Effect of Compaction Energy on Engineering Properties of Fly Ash –Granite Dust Stabilized Expansive Soil

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Abstract- The effects of compaction energy on engineering properties of an expansive soil stabilized with optimum percentage of fly ash-granite dust have been discussed in this paper. Expansive soil stabilized with optimum percentage of fly ash-granite dust was compacted with five compaction energy levels. Maximum dry density and optimum moisture content corresponding to each energy level were determined. Based on these maximum dry density and optimum moisture content, samples were prepared for unconfined compressive strength, soaked California bearing ratio, hydraulic conductivity and swelling pressure tests. From the test results it is found that increase in compaction energy increased the maximum dry density, unconfined compressive strength, soaked California bearing ratio and swelling pressure, and decreased the optimum moisture content and hydraulic conductivity.

Key Word: Compaction Energy, Expansive Soil, Stabilized, Soaked California bearing ratio, Hydraulic conductivity.

I. INTRODUCTION

Severe damages occur to lightly loaded structures founded on expansive soil due to its alternate swell-shrink behaviour. Stabilization using solid waste is one of the methods to treat this soil to make suitable for construction. Fly ash (FA) is a solid waste generated from, coal fired power plants. Granite dust (GD) is another solid waste produced from cutting and polishing of granite. Requirement of large space for disposal along with environmental pollution are the problems associated with the production of these solid wastes. Expansive soil has been stabilized with fly ash along with the other materials like quarry dust [1], sand [2], calcium carbide residue[3], fiber [4]-[6] etc. Granite dust has also been used alone [7] or along with lime [8] for stabilization of expansive soil. FA and GD can be combined together to stabilize expansive soil. Utilization of FA and GD in this manner can solve the problems arise, due to production of these two solid wastes along with the improvement in engineering properties of the expansive soil.

Compaction energy is one of the important factors which affect the engineering properties of both the unstabilized and stabilized soil. The effects of compaction energy on engineering properties of unstabilized and stabilized soil have been studied by a number of researchers in papers [9]-[15]. The effect of FA-GD on engineering properties of expansive soil and the effect of compaction energy on engineering properties of FA-GD stabilized expansive soil are limited in literature.

The objective of the present investigation is to study the effect of compaction energy on some engineering properties of an expansive soil stabilized with optimum percentage of FA-GD.

II. MATERIALS AND METHODS

A. Materials

Expansive Soil

The expansive soil used in the experimental programme was brought from a place approximately 250 km away from Bhubaneswar. The Geotechnical properties of the expansive soil are: 1)Grain Size Analysis: i)Sand size- 12% ii) Silt size- 24% iii) Clay size- 64% 2) Consistency Limits:-i) Liquid Limit - 61% ii) Plastic Limit-31% iii) Shrinkage Limit-11% 3) Compaction Properties i) Optimum moisture content (OMC)-22% ii) Maximum dry density(MDD)-16.2 kN/m^3 4) Unconfined compressive strength (UCS)-87 kN/m^2 5) soaked California bearing ratio (CBR)-1.72% 6) Hydraulic Conductivity-2.87×10^{-7} cm/sec. 7) Swelling Pressure-132 kN/m^2.

Fly Ash (FA)

The FA used in the experimental programme was collected from a power plant located in Odisha. It is a class-F FA (CaO-0.89%, SiO_2-69.31%, Al_2O_3-28.1%, Fe_2O_3-3.69%). The geotechnical properties of the FA are: 1)Grain Size Analysis: i) Sand size-14.22% ii) Silt size-83.46% iii) Clay size -2.32% 2) Specific gravity – 2.21 3) Compaction Properties i) OMC-24% ii) MDD-12.8 kN/m^3

Granite Dust(GD)

The GD used in the experimental programme was collected from a granite cutting and polishing industry located in Bhubaneswar. The geotechnical properties of the GD are: 1)Grain Size Analysis: i) Sand size-93.58% ii) Silt size- 6.42% iii) Clay size -00% 2) Specific gravity – 2.71.

