Improving Soft Clay Soil Using Fly Ash As Material Of Column

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ABSTRACT

An attempt is to improve the problematic clays made in this study to utilize fly ash after converting it in to fly ash aggregate as material of column as a replacement for the conventional aggregate and consolidation tests were conducted In order to evaluate the suitability of fly ash aggregate as column material in problematic clays by providing only one, two and three columns of conventional as well as fly ash aggregate. From the test results it is determined that t_{90} for stone aggregate column and fly ash aggregate column are comparable. The $\frac{C_{vr}}{C_v}$ ratio of clay with stone column is higher than the clay with fly ash aggregate column irrespective of number of columns. The compression index of clay with stone column and clay with fly ash aggregate column are lesser than that of clay without column. It is therefore concluded that fly ash aggregate may be utilized as column material in the strength enhancement of problematic clays

Key Words: Improvement, problematic clays, fly ash aggregate, column material, consolidation test, strength enhancement

Introduction

Due to less Suitable construction sites availability, to utilize problematic soils for foundation support become essential leads to strengthen the ground under existing structures. In this present investigation an attempt is made to utilize the Fly ash aggregate as column material in the place of conventional stone aggregate for the improvement of problematic soft clays. Strength variation were evaluated by conducting Consolidation characteristics tests on the prepared soft clay with and without Conventional aggregates and Fly ash aggregates as column material for varying number of columns and the results are presented in this report.

Load Carrying Capacity of Aggregate Column

The load carrying capacity of aggregate column is derived from the combined effect of properties of aggregate, Properties of soil c/c distance between columns, loading type and column placing zone etc.

Physical Properties of Fly Ash

Particle size ranging between0.01 mm to 0.1mm Fly ash is usually dark grey in colour but this depends on its chemical composition and mineral constituents.

Chemical Properties of Fly Ash

S.NO	Description	Compounds by weight %
1	SiO_2	23.52
2	Al_2O_3	13.07
3	TiO_2	0.20
4	Fe_2O_3	3.02
5	MnO, MgO, CaO,k_2O,Na_2O	traces
6	LOI	51.55
7	H_2O(-)	8.64

Table .1. Physical Properties and Classification of Natural Soil

S.NO	Description	Values
1.	Sand (%)	7
2.	Silt (%)	15
3.	Clay (%)	78
4.	Specific Gravity	2.70
5.	Liquid Limit (%)	66
6.	Plastic Limit (%)	27
7.	Shrinkage Limit (%)	10
8.	Free Swell Index (%)	80
9.	Max. dry density (kN/m^3)	16
10.	Optimum moisture content (%)	26
11.	BIS Classification	CH

Material Utilized

1. Natural Soils

The natural soil samples were collected from Thrumullaivoyal - Chennai. It is high compressible clay having liquid limit of 66%, used for consolidation and load test. The details of physical properties of natural soil are summarized in Table .1.

2. Fly ash aggregate

Fly ash bricks (Plate 1) manufacturing unit located in Tiruvallur was visited. In this industry fly ash bricks of size (230 x 110 x 70) mm with compressive strength of 100 kg/cm^2 were manufactured out. The composition of bricks includes fly ash powder, cement, lime, gypsum, sand, dust, and chips. These fly ash bricks were subjected to 20 days plastic sheet warm curing. Fly ash Bricks were broken and it was sieved to get sizes ranging from 5 mm to 10 mm. The fly ash aggregate has compressive strength of 43% and conventional coarse aggregate is about 1.8%.

PLATE 1 VIEW OF FLY ASH BRICKS

CONVENTIONAL COARSE AGGREGATE FLY ASH AGGERGATE

PLATE 2 MATERIALS USED IN THIS STUDY

Mechanical Tests on Aggregate

The crushing strength test was conducted for conventional as well as on fly ash aggregate material based on IS standards (IS: 2386 Part IV – 1963) and the crushing percentage values were reported as 1.8% for conventional stone aggregate and fly ash aggregate is 43%.

