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AN EXPERIMENTAL STUDY ON ENCASEMENT OF STONE COLUMNS IN COMPACTED POND ASH

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Abstract: Soil reinforcement can be an ideal solution for improvement of clay. Out of other conventional method, Stone columns are effectively being used for ground improvement, particularly for flexible structures such as road embankments, oil storage tanks, etc. The load capacity of the Stone columns mainly depends on the shear strength of the surrounding Black cotton soil. Stone columns are extensively used to improve the bearing capacity of poor ground and reduce the settlement of structures built on them. A stone column is one of the soil stabilization methods that are used to increase strength, decrease the compressibility of soft and loose fine graded soils, accelerate a consolidation effect and reduce the liquefaction potential of soils. They are mainly used for stabilization soft soil such as soft clays, silts and silty-sands. Laboratory investigation has been carried out to study the influence of area replacement ratios and length ratios of stone columns on load carrying capacity of organic clay treated with stone columns. The load capacity increases as the area replacement ratio and length ratio increase and length ratio of one gives the maximum load capacity.

Keywords: Stone column, Pond ash, Soil stabilization, Bearing Capacity, Soft soil.

1.0 INTRODUCTION

Current ash generation in India is about 112 million metric tons and its current utilization is only about 42 million metric tons (38% of ash generated). Rest of the unutilized ash is being disposed off on to the ash ponds. Disposal of this enormous amount of fly ash faces problem of huge land requirement, transportation, ash pond construction and maintenance. Also to meet the rising energy demand power generating industries in India growing rapidly. India shall continue to depend on coal as the prime source of energy. In India environmental issues became a major concern in the 21st century so the solid waste management for coal based thermal power plants shall continue to be a major area of priority.

Pond ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. When mixed with lime and water the fly ash forms a cementitious compound with properties very similar to that of Portland cement. Because of this similarity, fly ash can be used to replace a portion of cement in the concrete, providing some distinct quality advantages. The concrete is denser resulting in a tighter, smoother surface with less bleeding. Fly ash concrete offers a distinct architectural benefit with improved textural consistency and sharper detail. Pond Ash is also known as Fly ash, Pulverized Flue ash, and Pozzolona. Fly ash closely resembles volcanic ashes used in production of the earliest known hydraulic cements about 2,300 years ago. Those cements were made near the small Italian town of Pozzuoli - which later gave its name to the term "pozzolan". A pozzolan is a siliceous or siliceous/aluminous material that, when mixed with lime and water, forms an cementitious compound. Fly ash is the best known, and one of the most commonly used, pozzolans in the world. Instead of volcanoes, today's fly ash comes primarily from coal-fired electricity generating power plants. These power plants grind coal to powder fineness before it is burned. Fly ash - the mineral residue produced by burning coal - is captured from the power plant's exhaust gases and collected for use. Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. The difference between fly ash and Portland cement becomes apparent under a microscope. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. That capability is one of the properties making fly ash a desirable admixture for concrete.

1.1 ADVANTAGES OF STONE COLUMNS

Stone columns have following advantages:

1. Stone Columns are designed to reduce settlements of compressible soil layers in order to be able to build most structures with shallow footings and slab-on-grades on very soft soil;
2. When applicable, their draining characteristics result in an increase in the time rate of consolidation settlement in soft cohesive soil;

3. Because they are made of compacted granular material, no curing period is necessary and no cut-off to the shallow footing grades are required as the excavation of the footing can immediately follow the installation of the stone columns down to the required elevation;
4. High production rates;
5. Stone Columns are also well-adapted to the mitigation of liquefaction potential thanks to the combined effect/advantage of their draining potential and the increase of shear strength and stiffness of the improved soils.

2.0 LITERATURE REVIEW

Deb et al Proposed a combined simulation-optimization-based methodology to identify the optimal design parameters for granular based stone column improved soft soil. The methodology combines a finite difference based simulation model and an evolutionary multi objectives optimization model. For minimization of maximum settlement and minimization of differential settlement subjected to stress constraints and maximization of degree of consolidation subjected to stress constraints a combined optimization simulation technique is used. It shows that modular ratio and ultimate stress carrying capacity of stone column are the two important parameters for optimal design.

