iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** VI **Month of publication:** June 2019

DOI: http://doi.org/10.22214/ijraset.2019.6194

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue VI, June 2019- Available at www.ijraset.com

Load Carrying Capacity of Geosynthetic Encased Stone Column in Pond Ash Fills

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***Abstract:** Stone columns are vertical boreholes in the ground, filled with gravel compacted by vibrofloat compaction. Ground improvement using stone columns is a popular technique for foundation of embankments or structure on soft soils. The inclusion of gravel, which has a higher strength, stiffness and permeability than the natural soft soil, improves load carrying capacity of soft soil thus enhancing the stability of the embankments. They can reduces total and differential settlements, accelerates soil consolidation and reduces the liquefaction potential. Present study the author investigated the model study on Ordinary stone column (OSC), Geotextile encased column (GTESC) and Horizontal and Vertical encased column (HESC+VESC), in loose ash fills. The 85 mm diameter OSC, Geotextile encased stone column and Horizontal and Vertical encased column are tested under the circular footing of 200mm diameter and 14mm thickness in the model tank set up. The result show that load carrying capacity of pond ash was 154N, OSC was 660N, GTESC was 790N and HESC+VESC was 1320N. Columns can be used in embankment or natural slope to increase the slope stability, also these can be used to release the pore water pressure and making the soil resistant to liquefaction. Encasement helps the stone column to maintain its shape which is very difficult in case of soft soil.*
***Keywords:** Ordinary stone column (OSC), Geotextile encased stone column (GTESC), Horizontal and Vertical encased stone column (HESC+VESC), Bearing capacity, Settlement, Geogrid.*

I. INTRODUCTION

It is a ground improvement technique used to improve the load bearing capacity and reduce the settlement of the soil. Stone columns can improve a soil deposit by densification, reinforcement and drainage functions. Out of several techniques available for improving soft clay stone columns are ideally suited for structures with wide spread loads. In case of soil having medium to low safe bearing capacity ground improvement with the help of stone columns have been found economical and faster in construction. The main aim of soil improvement is to increase the shear strength, loading capacity, stability and settlement control. Stone columns may not be appropriate in very soft soils that do not provide enough lateral confinement to the columns. In those cases geosynthetic materials are generally suited as encasements owing to the excellent tensile properties enabling those to produce sufficient circumferential stress around the column and prevent the bulging failure in very soft soil having undrained shear strength below 12-15 kPa. Different types of geotextiles and geogrids of different tensile stiffness are used as the encasement material. Encased stone columns are easy to install as well as cost of the project gets enormously reduced. The columns, such as sand compaction columns, stone columns, and deep mixed columns, can fail due to shearing and bulging modes under embankment load. Bulging is the most common failure in stone columns under concentrated load and composite loads as shown in Fig. 1.

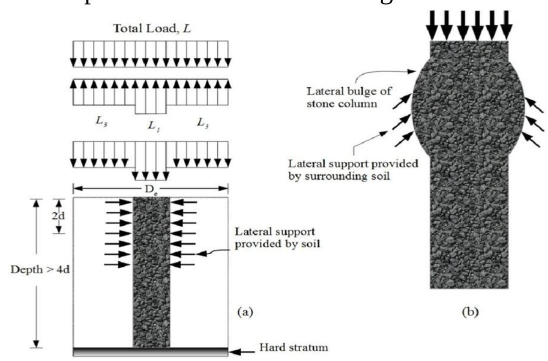

Fig. 1 Bulging, shear and punching failure mechanism of stone column *(IS 15284: 2003)*

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II. LITERATURE STUDY

The different researchers have been investigating the performance of encased granular columns. The work was conducted on analytical and numerical studies, experimental and field studies.