Consolidation Test on soil with and without columns

Consolidation test was performed on the prepared soft clay with conventional coarse aggregate and fly ash aggregate as column materials for varying number of columns with 3 varying pressures by taking L/D ratio as 3.2.

PLATE 3 VIEW OF FLY ASH BLOCK COMPRESSIVE TESTING

In order to study the settlement characteristics of virgin clay, clay with conventional stone aggregate column, clay with fly ash aggregate column and consolidation tests were conducted for L/D ratio of 3.2. The diameter of column is 31 mm and the length of column is 100 mm respectively. The details are shown in figure. 1.

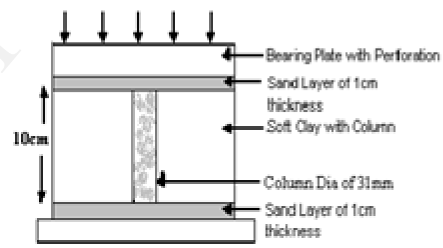

Fig 1 Consolidation test setup for L/D ratio of 3.2

The soft clay bed was prepared in the mould by taking a known quantity of soil mixed with water content of 55% in such a way that it gives a soft consistency having consistency index of 0.45 by gentle hand-remolding and tapped with a small wooden rod. For the formation of column with conventional stones and fly ash aggregates, the well graded crushed aggregates of size varying from 5 mm to 10mm were used. The single column was formed by placing PVC pipe of diameter same as the diameter of column to be formed at the centre of the mould up to the bottom of clay bed. The required quantity of soil prepared as above was placed around the pipe by gentle tamping. After filling the soil, the stones of required quantity to achieve a density of 15 kN/m^3 were poured into the pipe and compacted by a tamping rod. The construction of column in the prepared soft clay is explained by Figure 2 (a to c). For beds treated with columns the top and bottom surfaces of the bed were made impermeable by using steel plates with suitable holes to ensure drainage only through the columns.

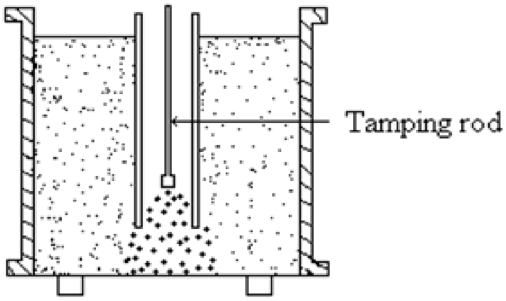

Fig 2(a) Partial withdrawal of pipe and simultaneous compaction

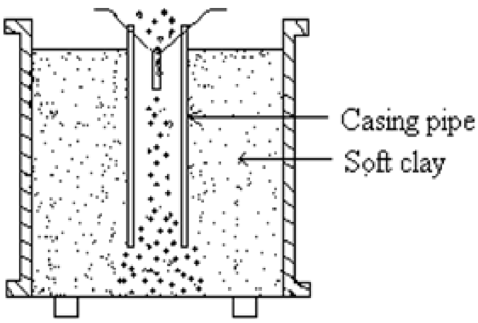

Fig 2 (b) Filling of next layer of charge and repeat till columns formed

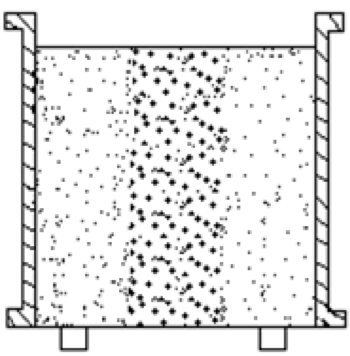

Fig 2 (c) Aggregate column ready

The soft clay with fly ash aggregate column were formed same as mentioned above by pouring respective materials of size ranging from 5 to 10 mm to achieve a density of 10 kN/m^3 respectively . For the formation of two and three columns the PVC pipes are placed at a spacing of 2.5 times the diameter of column (Figure 3) inside the mould and the columns with stone, fly ash aggregate materials in the similar way as mentioned above.

