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Correlation of Compressibility Behaviour with Activity of Clay

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ABSTRACT: Expansive soils or swelling soils are now a day considered as global problems that pose unpredictable problems for the engineers. They have severe consequences and budding natural vulnerability which may be the root cause to extensive damage to life and engineering structures. This type of soil swell coming in contact with the diffuse double layer and shrink when they dry out. The eradication to this problem depends on early detection and proper stabilization. Adding cementing admixture such as lime, industry emitted fly ash with soil results in improved geotechnical properties. Moreover , the bulk use of fly ash from thermal power plants also help the environmental sustainability to some extent .This paper illustrates the visible changes occurring due to stabilization that will further add to enhanced bearing capacity and strength. Stabilizing agents such as lime further alters the physical property of expansive soil reducing the swelling-shrinkage properties hence reducing the probability of settlement. In this study, soil brought from Sunderpada area of Bhubaneswar, India was stabilized using fly ash (Bhusan Steel Plant). When mixed with chemical additive such as quick lime in different proportion, further changes the clay particle by colloidal action. The index properties along with the Atterberg limits, particle size distribution, Light weight compaction characteristics, free swell index, swelling pressure, unconfined compressive strength and CBR value of both unstabilized and stabilized soil were tested and compared. Lime (0-6) % and fly ash (0-70) % were added to expansive soil and above tests were done.

Keywords: Soil, Fly ash, Lime, Plasticity characteristics, Activity.

Abbreviations: SL, Shrinkage Limit; Ip, Plasticity Index; FSI, Free Swell Index; OMC, Optimum moisture content; A, Activity; UCS, Unconfined Compressive strength; DFS, Differential free swell.

I. INTRODUCTION

The long term settlement problem of Structures found on expansive soils that are subjected to differential deflections and in turn cause distresses on soil can be stabilized by compacting suitable percentage of cementing agents by weight of soil. Lime in the form of quick lime and hydrated lime having sufficient calcium content are used for stabilization purpose [1-4]. Lime stabilization is done in soils having predominant clay size particles as effective ground improvement technique .The admixture mix of fly ash-lime results in long term strength gain and permanent reduction in shrinking, swelling and plasticity property of soil .With the course of time it also offers adequate durability that resist the detrimental effects of cyclic freezing and thawing. When pulverized coal is burnt to generate electrical power in thermal power plants, bulk quantity of fly ash are produced which can either be collected as slurry or can be collected by precipitators [5]. Fly ash is a major by-product. However, the self cementing properties and high calcium oxide in class-C fly ash make it useful raw material in brick industry and for making kerb stones and mosaic tiles. Utilization of fly ash is considered to be eco-friendly as it’s a recycled material. Majorly fly ash contains oxides of silicon and calcium. It can be replaced in place of cement, with the benefit of reducing green house gas emission. Similarly if used in bulk quantity whether in cement industry or stabilizing soil, the disposal volume also reduces.

Relationship between Atterberg Limit and clay content has also been established earlier [9, 12]. Rajsekaran and Rao (2000, 2002) examined the compressibility behaviour of lime-treated marine clay investigated [10-11]. Fly ash which is a major byproduct of thermal investigated the effect of age on strength parameters and hydraulic conductivity of fly ash which is a major byproduct of thermal power plants. Polidori (2007) illustrated the relationship between atterberg limit of clay contents [8]. Harichane *et al*., (2011) presented a study on the effect of natural pozzolana, lime and their combinations on Atterberg limits [7]. This research work helps to find out a better way of utilizing fly ash in a larger volume for ground improvement. The results mainly conclude on a positive note of improving soil properties as alteration in swelling parameter is directly related to index properties. The conclusions are based on the tests carried out on various soil-fly ash mixes selected for the same**.** The addition of fly ash reduces the plasticity characteristics of expansive soil. Liquid limit, plastic limit, plasticity index, linear shrinkage decreased drastically and shrinkage limit increased with the addition of fly ash. Here, the plasticity characteristics along with swelling properties are analyzed using regression curve. The regression curve interprets the relationship between plasticity Index, Activity of clay, Liquid Limit, swelling index of untreated and stabilized soil-fly ash-lime samples. The regression relation clearly shows how the plasticity characteristics get affected by fly ash-lime addition.