1) *Ghazavi. M., Yamchi. A. E., And Afsar. J. N(2018),* studied Bearing capacity of horizontally layered geosynthetic reinforced stone Columns. It was found that the bearing capacity of stone columns increases by using horizontally reinforcing layers. It was also observed that the lateral bulging of stone columns decreases by their frictional and interlocking effects with stone column aggregates. The bearing capacity increases considerably with increasing the number of horizontal layers and decreasing space between layers.
2) *Chen JF;Wang XT;Xue JF;Zeng Y;Feng SZ (2018),* studied behaviour of geotextile encased stone columns under uniaxial compression. The the uniaxial compressive strength of the encased stone columns is not affected by the initial void ratio but mainly by the tensile strength of the encasing geotextiles. The stress strain curves of the encased stone columns under uniaxial loading condition are nearly liner before failure, which is similar to the tensile behaviour of the geotextiles.
3) *Naderi. E And Asakereh . A and Dehghani. M.(2018),* studied the bearing Capacity Of Strip Footing On Clay Slope Reinforced With Stone Columns. Reinforcing Stone Columns with Encasing Cause Better Performance of Stone Columns and Increase in Bearing Capacity of Footing When the Stone Column Is Located Beneath the Strip Footing
4) *Castro J. (2017),* studied influence of length and arrangement on group of encased stone columns. Column Position Has A Small Influence On The Settlement Of Groups Of Encased Columns But Near The Edges Of A Rigid Footing, The Vertical Stresses Are Higher, So Columns Near The Edges Would Tend To Support Higher Loads. For Floating Columns When Area Replacement Ratio Is Same, Column Penetration into the Underlying Soil Is Greater When There Is Less Number of Columns and With Closer Spacing's.
5) *Gu, M., Zhao, M., Zhang, L., Han, J.(2016),* investigated the Geogrid Encasement On Lateral And Vertical Deformation Of Stone Columns In Model Test.It was concluded that Lateral Deformations Of SC Decreased Due To Additional Confining Stresses Provided By Geogrid Encasement.
6) *Miranda, M., Da Costa, A.(2016),* has done laboratory analysis of encased stone column. The effect of geotextile is noticeable once a certain axial strain is developed.
7) *Chen, J.F.; Li ,L.Y.; Xue J.F.; Feng , S.Z. (2015),*studied the failure mechanism Of geosynthetic encased stone columns in soft soils under embankment. It was found bending failure is the main failure mode in the geosynthetic encased Columns under Embankment Loading. The bending of the columns was caused by sliding of the embankment and the foundation soil and the unbalanced lateral loading acting on the columns.
8) *Yoo ,W.; Kim.B.,Choo,W.,(2015),* studied the behaviour of the geotextile encased sand pile in soft clay ground. Bearing capacity of the soft clay ground reinforced by the GESP (GEOTEXTILE ENCASED SAND PILE) is larger than that of the soft ground reinforced by the conventional sand piles and the failure mode of the GESP is buckling different from the bulging of the sand piles.
9) *Zhang ,L. Zhao,M. (2015),* conducted deformation analysis of geotextile encased stone columns. Selection of the geotextile stiffness for encased stone columns should be done in relation to column diameter and spacing because increased and decreased spacing have a great effect on settlement reduction.
10) *Choobbasti ,A.J. ; Pichka, H.(2014),* conducted experiment for improvement of soft clay using installation of geosynthetic encased stone columns. A single column compares well with the group results when the total surfaces are loaded.
11) *Murugesan, S., Rajagopal, K.(2010),* studied the behaviour of single and group of geosynthetic encased stone column. There was clear improvement in the load capacity of the stone column due to encasement. The Increase In the axial load capacity depends very much upon the modulus of the encasement and the diameter of the stone columns

III. MATERIAL AND EXPERIMENTAL SET UP

1) *Pond Ash:* Pond ash was used as the soft soil material in the experiment and it was taken from Ropar thermal power plant. Relative density of 40% was maintained in placing pond ash in tank. Relevant properties of pond ash (Ropar, Punjab) verifying its physical properties, chemical properties are tabulated below.

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Table 1- Physical properties of pond ash at left and chemical properties *(Trivedi and sud, 2007)* at right

Colour	Grey
Physical form	Fine grained
Specific gravity	1.6
Max. dry density	0.97g/cc
Uniformity coefficient	2.15
Curvature coefficient	1.12

Chemical components %	Ropar pond ash
Si [illegible]	57.5
[illegible]	27.2
[illegible]	5.4
CaO	3.1
MgO	0.4
[illegible]O, [illegible]O	0.9
S [illegible]	-
Unburned carbon	4.1

2) *Recycled Aggregates:* Recycled aggregate is produced by crushing concrete, and sometimes asphalt, to reclaim the aggregate. Particle size of aggregates lies in range of 2 mm to 20 mm. Aggregates were non- uniformly well graded aggregate mix.