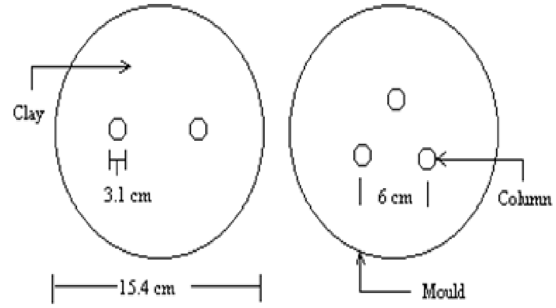

Fig 3 View of Arrangements of column

The tests were conducted for four pressure increments 0-20 KN/m^2, 20-40 KN/m^2 and 40-80 KN/m^2. The dial readings were taken at regular time intervals till equilibrium void ratio is achieved for each pressure increment. After completion of the test, water content of the consolidated clay sample was determined at top, middle and bottom.

Determination of C_V and C_{Vr} for Soft Clay with and without Column

The coefficient of consolidation C_V of soft clay with and without column were determined by rectangular hyperbola method (Das, 2000). The time- compression curves for any pressure increments were re-plotted into time/compression versus time curves. The transformed plot shows a linear relationship with high correlation coefficient. From the best fit linear equation, time corresponding to 90% consolidation for all the pressure increments in the case of clay with and without one, two and three columns of stone aggregate, fly ash aggregate for L/D ratios of 3.2 were determined.

Plates 4 Consolidation Test Arrangement

For the computation of $\boldsymbol{C_{Vr}}$ in the case of clay with single column of different materials, the diameter of influence has been taken as equal to 5 times the diameter of the column. In case of clay with two and three columns of different material, the diameter of influence is taken as 1.138 times the spacing of columns for two columns cases (square pattern) and 1.05 times the spacing of column for three column cases (triangular pattern) (Barnes 2000).

RESULTS AND DISCUSSION

Variation of C_V and C_{Vr} Values for soft clay with CCA and FAA Columns.

Barron's (1948) equation is commonly used wherein coefficient of radial consolidation (rate of radial settlement) is determined with the help of spacing and diameter of sand drains. In the present case, $\boldsymbol{C_{Vr}}$ values were determined for the diameter (D) of stone column of 31mm, for the spacing of 60 mm and 'n' values of 5 respectively for one, two and three number of columns. For clays without column, Terzaghi's one dimensional consolidation equation is used to determine the coefficient of vertical consolidation.