B. Methods

The experimental programme consists of two stages. In the first stage, the optimum percentage of FA-GD for stabilization of expansive soil was found out. For that purpose, by addition of one part of FA and two parts of GD, FA-GD mixes were made. At an increment of 6%, up to 54%, by replacement of expansive soil, FA-GD mixes were added to expansive soil.UCS tests were conducted on expansive soil stabilized with different percentage of FA-GD. The samples for UCS tests were prepared by compacting them with corresponding MDD and OMC for that purpose standard Proctor compaction tests were conducted on the stabilized soil samples. In the second stage of the experimental programme, after getting optimum percentage of FA-GD, the soil-FA-GD mix was compacted in five compaction energy levels, one standard proctor energy level in a standard Proctor mould with standard Proctor compaction test specification[16], and four compaction energy levels on modified Proctor compaction mould with modified Proctor compaction test specification[17] with change in number of blows. The five compaction energy levels are 592 kJ/m^3, 1080 kJ/m^3, 1621 kJ/m^3, 2161 kJ/m^3 and 2700 kJ/m^3.

III. ANALYSIS OF TEST RESULTS

The change in the values of MDD of expansive soil due to addition of FA-GD has been shown in Fig.1.Increase in MDD occurs with increase in percentage of FA-GD. Similar observations were made by Sabat and Bose[1] while adding fly ash-quarry dust to expansive soil.

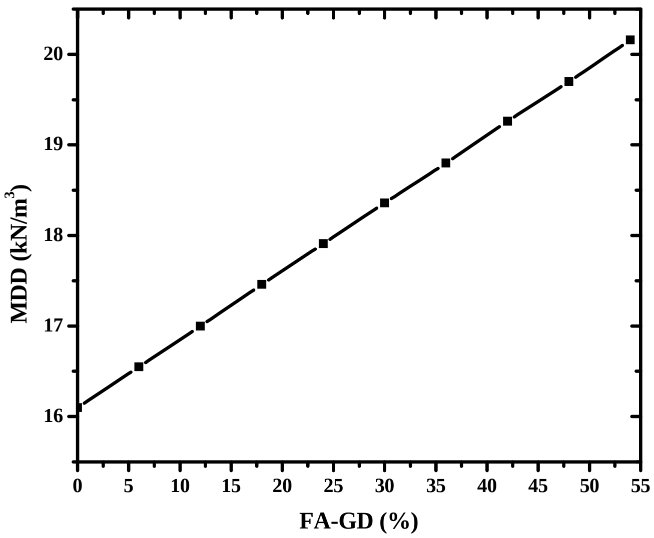

Fig.1. Variation of MDD with FA-GD

The change in values of OMC of expansive soil due to addition of FA-GD has been shown in Fig.2. Decrease in OMC occurs due to increase in FA –GD percentage. Similar observations were made by Sabat and Bose [1], while adding fly ash-quarry dust to expansive soil.