Fig. 2 Pond ash field (in thermal power plant), recycled aggregates (From Construction & Demolition waste) and Geogrid

3) *Geogrid:* Geogrids are made up of polyethene (HDPE), commonly used to reinforce retaining walls as well as sub bases or subsoil's below roads or foundations.. Geogrids imparts the tensile strength (Fig. 2). The tensile strength of the geogrid is 33KN/m in longitudinal and lateral direction. The properties are displayed in Table 2.

Table 2- Properties of Uniaxial Geogrid *(SGi-040: Courtesy M/S Strata Geosystems (India) Pvt. Ltd, Mumbai, India)*

Aperture size	25mmx25mm
Cross Machine Direction	
Single rib tensile strength	33.4 kN/m
Single rib elongation at 30 kN/m	10.30%
Machine Direction	
Single rib tensile strength	33.4 kN/m
Single rib elongation at 30 kN/m	11%

Table 3- Properties of Non-woven Uniaxial Geotextile

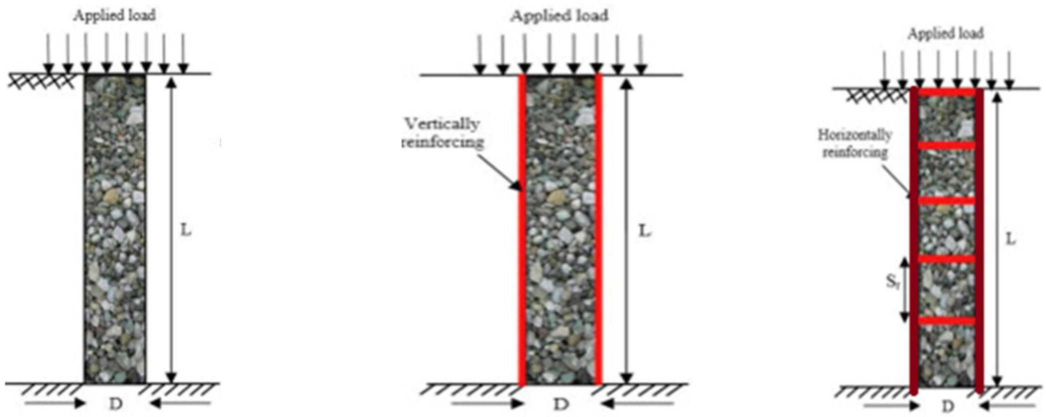
Property	Value
Tensile strength	1kN/m
Elongation	50%
Trapezoidal Tear	0.13kN
CBR Puncture strength	0.78kN
Permittivity	2.2 per Sec
Water flow rate	150gpm/ft

4) *Model Tank Set Up*: A model test tank with the dimensions having length (Lt) 830 mm, width (Bt) 680mm and depth (Dt) 630mm is designed and fabricated to perform the test as shown in Fig. 4. The sides of the model tank are made 12mm thick iron metal sheets. It is stiff enough to prevent any deformation of the ash during the process of compaction and at application of the load as well. The inside of the tank is smooth to reduce the side friction.

Fig. 3 Model tank including loading plate and dial gauges

Loading machine was developed by AIMIL for load settlement test. It is a manually operate machine and dial gauge (50mm) of least count 0.01mm are used for displacement reading and digital load cell for load measurement. A circular footing of 200 mm diameter 14mm thick plate attached vertically.