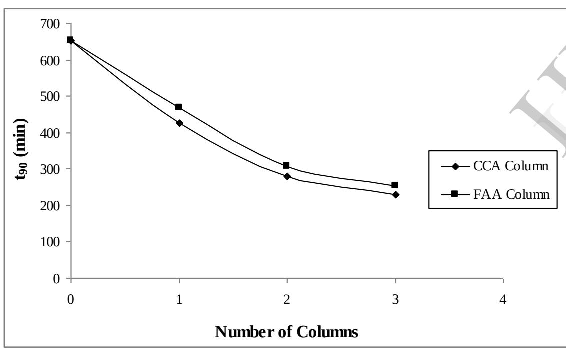

Fig 4 (a) Number of Column Vs t_{90}, P: 0-20kN/m^2

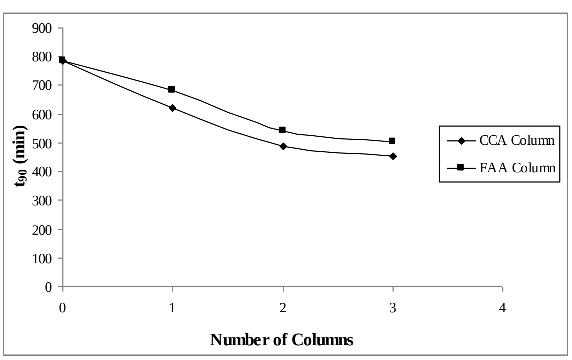

Fig 4 (b) Number of Column Vs t_{90}, P:20-40 kN/m^2

Table 2 variations of C_V and C_{Vr} Values

Column Material	Pressure P, kPa	t_{90} min	C_V $\frac{cm^2}{min}$	C_{Vr} $\frac{cm^2}{min}$	$\frac{C_{vr}}{C_V}$ Ratio
Virgin Clay	0 - 20	653	0.093	--	--
	20 - 40	784	0.038	--	--
	40 - 80	919	0.031	--	--
Clay + 1 CCA Column	0 - 20	425	--	0.151	1.615
	20 - 40	622	--	0.105	2.755
	40 - 80	703	--	0.091	2.954
Clay + 2 CCA Column	0 - 20	279	--	0.229	2.958
	20 - 40	489	--	0.131	3.436
	40 - 80	506	--	0.126	4.104
Clay + 3 CCA Column	0 - 20	230	--	0.278	2.982
	20 - 40	453	--	0.141	3.709
	40 - 80	514	--	0.124	4.040
Clay + 1 FAA Column	0 - 20	469	--	0.136	1.463
	20 - 40	684	--	0.094	2.458
	40 - 80	754	--	0.085	2.754
Clay + 2 FAA Column	0 - 20	308	--	0.208	2.230
	20 - 40	543	--	0.118	3.094
	40 - 80	582	--	0.110	3.568
Clay + 3 FAA Column	0 - 20	254	--	0.252	2.701
	20 - 40	503	--	0.127	3.341
	40 - 80	536	--	0.119	3.874

The $\boldsymbol{C_V}$ or $\boldsymbol{C_{Vr}}$ values are the indicative of settlement rate of the given sample and is a function of permeability of the soil. Generally, increase of coarser fraction in clays increases $\boldsymbol{C_V}$ or $\boldsymbol{C_{Vr}}$ values and vice versa. In the present case for any pressure increment $\boldsymbol{C_{Vr}}$ values increases with number of columns.

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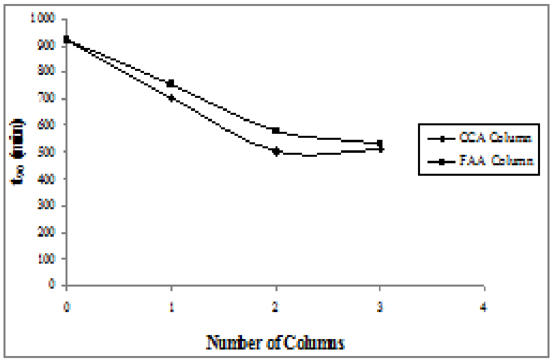

Fig 4 (c) Number of Column Vs t_{90}, P:40 –80kN/m^2

Further the ratio of $\frac{C_{vr}}{C_V}$ is ranging from 1.6 to 3.0 for clay with single stone column, 2.5 to 4.0 for clay with two stone column and 3.0 to 4.0 for clay with three stone columns. For clays with single, two and three columns of fly ash aggregate, the ratio of $\frac{C_{vr}}{C_V}$ are 1.5 to 3.0, 2.2 to 3.5 and 2.7 to 3.8 respectively.

From Figure 5.(a) ,5.(b) and 5.(c) the $\frac{C_{vr}}{C_V}$ values increases with the number of columns for stone aggregate column and there is a marginal decrease in $\frac{C_{vr}}{C_V}$ values for fly ash aggregate column when compared with stone aggregate column.

The C_{vr} is the maximum for clay with three stone aggregate column and minimum for clay with fly ash aggregate column and other values lie in-between. Generally, the C_{vr} variation for three column case is in the order of clay with three fly ash aggregate column < clay with three stone aggregate column. The same trend continues for clay with one and two columns of stone and fly ash aggregate columns.