Bera et al. implemented on the effective utilization of pond ash, as foundation medium. A series of laboratory model tests have been carried out using square, rectangular and strip footings on pond ash. The effects of dry density, degree of saturation of pond ash, size and shape of footing on ultimate bearing capacity of shallow foundations are presented in this paper. Local shear failure of a square footing on pond ash at 37% moisture content (optimum moisture content) is observed up to the values of dry density 11.20 kN/m3 and general shear failure takes place at the values of dry density 11.48 kN/m3 and 11.70 kN/m3. Effects of degree of saturation on ultimate bearing capacity were studied. Experimental results show that degree of saturation significantly affects the ultimate bearing capacity of strip footing. The effect of footing length to width ratio (L/B), an increase in ultimate bearing capacity of pond ash, is insignificant for $L/B \geq 10$ in case of rectangular footings. The effects of size of footing on ultimate bearing capacity for all shapes of footings viz., square, rectangular and strip footings are highlighted.

Ghosh et al have studied the Scanning electron micrographs of modified fly ash specimen and show that the addition of lime to fly ash produces a compact matrix and that a long curing period is necessary to achieve more compact structures. The formation of a densified interlocking network of reaction products is prominent for the mixes containing gypsum, cured for 10 months at 307C. The Ca:Si ratio obtained from the EDAX analysis varies from 1.690 to 0.224 depending on the mix proportions and curing period. This variation may be attributed to the formation of different hydration products. The compact matrix, mainly due to pozzolanic reaction products as observed in SEM micrographs for the specimens stabilized with high lime (10%) and gypsum (1%) and cured for a longer curing period, is responsible for high strength and durability. The permeability has reduced to 10^{-7} cm/s due to the reduction in interconnectivity of the pore channels of the hydration products. 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. Thus this modified material with improved engineering characteristics may find potential applications in different civil engineering fields.

Jakka et al. studied carried on the strength and other geotechnical characteristics of pond ash samples, collected from inflow and outflow points of two ash ponds in India, are presented. 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.

Chand et al. presented the effects of lime stabilization on the strength and durability aspects of a class F pond ash, with a lime constituent as low as 1.12%, are reported. Lime contents of 10 and 14% were used, and the samples were cured at ambient temperature of around 30°C for curing periods of 28, 45, 90, and 180 days. Samples were subjected to unconfined compression tests as well as tests that are usually applied to rocks such as point load strength tests, rebound hammer tests, and slake durability tests. Unconfined compressive strength (UCS) values of 4.8 and 5.8 MPa and slake durability indices of 98 and 99% were achieved after 180 days of curing for samples stabilized with 10 and 14% lime, respectively. Good correlations, that are particularly suitable for stabilized materials of low density and low strength, have been derived for strength parameters obtained from UCS tests, point load strength tests, and Schmidt rebound hammer tests, and also between UCS and slake durability index.

Ghosh et al. presents the laboratory test results of a Class F pond ash alone and stabilized with varying 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. Standard and modified Proctor compaction tests have been conducted to reveal the compaction characteristics of the stabilized pond ash. Bearing ratio tests have been conducted on specimens, compacted at maximum dry density and optimum moisture content obtained from standard Proctor compaction tests, cured for 7, 28, and 45 days. Both un-soaked and soaked bearing ratio tests have been conducted. This paper highlights the influence of lime content, PG content, and curing period on the bearing ratio of stabilized pond ash. The empirical model has been developed to estimate the bearing ratio for the stabilized mixes through multiple regression analysis. Linear empirical relationship has been presented herein to estimate soaked bearing ratio from un-soaked bearing ratio of stabilized pond ash. The experimental results indicate that pond ash-lime-PG mixes have potential for applications as road base and sub base materials.

Rajasekaran et al Apart from modifying the plasticity and swelling characteristics, lime can stabilize the soils through cementation giving rise to visible increase in strength and stiffness due to pozzolanic reactions and can significantly improve the long term performance of the stabilized soils**.**

3.0 BEARING CAPACITY OF STONE COLUMNS

Footing load tests were carried out on untreated pond ash specimens compacted to their corresponding MDD and OMC .This test was carried out to study the load settlement behavior of pond ash reinforced with stone column in different length ratio of their respected area ratio. By increase of length ratio from 0.25 to 1the failure stress of varying area ratio 10,20,30,40% is 2.844 to 4.124 kg/cm^2,3.26 to 4.868 kg/cm^2,4.133 to 6.234 kg/cm^2 and 4.767 to 7.841 kg/cm^2 respectively. From the graph it can be concluded that for each length ratio the failure stress increases linearly with the area ratio. With the decrease in the length ratio, the failure strain is observed to be increasing. This is due to the fact that, for the case of higher length ratio the stone column- having a higher angle of friction and higher density- leads to a lower strain. For the case of low length ratio, the particles of the stone column and the pond ash settle on application of the load. Also, the maximum failure stress depends on the maximum area ratio and length ratio. After reaching the maximum failure stress, the failure zone rises to the upper surface of pond ash bed as shown in Figure.