5) *Tank bed and Stone column Preparation*: Pond ash tested in the laboratory in order to find physical parameters. The ash was uniformly and thoroughly placed in the tank using raining technique to maintain 40% relative density. The compaction purpose author used raining technique. After placing the ash uniformly in the tank, the tank circular plate load using footing of diameter 200 mm was conducted on ash alone at 40% relative density to determine the load settlement behaviour. In second series with the help of small auger kind of device used to create the bore hole. Bore hole was immediately encased with the PVC pipe so that ash should not cave in. Third level author tested only ordinary stone columns, that is encased bore hole filled the recycled concrete aggregates. The aggregates filled in layers and used the 20mm tamping rod to compacting the aggregates in the column and simultaneously encased pvc pipe was pulled out as column is filled. Circular plate load test applied on ordinary stone column to determine the load deformation behaviour of the composite ash. Fourth level aggregates removed from the column, PVC pipe rapped with the geotextile lowered the pipe into the column. Filling the column with aggregates, slowly pvc pipe was pulled by leaving the geotextile inside the wall of the column. Utmost care was taken at this stage and aggregates are filled in the column with the compaction. Circular plate load test was applied to understand the behaviour of the ultimate bearing capacity and settlement of geotextile encased stone column (GTESC). Fifth level again aggregates along with geotextile were removed from column and vertical encasement of geotextile and horizontal encasement of geogrid were provided to column.PVC pipe rapped with the geotextile lowered the pipe into the column and filling the column with aggregates was done in layers, at end of each layer horizontal disc was placed and then slowly pvc pipe was pulled by leaving the geotextile inside the wall of the column and horizontal discs along the length of column at interval 1.5D. Circular plate load test was applied to understand the behaviour of the ultimate bearing capacity and settlement.



(OSC) (GTESC) (HESC+VESC)

Fig 4 Different cases of stone column taken into study

IV. RESULTS AND DISCUSSION

A. Load and Settlement Relationships

Fig 5 shows that when plate load test was conducted then load at settlement of 50 mm in case of pond ash alone was 154 N and when an ordinary stone column was made at the centre then load increases to 660 N showing increase of 328.57% in load at same settlement. In case of GTESC Load further increase to 790 N showing a increase of 19.7% as compare to ordinary stone column and 413% compared to pond ash alone. Further strengthening GTESC column by providing geogrid horizontal reinforcement load increases to 1320 N showing increase of 100% as compare to ordinary stone column and 757.14% increase as compare to pond ash alone.