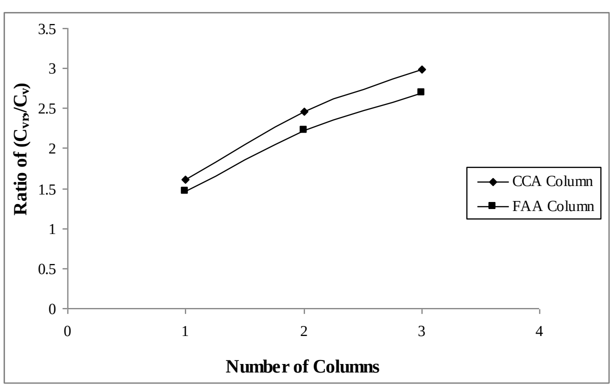

Fig 5 (a) Number of Column Vs $\frac{C_{Vr}}{C_V}$ P: 0-20 kN/m^2

If the C_{vr} values are equal to C_v values that is the ratio of $\frac{C_{vr}}{C_V}$ is becoming unitythen it means that prosision of stone column did not improve the consolidation characteristics of clays. However, the results imply that the stone column and fly ash aggregate column incraeses the rate coeffecient of radial consolidation and $\frac{C_{vr}}{C_V}$ ratio (between 2 to 3) is always high.This ensures that there is no crushing of Fly ash aggregate had taken place.

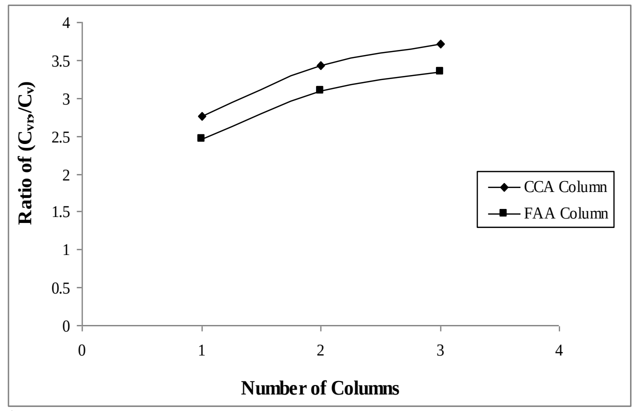

Fig 5 (b) Number of ColumnVs $\frac{C_{Vr}}{C_V}$ P:20-40 kN/m^2

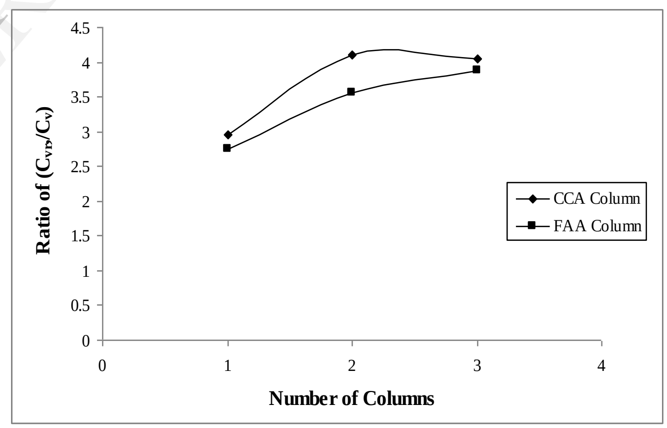

Fig 5 (c) Number of ColumnVs $\frac{C_{Vr}}{C_V}$ P:40-80 kN/m^2

Variation of Moisture Content of Consolidated Clay Sample

Figure 7shows the variation of final moisture content of the consolidated clay sample for different number of columns and column materials. It is observed that moisture content variation in top, middle and bottom of the clay sample are more or less, same as seen from figure, irrespective of sample thickness and thus confirming that consolidation of 10 cm sample has taken more or less uniformly, even though duration of loading varied between 24 to 48 hrs. For no column case and one column, the load increment was applied for every 48 hours and for two and three columns because of increased drainage path only 24 hrs allowed for each load increment.