4.0 RESULT & DISCUSSIONS

It was found that from direct shear test as the increase of compaction energy the dry density, angle of internal friction also increasing gradually. However the OMC decreases drastically with increase of compaction energy. When the same sample was conducted on direct shear test at saturation same thing has happen as OMC of respective compaction energy and dry density, angle of internal friction also increasing gradually. However the OMC decreases drastically with increase of compaction energy. From the both case at OMC and saturation which result has got at saturation dry density and angle of internal friction is less than OMC result. Cohesion value of pond ash has increased due to addition of water and compaction energy, due to compaction energy the particle get come closer, the pond ash has some surface activity due to which cohesion value has increased. On the case of saturation the particle has lose its strength of surface activity and cohesion value has decreased as compare to OMC. Angle of internal friction basically depends upon compaction energy it will show maximum at OMC, due to the maximum compaction energy on the case of saturation angle of internal friction has decreased due to water particle will behave as a lubricate effect on the surface of ash pond particle.

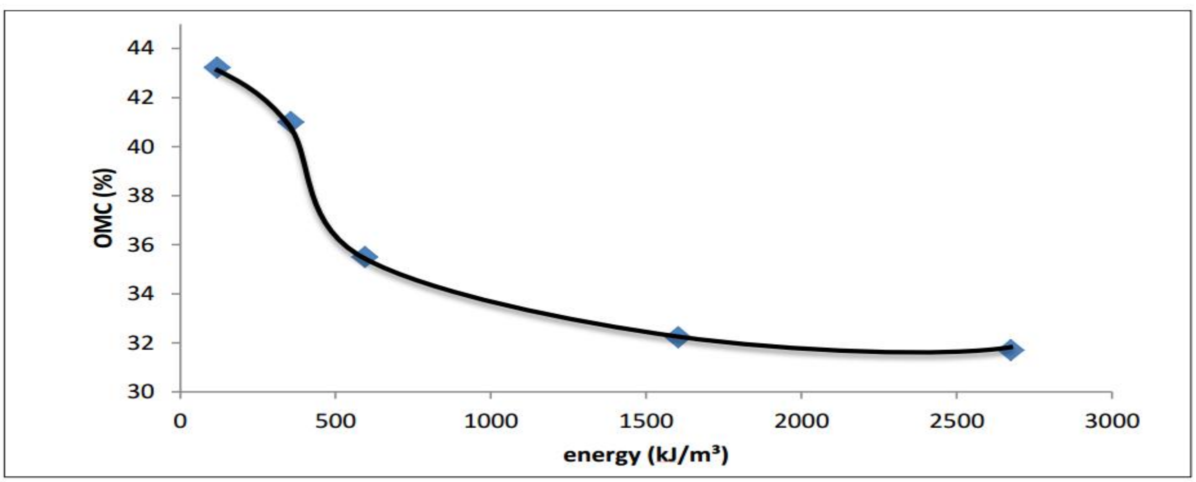

Fig. 1: Variation of OMC at different compactive level

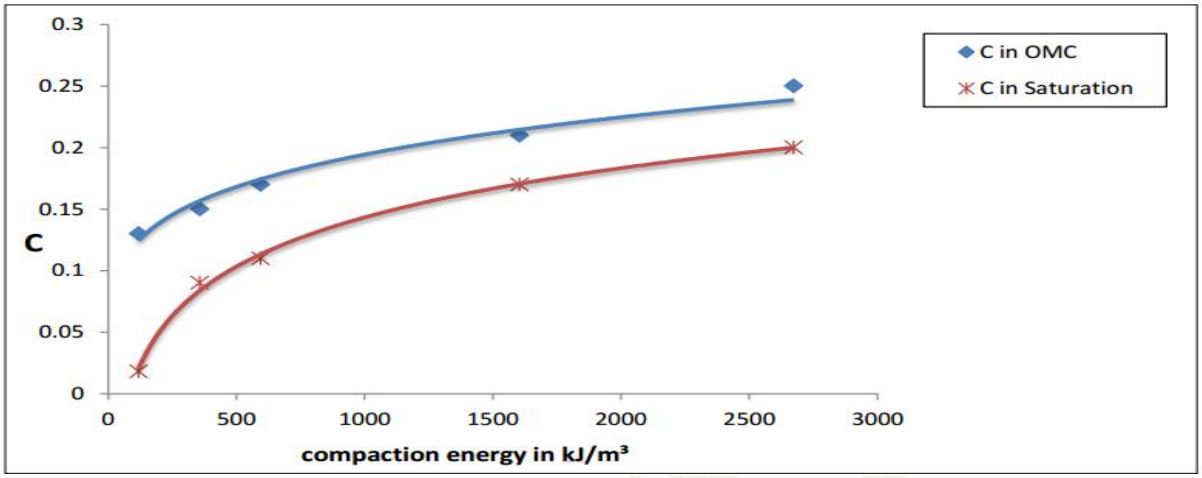