II. MATERIALS AND METHODS

In this work the soil brought from Sunderpada area of Bhubaneswar was stabilized using fly ash-lime mixes. The fly Ash was collected from Bhusan steel Plant, Angul, Odisha. The fly ash is collected from furnace using electrostatic precipitators. The precipitators collect and deposit the ash into hoppers which have an opening at the bottom end which is opened and closed by means of a valve system. The fly ash was brought from the hoppers. Quick lime (CaO) was bought and then water was added to it. The quick lime by chemical reaction with water produces Slake lime ($Ca(OH)_2$). This slake lime was powdered and sieved through 1mm sieve and then the powder collected was used in the further experiments [9].

This paper presents laboratory test results to show the effect of addition of fly ash on the engineering behavior of the expansive soil in terms of grain size distribution, Atterberg limits, compaction characteristics, free swell Index properties, swelling pressure and unconfined compressive strength as per IS code. The soils used in this study are Soil collected from sunderpada area of Bhubaneswar and the fly ash collected from Bhusan steel Plant (Anugul). The expansive soil is mixed with various proportions of fly ash ranging from 0, 20, 40, 60, 80, 90 percentages and lime ranging from 2 to 6%. The geo-engineering properties and strength parameter of soil-fly ash-lime mixture have been illustrated in this work. The particle size distribution was studied for the different mixes by hydrometer analysis. Specimens for swelling pressure were prepared using standard proctor compaction effort of 592.8 kJ/m^3 with optimum water content and maximum dry weight in consolidation apparatus according to IS:2720(part XLI)-1977. Specimens for the unconfined compressive strength test was prepared by using sample of 50mm diameter and 100mm height were prepared under the optimum water content and dry density corresponding to 95% of maximum dry unit weight of soil. The free swell index was obtained according to IS : 2720 (Part XL) and swelling pressure was obtained by using odometer apparatus. The physical and chemical composition of fly ash are given respectively in Table 1 and 2.

III. RESULTS AND DISCUSSION

Atterberg limits and activity of clay together act as important soil parameter. Stabilization with fly ash can change the expansive soil structure and decrease the adsorbed layer and flocculate the particles increasing the coarser particles content by altering the soil grain type of finer soil particles making it more coarser [6].

The short term and long-term effects of chemical reaction occurring due to optimum addition of admixtures such as lime and fly ash for stabilization make the soil make beneficial change in atterberg limits of soil. Alteration in index properties are directly related to compressibility hence further it reduces the swelling characteristics of soil. Here the immediate short term effects of addition of lime are being examined. All these factors correspond to the effective decrease in Liquid Limit, Plastic Limit, swelling indices. Liquid limit percentages of the soil samples decreased sufficiently as desired with optimum stabilizer percentages of 20% fly ash and 6% lime. Addition of 20% fly ash is found to be optimum percentage of the mix with decrease in the liquid limit of clay by 13% which further reduces by 38% upon addition of 6% lime. Plastic limit values of the soil samples decreased with increasing stabilizer percentages. Addition of 20% fly ash caused the decrement 13% in the plastic limit of soil sample which further reduces by 34% upon addition of 6% lime. Plasticity indices of the samples reduced remarkably with mixing stabilizer percentages. Plasticity index will decrease with decrease in percentages of liquid limit and plastic limit shrinkage limit increases with decrease in plasticity index. As a result of addition of fly ash and lime in stabilization process, flocculation and coagulation takes place as a result of short term reaction. This reaction affects the physical properties of the soil such as consistency limit and grain size distribution. The liquid limit, plastic limit, free swell, UCS value decreased but the optimum strength is obtained at 20% addition of fly ash with 6% lime.Generally the quantity of lime needed to alter properties of a clay soil varies from 1% to 3% depending upon the purity of lime whereas that required for cementation varies from 2% to 8%. This percentage of optimum lime vary according to purity of lime In this work, index property and swell pressure remarkably vary with increase in lime upto 6%. This addition also altered grain size as a result of cementation process.