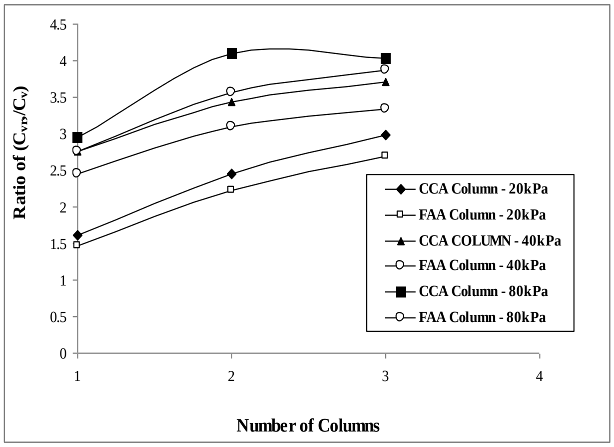

Fig 6 Number of Column Vs C_{vr} Relationship for Pressure of 0-20,20-40,40 – 80 kN/m^2

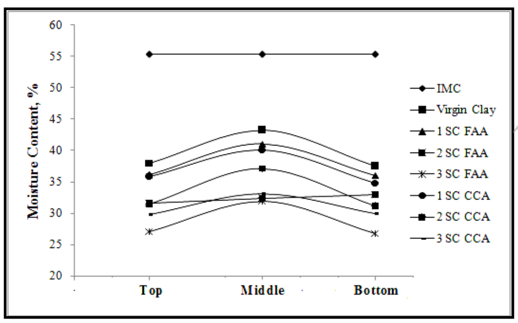

Fig 7 Moisture Content Variation of the Consolidated Clay Sample

Comparison of C_c Values for Clay with CCA and Clay with FAA Columns

The variation of C_c is in the order of clay with stone aggregate column < clay with fly ash aggregate column. It is clear that even for the wide pressure range of 0 to 80 kN/m^2 the reduction in settlement at any pressure is more or less same irrespective of column materials. Based on t_{90}, C_{vr} and C_c, it is hence suggested that fly ash aggregate can be used as column material to increase the rate of settlement and also reduce total settlement in the place of conventional stone aggregate for the improvement of soft clay deposits.

Table 3 Variation of C_c Values of Clay with and without Column

Description	C_c
Virgin Clay	0.1518
Clay + 1 SC CCA	0.1420
Clay + 2 SC CCA	0.1330
Clay + 3 SC CCA	0.088
Clay + 1 SC FAA	0.149
Clay + 2 SC FAA	0.141
Clay + 3 SC FAA	0.135

Comparison of m_V of Clay + CCA and Clay + FAA Columns

The m_V values were computed from coefficient of compressibility values and initial void ratio and the same is plotted against pressure as shown in Figure 4.14. The m_V values generally decrease with pressure irrespective of different column materials and number of columns. The trend of m_V variation is similar to void ratio – pressure relationship. Based on m_V classification chart given by Tomlinson (1995), the clay with single, two and three column of stone and fly ash aggregate are classified as clay of medium to low compressible. It may be noted that the soft clay alone without column is corresponding to the classification of clay of high compressible nature. On increasing number of columns and different column materials, the high compressible clays have changed on to medium and low compressible clays. This is an added advantage of using solid waste material FAA to improve the compressibility behavior of soft clays.

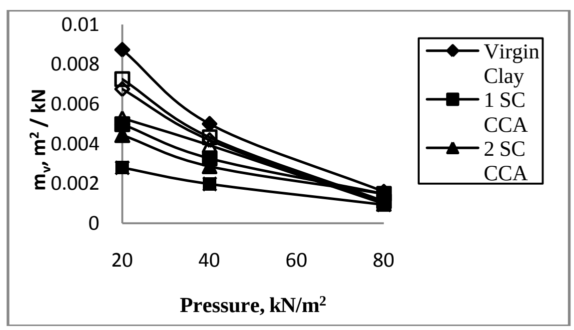

Fig 8 Variation m_V of with Pressure for CCA and FAA Columns in Soft Clay

CONCLUSIONS

Based on the consolidation characteristics of soft clay with conventional coarse aggregate as column material and fly ash aggregate material the following general conclusions may be drawn.

The crushing strength of fly ash aggregate is lower than the stone aggregate.