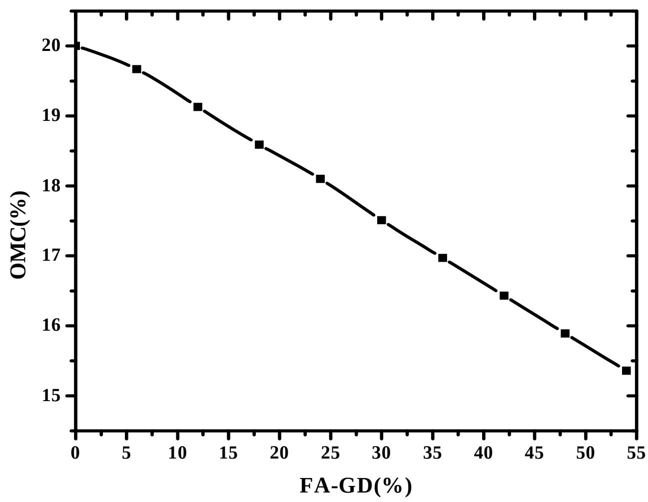

Fig.2. Variation of OMC with FA-GD

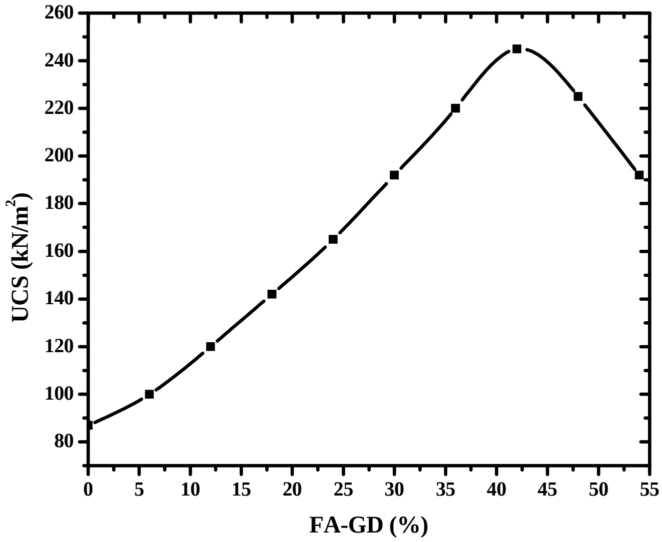

Fig.3. Variation of UCS with FA-GD

The result of UCS test has been shown in Fig.3. Addition of FA-GD increased the UCS values of the expansive soil. The UCS reaches highest value when percentage addition of FA-GD is 42%.UCS decreases when the percentage addition of FA-GD mix is more than 42%. Hence, for stabilization of expansive soil, 42% of FA-GD is taken as the optimum percentage. Similar observations were made by Sabat and Bose [1] while adding fly ash-quarry dust to expansive soil.

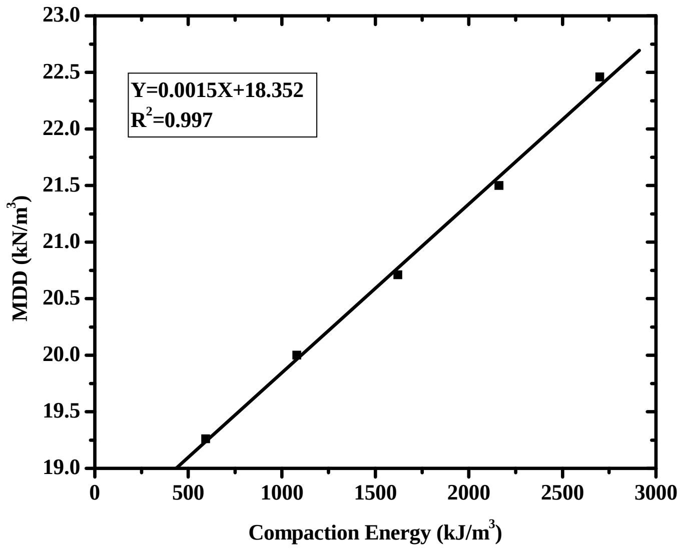

Fig.4. Variation of MDD with compaction energy

Fig.4 shows the effect of compaction energy on MDD of expansive soil stabilized with optimum percentage of FA-GD. With increase in compaction energy the MDD goes on increasing. The MDD increased to 22.46 kN/m^3 from 19.26 kN/m^3 when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3. As the increase in compaction energy decreases the voids ratio and results in closer packing of the soil-FA-GD particles, the MDD increases. The variation of MDD of expansive soil stabilized with optimum percentage of FA-GD, with compaction energy has been represented by a linear regression model. The model is,

$Y= 0.0015X +18.352$, $R^2= 0.997$, $R=0.99$

Where, Y= MDD (kN/m^3) of the expansive soil stabilized with optimum percentage of FA-GD. R^2= Coefficient of determination and R= Coefficient of correlation, X= Compaction energy in kJ/m^3