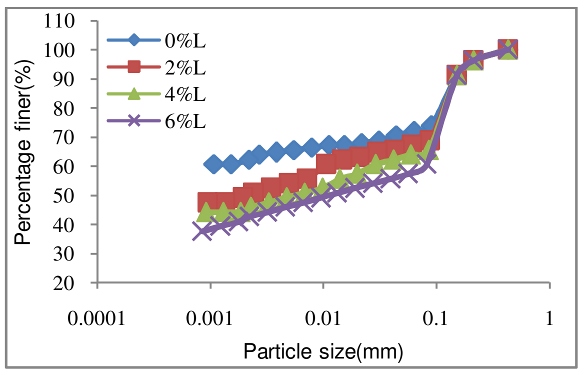

Fig. 1. Particle size distribution curve of 20% Fly ash mix with 80% Clay for different lime proportions.

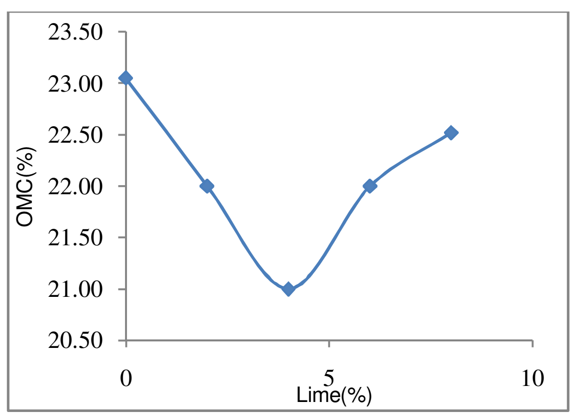

Fig. 2. Variation of OMC of 20% fly ash mix with varying lime(%).

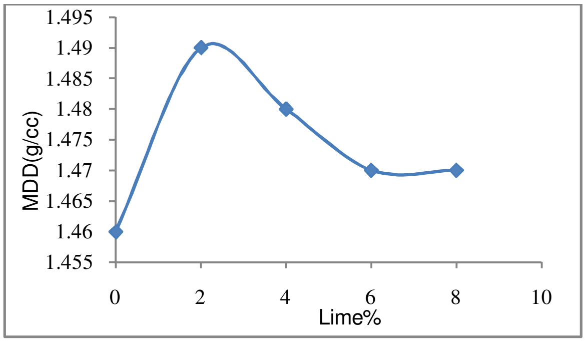

Fig. 3. Variation of MDD of 20%fly ash mix with varying lime(%).

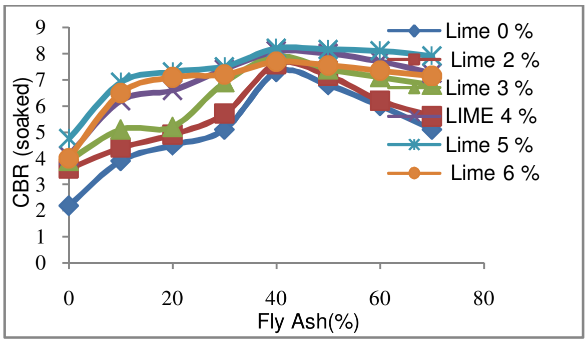

Fig. 4. Effect of lime on CBR of Various fly ash mix.