The time required for 90% consolidation of stone aggregate and fly ash aggregate column in soft clay are comparable irrespective of pressure increment, number of columns.

The coefficient of radial consolidation C_{vr} of fly ash aggregate column in soft clay is comparable with that of conventional stone aggregate column for any pressure increment irrespective of number of columns. The increase of $\frac{C_{Vr}}{C_V}$ ratio is in the order of stone aggregate > fly ash aggregate of one, two and three number of columns.

The compression index values of one, two and three columns of stone aggregate and fly ash aggregate are lower than that of clay without column. The C_c values of one, two and three columns of FAA are comparable with CCA.

The coefficient of volume change $\boldsymbol{m_V}$ of one, two and three columns of stone aggregate and fly ash aggregate are comparable and at the same time much lower than $\boldsymbol{m_V}$ of clay without column.

It is hence concluded that fly ash aggregate may be effectively utilized as column material in the place of conventional coarse aggregate in the improvement of soft clay.

REFERENCES

1. Barksdale R.D. and Bachus R.C. (1983) Design and construction of stone columns. Federal Highway Administration, Final report SCEGIT, pp 83-104.
2. Bijen J.M., (1986),Manufacturing Processes of Artificial Light Weight Aggregates from Fly ash, The International Journal of Cement Composites and Light Weight Concrete, Vol.8, pp 191-199.
3. Gokhan Baykal and Ata Gurhan Doven (2000), Utilization of Fly ash by Pelletization Process; theory, application areas and research results, Resources, Conservation and Recycling, Vol.30, pp 59-77.
4. Green Wood D.A. (1970), Mechanical Improvement of Soils below Ground Surface, Engineering Proceedings Conference Organized by the Institution of Engineers – London, pp 11-22.
5. Guetif Z., Bouassida M. and Debats J.M. (2007), Improved Soft Clay Characteristics due to Stone Column Insatallation, Computer Geotechnics,Vol.34, pp 104 – 111.
6. Holmstrom C. and Christopher W.Swan (1999), Geotechnical properties of Innovative, Synthetic Light Weight Aggregates, International Ash Utilization Symposium, Center for Applied Energy Research.
7. Hughes J.M.O. and Withers N.J. (1974) Reinforcing of soft cohesive soils with stone columns, Ground Engineering, Vol 17(3), pp 42-49.
8. IS: 15284 (Part 1) – 2003. Indian Standard code of practice for design and construction for ground improvement – guidelines, Stone columns, Compendium of Indian Standard on Soil Engineering.
9. Kayali O. (2008), Fly ash Light Weight Aggregates in high Performance Concrete, Construction and Building Materials, Vol.22, pp 2393-2399.
10. Manikandan R. and Ramamurthy K. (2007), Influence of Fineness of Fly ash on the Aggregate Pelletization Process, Cement and Concrete Composites, Vol.29, pp 456-464.
11. Meyerhof B. (1997), Analysis of Behaviour of Stone Columns and Lime Columns, Computer Geotech , Vol.20(1), pp 47 – 70.
12. Min-Hong Zhang and Odd Gjorv.E (1990), Pozzolanic Reactivity of Light Weight Aggregates, Cement and Concrete Research, Vol.20, pp 884-890.
13. Moseley M.P. and Kirsch K. (2004) Ground Improvement, 2nd Edition, pp 58 – 92.
14. Muir Wood D., Hu W., and Nash D.F.T. (2000), Group effects in stone column foundations: model test, Geotechnique, 50(6), pp 689–698.
15. Poorooshasb H.B. and Mayerhof G.G. (1997), Analysis of behaviour of stone columns and lime columns. Computers and Geotechniques, 20 (1), pp 47–70.
16. Purushothamaraj P. (1999) Ground Improvement Techniques, 1st Edition, pp 140 – 144.
17. Rajamane N.P., Anne Peter J. and Ambily P.S., (2007), Effect of Fly ash in Light Weight Concrete containing Sintered Fly ash Aggregates, IE(I), Vol.87, pp 32-36.