work is an effort to analyze the utilization of red mud which would be very useful in the context of environmental concerns for disposal and utilization of red mud. Marble is one of the most important materials used in buildings since ancient times, especially for decorative purposes. Marble dust powder is produced from processing plants during the sawing and polishing of marble blocks and about 25% of the processed marble is turned into powder form. Disposal of marble dust material from the marble industry is one of the environmental problems worldwide today. In India, the marble processing is one of the most flourishing industry. Marble industries in India grow by more than 3500 metric tons of marble powder slurry per day. Around 4000 marble mines and 1100 marble processing units spread over 16 districts

of Rajasthan .Marble dust powder finds bulk utilization potential in road pavement layers and in embankments. In this scenario, it is planned to study the engineering properties such as unconfined compressive strength, split tensile strength, durability, bearing ratio on red mud-fly ash-marble dust mix in order to assess its potential for civil engineering application.

LITERATURE REVIEW

The quantities of these waste materials produced around the world are huge and causing disposal problems that are both financially and environmentally expensive. One method to reduce some portion of the fly ash and red mud disposal problem is by mixing them together in the presence of stabilizer like marble dust powder and utilizing the composite so produced for civil engineering applications. Further, in India, extensive road network is under construction. Civil engineers around the world are in search of new alternative materials which are required both for cost effective solutions for roads and for conservation of scarce natural resources. The chapter briefly reviews the literature related to compaction, unconfined compressive strength, unconsolidated undrained strength, durability and bearing ratio on fly ash, red mud and fly ash-red mud-marble dust mixes As reported by that the grain size distribution of fly ash is independent of lime content, for high calcium fly ash, chemical and mineralogical differences have been observed for different size fractions.

Compared to low calcium fly ash, optimum moisture content is low and maximum dry density is high for high calcium fly ash. Optimum moisture content is directly proportional and maximum dry density is inversely proportional to the carbon content. The mode and duration of curing have significant effect on strength and stress–strain behaviour of compacted fly ash that factor like lime content (CaO), iron content (Fe_2O_3). In short loss of ignition, morphology, and mineralogy govern the geotechnical properties of fly ashes. Studies were carried on the strength and other geotechnical characteristics of pond ash samples by collected from inflow and outflow points of two ash ponds in India. Strength characteristics were investigated using consolidated drained (CD) and undrained (CU) triaxial tests with pore water pressure measurements, conducted on loose and compacted specimens of pond ash samples under different confining pressures. Ash samples from inflow point exhibited behaviour similar to sandy soils in many respects. They exhibited 38 higher strengths than reference material (Yamuna sand), though their specific gravity and compacted maximum dry densities are significantly lower than sands. Ash samples from outflow point exhibited significant differences in their properties and values, compared to samples from inflow point. Shear strength of the ash samples from outflow point are observed to be low, particularly in loose state where static liquefaction is observed. Bose [23] used fly ash to stabilize highly plastic clay.

The geo-engineering properties such as, Atterberg limits, grain size distribution, linear shrinkage, free swell index, welling pressure, compaction characteristics, unconfined compressive strength and CBR value of virgin clay and stabilize with fly ash were evaluated. Expansive soil was stabilized with various proportion of fly ash. The results showed that plasticity index of clay-fly ash mixes decreased with increase in fly ash content. Thus addition of fly ash increases its workability by colloidal reaction and changing its grain size. The free swell index value and swelling pressure of expansive clay mixed with fly ash decreased with increase in fly ash content. Furthermore, addition of fly ash reduced the optimum moisture content but the dry density increased and unconfined compressive strength of clay-fly ash mixes is found to be maximum. So, it is concluded that the fly ash has a good potential for improving the engineering properties of expansive soil.

Studies on Red Mud

Various researchers have worked on the properties of red mud to judge its suitability as a construction material in various fields of civil Engineering Studies pertaining to geotechnical characterization of red mud are limited and are presented as follows. As investigated the different uses of red mud waste, the potential use of red mud for the preparation of stabilization material. He studied the effects of red mud on the unconfined compressive strength, hydraulic conductivity, and swelling percentage of compacted clay liners as a hydraulic barrier. The test results show that compacted clay samples containing red mud and cement–red mud additives have a high compressive strength and decreased the hydraulic conductivity and swelling percentage as compared to natural clay samples. Consequently, it is concluded that red mud and cement–red mud materials can be successfully used for the stabilization of clay liners in geotechnical applications. Studied the potential use of red mud for synthesis of inorganic polymeric materials through geo-polymerization process.