Unconfined compressive strength result illustrated that 20% fly ash mix gives better strength. In the process of stabilization of soil treated with or without additive such as fly ash and lime, it was observed that the plasticity index bears a linear relationship with Free Swell Index and Plasticity Index value. The relationship shown in regression graph take into account the following variation of sample starting from only soil to lime mix 2%, 4% and 6% respectively as the relationship in regression curve are representation of different parameters of gradually varying percentages of only soil with varying percentages of lime for the most appropriate proportion of fly ash (20%). As the UCS (N/mm^2) of soil mix with 20% fly ash gave optimum strength compared to other mixes, the gain in strength with further addition of lime was also studied. The result ensures optimum percentage of lime to be 4% for stabilization of 80% soil and 20% fly ash mix and observed a decrease in value of UCS with further addition of lime. Regression analysis of the plasticity index and free swell index percentages are shown in graphical form in figure. The correlation shows a linear increase in Free Swell Index property with increase in plasticity characteristics and a linear decrease in shrinkage limit percentages with increase in plasticity index. The plasticity index property vary with free swell index property as a linear function expressed as $Y = 2.33X + 14.99$ where 'X' designates to Free swell index value and 'Y' represents Plasticity Index expressed in percentage. The plasticity index property vary with Shrinkage limit as a linear function as well expressed as $Y = -0.965X + 39.35$ where 'X' designates to Shrinkage limit and 'Y' represents Plasticity Index (%). The Activity vary with clay fraction as a linear function as well expressed as $Y = 0.416X + 38.66$ where 'X' designates to Liquid Limit(%) and 'Y' represents Activity of clay. The Activity vary with clay fraction as a linear function as well expressed as $Y = 0.024X + 0.248$ where 'X' designates to Clay percentage finer than 2µm and 'Y' represents Activity of clay. The optimum moisture content of 20% fly ash stabilized soil was minimum and it was further minimized when added with 4% lime as admixture. Addition of lime improved the unconfined compressive strength [7]. The reverse manner of curve to that of OMC was obtained in maximum dry density comparison curve where the same fraction of fly ash percentage when added with 4% lime illustrates maximum dry density value. CBR curve shows two peaks in 20% and 40% fly ash addition. These peaks are attributed to destruction of capillary forces. Double peak also indicates that compaction has been carefully done and soil grain bonded well with one another [13].

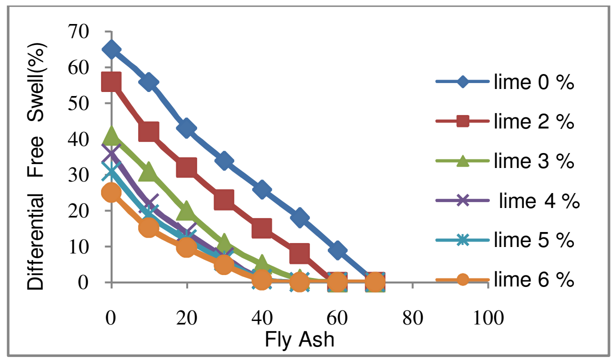

Fig. 5. Effect of lime on DFS of various fly ash mix.

The differential free swell index value go on decreasing with addition of lime up to 6% in an gradual increment of 2%. This is attributed to particle size alteration and breaking of diffuse double layer in clay. Zha *et al.,* (2008) [11] also established the same result. As plasticity decreases, swelling quotient also decrease. The free swell index value when compared with plasticity index value, gives correlation coefficient of 0.954 and the swelling pressure when compared with Activity of clay gives R^2 value to be 0.902. Shrinkage Limit when compared with plasticity index gives correlation coefficient of 0.881. Similarly Percentage clay fraction with Activity establishes R^2 value to be 0.901.

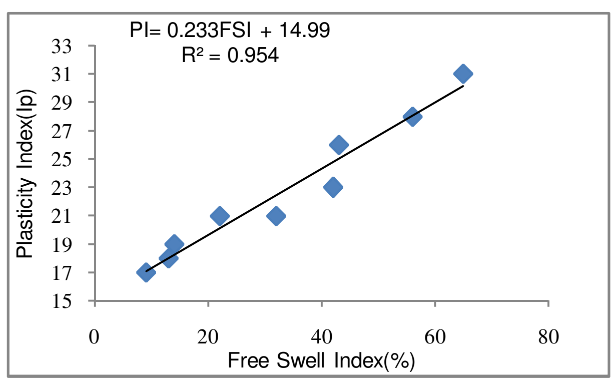

Fig. 6. Relationship between FSI and Ip.