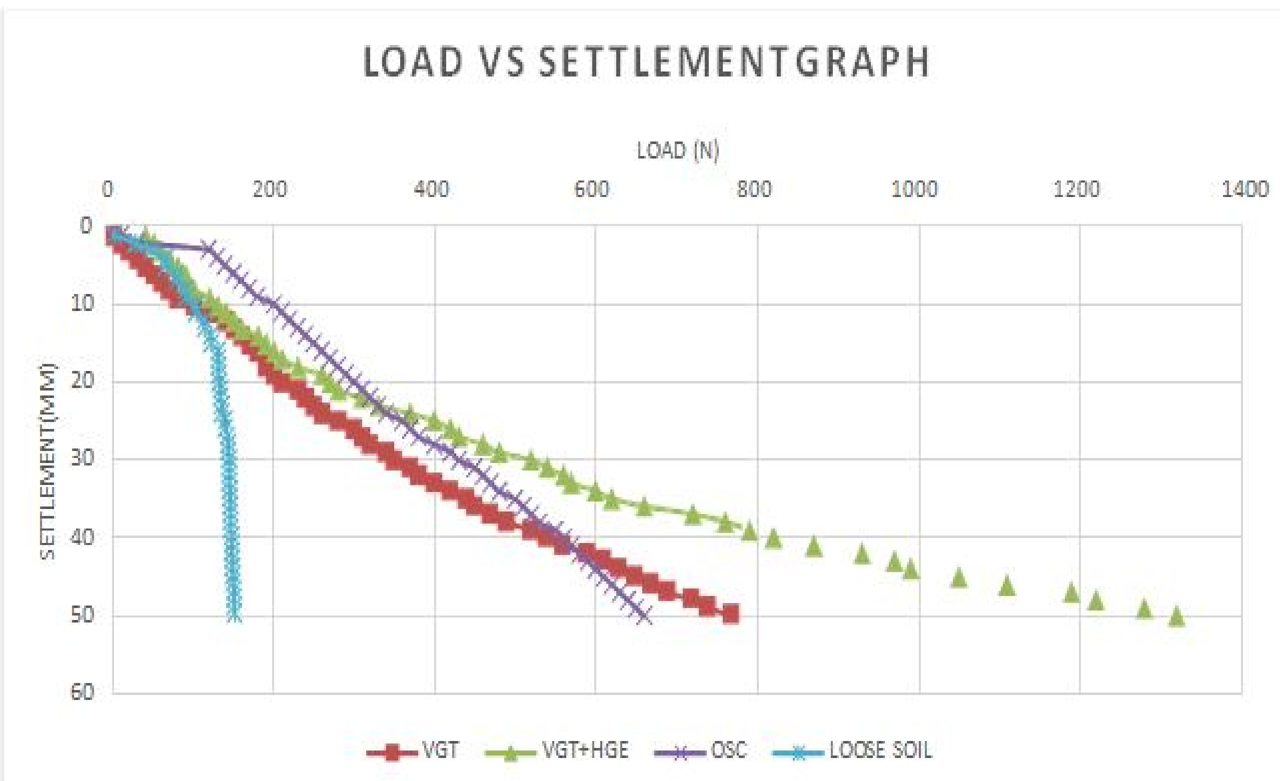


Fig 5 Comparison of load to settlement values of pond ash alone, OSC, GTESC, HESC+VESC

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B. Bearing capacity ratio (BCR): -

Bearing capacity ratio is the ratio of bearing capacity of ordinary stone column to the bearing capacity of Pond ash.

BCR = □ □□□□ கசா · ௗா· · · சா0க · · · உ· · / · · · · · · கசா · · ௗா 0·

Values of B.C.R. obtained while performing plate load test on different materials used for stone column are tabulated below.

Table 4- BCR values of pond ash alone, OSC, HESC, GGESC, HESC+VESC at 28mm settlement

Material	Pond ash	OSC	GTESC	HESC+VESC
BCR value	1	2.44	3.5	7.75

Fig 6 shows that BCR value for pond ash is 1 where as it increases to 2.44 in case of OSC that means increase in bearing capacity of ash after the instalment of column. After making HESC it further increase to 3.5 and with BCR value increase to 7.75 when both HESC and VESC used at same time.