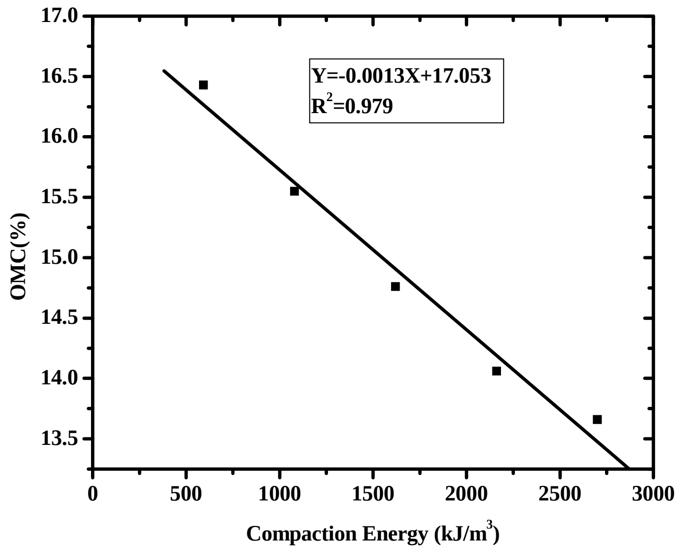

Fig.5. Variation of OMC with compaction energy

Fig.5 shows the effect of compaction energy on OMC of expansive soil stabilized with optimum percentage of FA-GD. With increase in compaction energy the OMC goes on decreasing. The OMC decreased to 13.66% from 16.43% when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3 .Increase in compaction energy decreases the OMC, when water is added to soil, the soil particle will be lubricated, when compacted they will come to a denser state, hence less water will be required with higher compaction energy to achieve

MDD. The variation of OMC with compaction energy has been represented by a linear regression model. The model is,

Y= -0.0013X+17.053, R^2=0.979, R=0.99

Where, Y= OMC (%) of the expansive soil stabilized with optimum percentage of FA-GD

X= Compaction energy in kJ/m^3

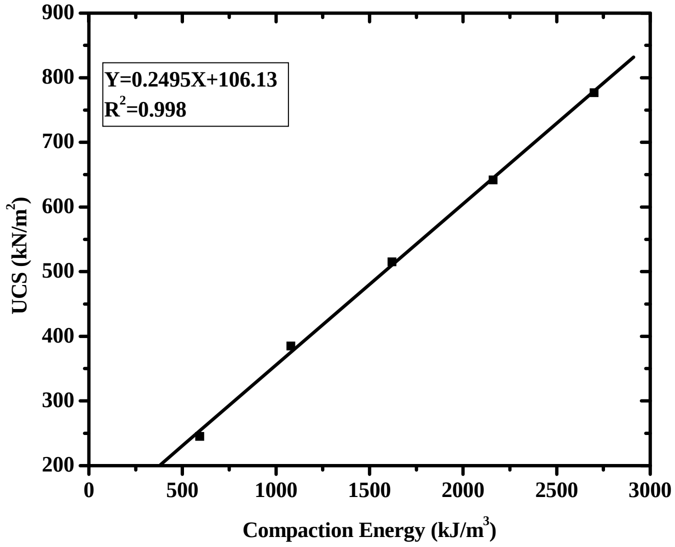

Fig.6. Variation of UCS with compaction energy

Fig.6 shows the effect of compaction energy on UCS of expansive soil stabilized with optimum percentage of FA-GD. With increase in compaction energy the UCS goes on increasing. The UCS increased to 777 kN/m^2 from 245 kN/m^2 when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3.As the MDD increases with increase in compaction energy, the UCS increases. The variation of UCS with compaction energy has been represented by a linear regression model. The model is, Y=0.2495X+106.13, R^2 =0.998,R=0.99

Where, Y= UCS (kN /m^2) of the expansive soil stabilized with optimum percentage of FA-GD

X= Compaction energy in kJ/m^3

Fig.7 shows the effect of compaction energy on soaked CBR of expansive soil stabilized with optimum percentage of FA-GD. With increase in compaction energy the soaked CBR goes on increasing. The soaked CBR increased to 6.1 % from 1.72 % when 42% of FA-GD is added to it, and increased to 16.8% from 6.1% when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3.As the MDD increases with increase in compaction energy, the soaked CBR increases. The variation of soaked CBR with compaction energy has been represented by a linear regression model. The model is,