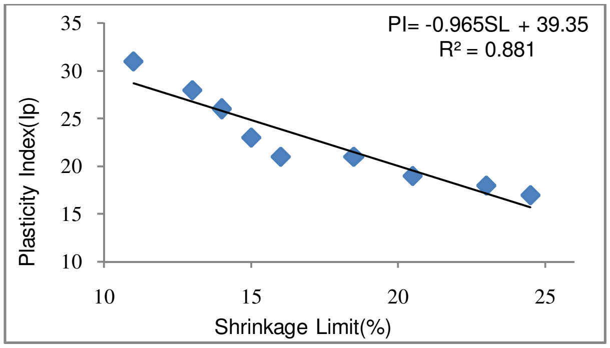

Fig. 7. Relationship between SL and Ip.

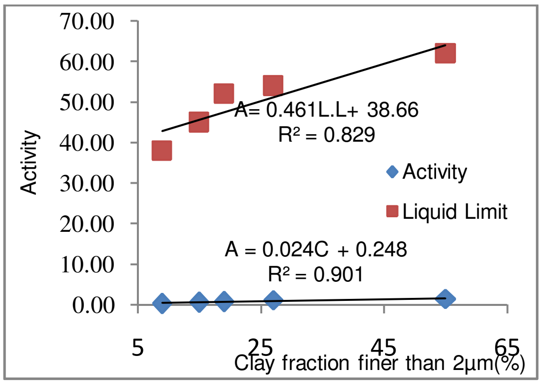

Fig. 8. Relationship between Activity against clay fraction of soil mixes.

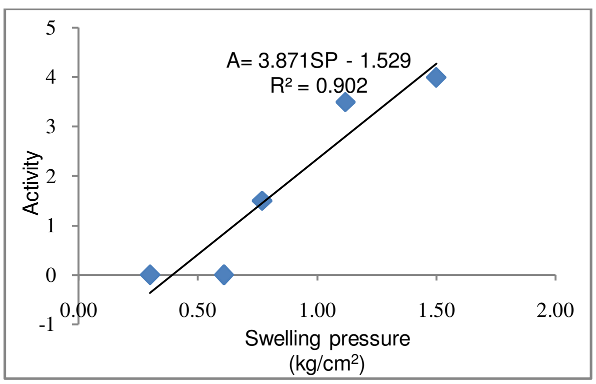

Fig. 9. Relationship between swelling pressure of soil mixes.

IV. CONCLUSIONS

A series of laboratory test were conducted to study the effect of granite dust stabilization and reinforcement on OMC, MDD, UCS, soaked CBR and swelling pressure of an expansive soil. The following conclusions are drawn from this study. Changes in the physical properties and swelling potential of the Soil due to the addition of fly ashes is a result of additional silt size particles to some extent and due to chemical reactions that cause immediate flocculation of clay particles. The decrease in swelling potential can be attributed to time-dependent pozzolanic and self-hardening properties (formation of cementitious compounds) of fly ashes. The liquid limit, plastic limit, plasticity index, decreased significantly and shrinkage limit increased with the addition of fly ash-lime. The free swell Index value and swelling pressure is found to decrease by treating the soil with fly ash-lime mixes. Particle size distribution graph shifts downwards as grain Size of soils were altered by the addition of admixtures. The silt and sand fractions increased with increase in the amount of lime. Activity of clay plays very crucial role in identifying swelling characteristics of expansive soil and lime reduces it effectively. Maximum dry density and unconfined compressive strength was obtained at 20% fly ash mix with clay and it was observed that further addition of fly ash reduces the strength. The unconfined compressive strength of untreated expansive soil was 0.087 N/mm^2. But after stabilization of expansive soil with 20% fly ash, the percentage of strength gain increased by nearly 14%. The CBR values of stabilized soil mixes, tested under soaked conditions, shows peaks at 20% and 40% ash content. The regression analysis of plasticity index shows linear relation with Liquid Limit, Shrinkage Limit, Free Swell Index and Activity of clay and the R^2 value in the interpreted cases shows value nearly equal to unity. Hence both laboratory and regression result move alongside to establish the fact that Proper addition and stabilization will be helpful for many ground improvement related problems where eradication of soil is not possible. Further stabilization effect can be analyzed by taking into effect the curing time variation.

V. FUTURE SCOPE

This work can be extended to further study the effect of strength of this optimum mix with age with curing period and time. This regression analysis can be compared with further curing days plot for the same mixes.

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