The results showed that the produced materials have high compressive strength, very low water absorption, satisfactory apparent density, and excellent fire resistance. Therefore, this work proved that the red mud-based inorganic polymeric materials have promising properties and have the potential to be used as artificial structural elements in the construction sector. Observed that red mud is of low plasticity with liquid limit (LL) of 45% and plasticity index (PI) of 10% with relatively high specific gravity (GS) of 2.8-3.3. Due to its lack of clay mineralogy, these wastes show many geotechnical properties similar to clayey tailings found in other mineral processing [e.g., mineral sands, gold, etc.] Studied that red mud can be used as a road-base, levee material, fertilizer fillers and synthetic soils, which is stacked and compacted by heavy

equipment. The red mud roads have a good condition even after a long period of time. Environmental concerns were addressed during development. Extensive TCLP results show no metal leachate problems. Treated red mud using sulphuric acid, which deactivates it along with the addition of Fe-Al coagulants before heat treatment to produce red mud building materials meet specifications. The reuse of red mud in the ceramic industry is also posssible. Carried out investigations on physiochemical and mechanical properties of red mud at a site in the United Kingdom. Based on a set of laboratory tests conducted on the red mud, the compression behaviour found to similar to clayey soils, but frictional behaviour closer to sandy soils. The red mud appears to be "structured" and has features consistent with sensitive, cemented clay soils.

Studies on Marble Dust

Studied the potential of marble dust as a stabilizing additive to red tropical soils. The parameters tested included the particle size distribution, specific gravity, Atterberg limits, the standard compaction characteristics, the compressive strength and the California bearing ratio (CBR).The strength tests were repeated after normal 28 day curing of the treated samples and also after accelerated 24 h curing at temperatures of 40°C, 60°C and 80°C.Results showed that the geotechnical parameters of red tropical soils are improved substantially by the addition of marble dust; plasticity was reduced by 20 to 33%and strength and CBR increased by 30 to 46%and 27 to 55% respectively. The highest strength and CBR values were achieved at 8%marble dust. investigated the new technology of marble slurry waste utilization in roads. Study indicates besides embankment construction with this waste, 20-30% of soil can be replaced by MSD for subgrade preparation. Technology has been validated by taking full scale trials in the field. Investigate the effect of marble dust on the strength and durability of rice husk ash stabilized expansive soil. Optimum percentage of RHA found out to be 10%, the UCS and soaked CBR of the soil increases up to 20% addition of marble dust. Further from durability results it is found that soil becomes durable after the addition of the marble dust and RHA.

Studied the influence of marble dust, fly ash and beas sand on the subgrade characteristics of the expansive soil. The series of test conducted in laboratory on fly ash, sand stabilized black cotton soil which further blended with 0-20 % marble dust and concluded that the soaked California bearing ratio value of black cotton soil improved significantly i.e. from 2.69% to 8.07% approximately 200% with addition of sand, fly ash and marble dust in appropriate proportion. Reviewed the improvement of engineering characteristics of locally available soil mass by use of marble dust. Results shows the addition of marble powder to soil improved the gradation of soil, reduces swelling characteristics, increased the maximum dry density, reduced the optimum moisture content increases shear resistance and reduced the permeability as well. Studied to incorporate marble and granite wastes in green concrete production tests revealed that 10% substitution of sand by the marble waste in the presence of a super-plasticizing admixture provided maximum compressive strength at the same workability level.

EXPERIMENTAL WORK

Marble Dust Marble dust is generated as a by-product during cutting of marble. The waste is approximately in the range of 20% of the total marble handled. The stabilizer material used in this study was marble dust. The Marble dust was obtained from a marble cutting and polishing industry in Rajasthan. The specific gravity of the marble dust id 2.5743. The marble dust used in the work is shown in Fig. 1.

Fig. 1. Marble dust used in the work

Tests Performed

Table 1 gives the list of experiments that are conducted and relevant codes of practice that are adopted in this study

Table 1 Tests performed and their relevant codes

Tests	I.S. Code
Standard proctor compaction test	IS: 2720 (Part VII-1980)(Reaffirmed 2011)
Unconfined compressive strength	IS 4332: Part (V-1970) (Reaffirmed 2001)
Split tensile strength	IS: 10082-1981
Durability test	IS 4332: Part IV (1968)
Bearing ratio test	IS 2720: Part XVI (1987) (Reaffirmed 1997)
Unconsolidated Undrained Triaxial Tests	IS 2720: Part XI (1993)

Sample Preparation for Unconfined Compression Strength Tests

The fly ash and red mud was crumbled lightly with the help of a pestle to segregate the individual particles. A metallic mould (Fig. 2) having dimensions of 38 mm diameter and 76 mm height as inner dimensions along with two detachable collars at both ends was used to prepare cylindrical samples for unconfined compression strength (UCS) tests.

Fig. 2 Cast iron mould with detachable collars for UCS sample

In the reference mix of red mud 70% and fly ash 30% are mixed together in which 8% marble dust by weight of mix is added and samples are prepared by adding the required amount of water (corresponding to optimum moisture content (OMC), There was no significant interpretation from the compaction studies for fixing the reference mix. The composite of red mud 70% + 30 % fly ash + 8% marble dust was fixed as reference mix from the UCS as detailed in. Sample should be compacted uniformly by compressing statically from both the ends. The sample should be sufficiently compacted so that it attains the required dimensions. The compacted sample is then extracted with the help of mechanical sample extractor and then the sample is kept in an air tight polythene bag to keep the moisture intact within the sample and then the polythene is kept inside an irtight plastic container (Desiccator) and left for curing.