Y= 0.005X+2.7164, R^2 =0.99, R=0.99

Where, Y= soaked CBR (%) of the expansive soil stabilized with optimum percentage of FA-GD

X= Compaction energy in kJ/m^3

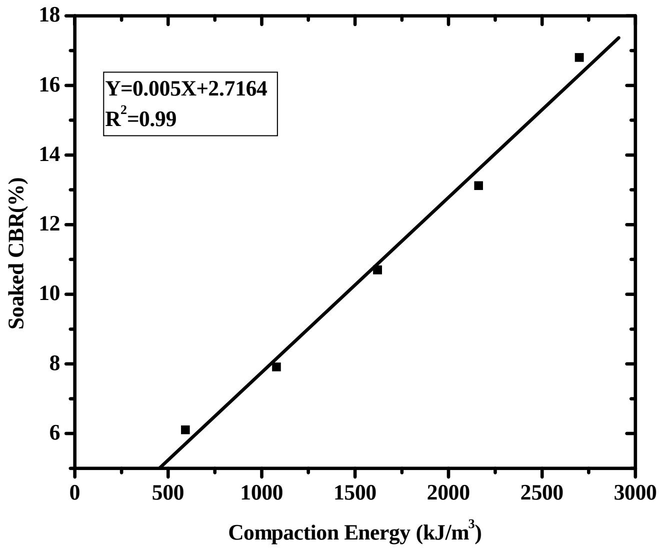

Fig.7. Variation of soaked CBR with compaction energy

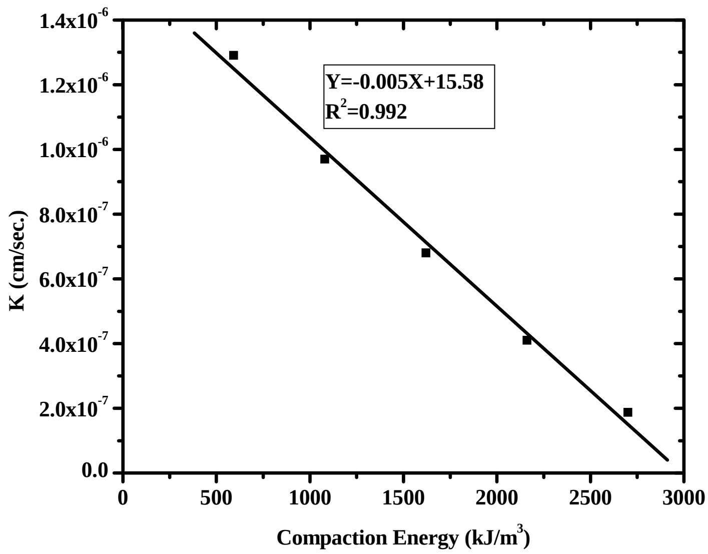

Fig.8. Variation of Hydraulic conductivity with compaction energy

Fig.8 shows the effect of compaction energy on hydraulic conductivity (K) of expansive soil stabilized with optimum percentage of FA-GD. Addition of 42% of FA-GD increased the hydraulic conductivity of expansive soil to 12.91×10^{-7} cm/sec. With increase in compaction energy the hydraulic conductivity of the FA-GD stabilized expansive soil goes on decreasing. The hydraulic conductivity decreased to 1.88×10^{-7} cm/sec from12.91×10^{-7} cm/sec when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3. Addition of 42% of FA-GD makes the expansive soil porous, increase in compaction energy increased the MDD and reduces the volume of voids, hence hydraulic conductivity decreases. The variation of hydraulic conductivity with compaction energy has been represented by a linear regression model. The model is,

$Y=-0.005X+15.58$, $R^2=0.992$, $R=0.996$

Where, Y= Hydraulic conductivity (cm/sec.) of the expansive soil stabilized with optimum percentage of FA-GD