Fig 2: Variation of unit cohesion at OMC and saturation under different Compactive level

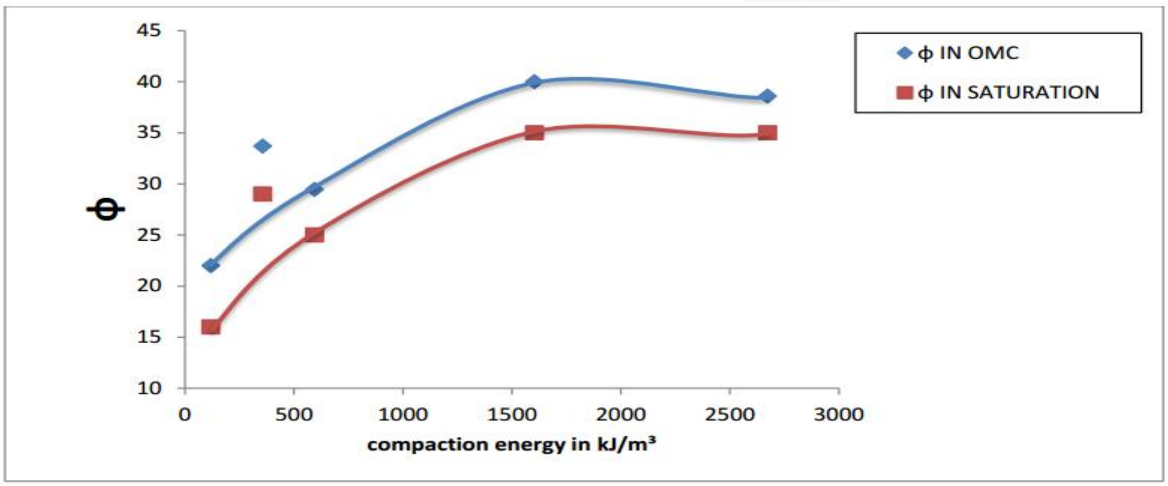

Fig 3: Variation of frictional angle at OMC and saturation under different compactive level

5.1 CONCLUSION

1. An increase in compaction energy results in closer packing of particles thus increase in dry density whereas the optimum moisture content decreases.
2. Pond ash possesses low unit cohesion. But both the unit cohesion and frictional angle is found to increase with increase in compaction energy. The increase in frictional angle is attributed to closer packing and interlocking of particles
3. In the footing load test the failure stress increases linearly with the area ratio. With the decrease in the length ratio, the failure strain is observed to be increasing. This is due to the fact that, for the case of higher length ratio the stone column- having a higher angle of friction and higher density- leads to a lower strain.
4. For the case of low length ratio, the particles of the stone column and the pond ash settle on application of the load. However, since pond ash forms a major portion of the specimen, the strain caused is higher than for the larger length ratios.
5. It shows higher stress for higher area ratios. Similarly higher stresses for a particular area ratio were observed for higher length ratios. Because of the higher angle of internal friction it has, stone column plays a major part in increasing the strength of pond ash.

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