Studies on Red Mud-Fly Ash Mixes

Made efforts at CBRI to produce burnt clay bricks by partially replacing the clay with red mud and fly ash. Attempts made to contain a small per cent of lime and combine it at OMC. A maximum wet compressive strength of 3.75 MM/m2 with 5 % lime and 4.22MN/m2 with 8% lime has been obtained after 28 days of casting. The primary aim was to utilize red mud as material for low cost shelters. Mixed red mud and fly ash to prepare glass-ceramic products that can be used to decorate the exteriors in the building industry. The process involves addition of small quantity of glass former along with traces of nucleating agents to aid crystallization, to a specific mixture of fly ash, red mud and spent pot lining. Assess the potential of fly ash to neutralize red mud slurry, an alkaline residue from bauxite ore processing for alumina production, and studies indicate that large doses of fly ash are required to neutralize red mud, and the rate of neutralization is slow. Further the slow kinetics of neutralization imply a long time for neutralization, making fly ash a feasible but less-than-optimal bauxite residue neutralization agent.

Investigated the geopolymerization of red med and fly ash for civil infrastructures applications using very limited waste materials, red mud and fly ash ratio varied to assess the influence on mechanical properties. The UCS testing shows that these factors have significant influence on the mechanical properties, the UCS ranges from 3-13 MPa and the high values are comparable with certain types of Portland cement, and it suggests that two wastes can be used to produce geopolymers that may replace Portland cement. Studied the development of low cost remediation methods using various industrial residues which do not alter the physical and chemical properties of soils plays a leading role. This would also reduce waste disposal giving new value to industrial wastes through converting them into industrial by-products. Studied the behaviour of waste plastic content on stabilized red mud and fly ash and red mud-fly ash mix and reported an appreciable increase in the dry density of the mix but the increase was not much after 2% addition of plastic.

Developed paving blocks by synergistic use of red mud and fly ash using geopolymerization, the Red mud and fly ash mix has been used for ambient temperature geopolymerization. Red mud addition enhanced the intensity of reaction and structural reorganization. Paving blocks with 10–20% red mud meets IS 15658 specification. Conducted experimental study for development of brick using red mud and fly ash mix and compared with the ordinary bricks, studies shows study that a red mud brick shows better performance than ordinary brick. Red mud + fly ash brick is having the lowest water absorption and highest compressive strength Moreover, the strength increases with curing period. [49] studied the effect of fly ash and phosphogypsum on properties of expansive soils, their test results on clayey soil treated with different dosages of stabilizer shows that the increase in PG with FA content increases the volume stability as well as the strength of the soil.

The study on addition of 6% PG with 5% FA for at most 60 days indicates the increase of the unconfined compressive strength of the clay soil and the strength might increase if extended beyond 60 days. Strengths of stabilized clays increase with curing time and admixture contents. Studied the stabilization of red mud by lime, gypsum for using it as geotechnical material in civil construction, their test data shows that with 12% lime with 1% gypsum the mix has shown higher UCS value compared to other percentages for 7 days of curing. A higher value of CBR i.e. 7.9% was obtained for 12 % Lime. Studied the utilization of red mud using fly ash for ground improvement techniques and from the results the maximum dry density increases with the increases with the increase in red mud but OMC increases because red mud is heavy weight and surface area increases with percentage.

CONCLUSION

A comprehensive review is carried out to study the compaction and unconfined compressive strength of Bentonite stabilized with lime-phosphogypsum and random inclusion of sisal fibers. The study brings forth the following conclusions.

1. The dry unit weight and optimum moisture of Bentonite- lime mix increased with the addition of phosphogypsum.

2. The dry unit weight of the reference mix decreased and the optimum moisture content increased with the addition of sisal fibres.

3. The unconfined compressive strength of the Bentonite increased with the addition of 8% lime. Beyond 8 %, the unconfined compressive strength decreased.

4. The unconfined compressive strength of the Bentonite + 8% lime increased up to 8% phosphogypsum. Beyond 8%, the unconfined compressive strength decreased.

5. The unconfined compressive strength of the reference mix increased with the addition of sisal fibers up to 1%. The trend was reversed after that.

6. The unconfined compressive strength of Bentonite lime-phosphogypsum increased with the addition of sisal fibers and with the increase in curing period.

7. The improvement in post peak region was better for the reinforced sisal fibers as compared to the unreinforced soil.

8. The optimum value of lime content, phosphogypsum content and sisal fiber content in Bentonite- lime phosphogypsum-sisal fiber mixtures may be taken as 8%, 8 % and 1%, respectively.

On the whole, this study has attempted to provide an insight into the compaction and unconfined compressive strength of Bentonite stabilized with lime and phosphogypsum reinforced with sisal fibres. The improved behavior of the Bentonite-lime phosphogypsum-sisal fiber mixture will boost the construction of temporary roads on such problematic soils. Further, its use will also provide environmental motivation for providing a means of consuming large quantities of phosphogypsum and sisal fibers.

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