X= Compaction energy in kJ/m^3

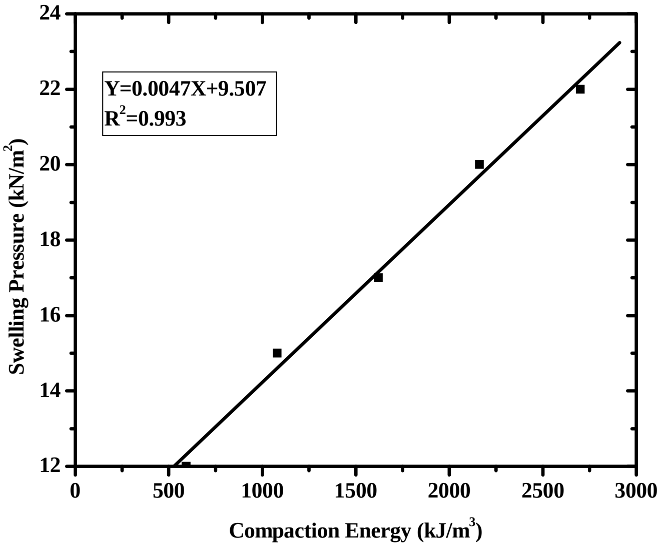

Fig.9. Variation of swelling pressure with compaction energy

Fig.9 shows the effect of compaction energy on swelling pressure of expansive soil stabilized with optimum percentage of FA-GD. With increase in compaction energy the swelling pressure goes on increasing. With addition of 42% of fly ash –granite dust the swelling pressure decreased to 12 kN /m^2 from 132 kN/m^2. The swelling pressure increased to 22 kN /m^2 from 12 kN/m^2 when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3.Addition of 42% FA-GD reduced the clay content of expansive soil hence, swelling pressure decreased, and increase in compaction energy increased the MDD hence, the swelling pressure increased. The variation of swelling pressure with compaction energy has been represented by a linear regression model. The model is,

$Y= 0.0047X+9.507$, $R^2 =0.993$, $R=0.996$

Where, Y= Swelling pressure (kN/m^2) of the expansive soil stabilized with optimum percentage of FA-GD

X= Compaction energy in kJ/m^3

IV. CONCLUSIONS

The conclusions drawn from the study undertaken are as follows.

- The optimum percentage of FA-GD, for stabilization of the expansive soil is found to be 42%.
- With increase in compaction energy the MDD of the FA-GD stabilized expansive soil goes on increasing, and the OMC goes on decreasing. The MDD increased to 22.46 kN/m^3 from 19.26 kN/m^3 and the OMC decreased to 13.66% from 16.43% when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3.
- With increase in compaction energy the UCS of the FA-GD stabilized expansive soil goes on increasing. The UCS increased to 777 kN/m^2 from 245 kN /m^2 when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3.
- With increase in compaction energy the soaked CBR of the FA-GD stabilized expansive soil goes on increasing. The soaked CBR increased to 16.8% from 6.1% when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3.
- With increase in compaction energy the hydraulic conductivity of the FA-GD stabilized expansive soil goes on decreasing. The hydraulic conductivity decreased to 1.88x10^{-7} cm/sec from 12.91x10^{-7} cm/sec when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3.
- With increase in compaction energy the swelling pressure of the FA-GD stabilized expansive soil goes on increasing. The swelling pressure increased to 22 kN/m^2 from 12 kN/m^2 when the compaction energy increased to 2700 kJ/m^3 from 592 kJ/m^3.

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Dr. Akshaya Kumar Sabat has published 34 papers in National and International Journals. He has received 4 Awards for his research papers from the Institution of Engineers (I) Odisha Chapter, and 3 Awards from Orissa Engineering Congress. He has also received the 'Outstanding Teacher' Award from KIIT University Bhubaneswar. His Biography has been published in "Marquis Who's Who in the world" in the 32nd Edition 2015. Some prominent International Journals where he is reviewer are, Geotechnical and Geological Engineering, Environmental Earth Sciences, Measurement, Neural Computing and Applications, International Journal of Environment and Waste Management, and International Journal of Earth Sciences and Engineering. His research interest includes, Waste Utilization in Geotechnical and Geoenvironmental Applications, Applications of Soft computing Techniques in Geotechnical Engineering Problems etc.

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