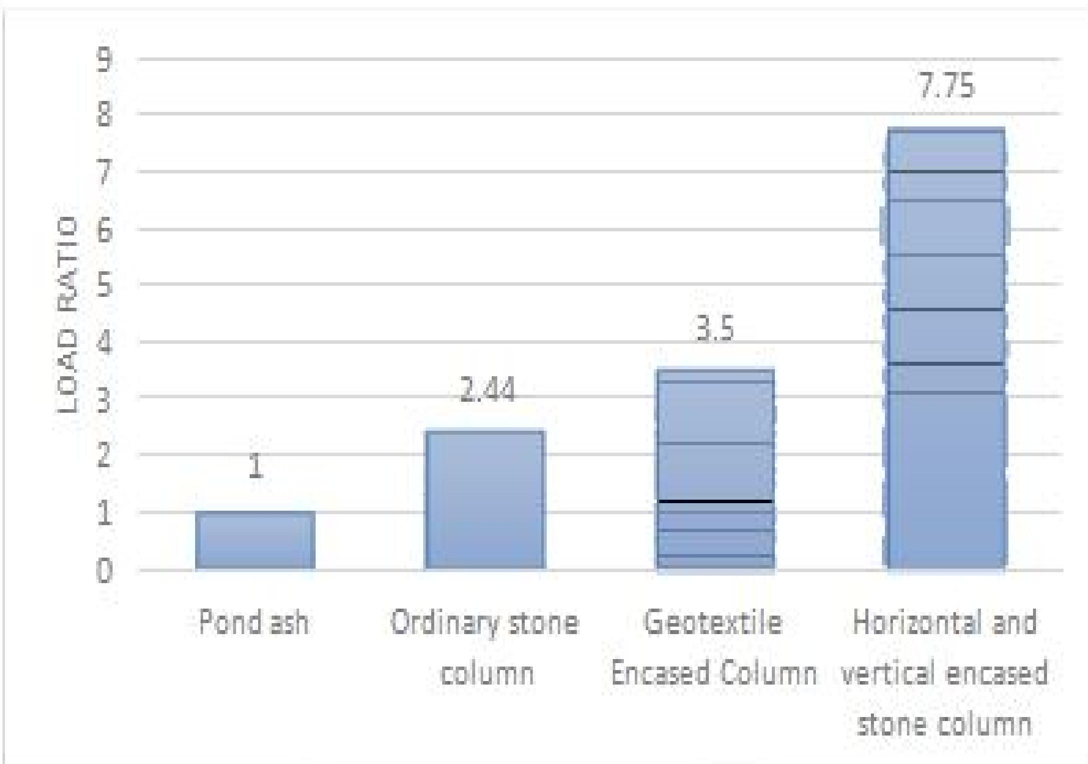

Fig 6 BCR values of pond ash alone, OSC, GTESC, HESC+VESC

Table 5- Load ratio vales of pond ash alone, OSC, GTESC, HESC+VESC

Settlement (mm)	Diameter of plate (mm)	LOAD RATIO 1	LOAD RATIO 2	LOAD RATIO 3	Settlement/Diameter of plate
		(OSC by pond ash)	(GTESC by pond ash)	(HGSC+VGSC) by pond ash	S/D
29	200	2.63	2.13	3.00	14.5

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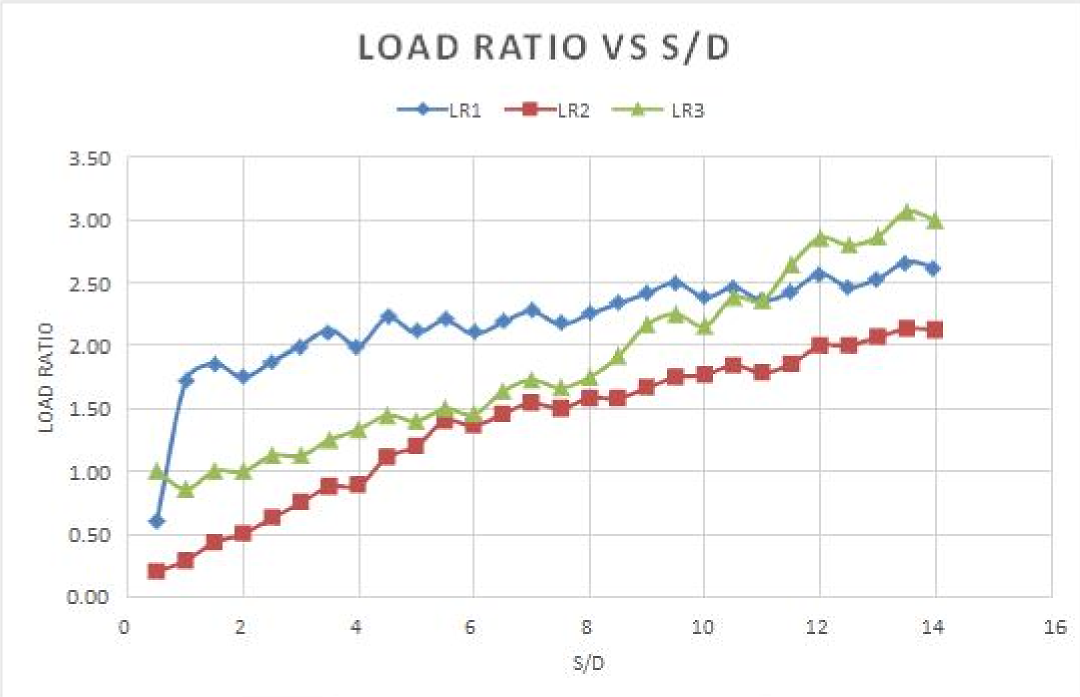

Fig 7 Variation of load ratio to settlement/Diameter values of OSC, GTESC and HESC+VESC

V. CONCLUSIONS

After performing the plate load test on pond ash using different types of stone column following conclusions are made:-

A. Load carrying capacity of untreated (pond ash alone) case is 154 N at the settlement of 50mm at 40% relative density.
B. When pond ash is treated with ordinary stone column, the load carrying capacity is 660 N at settlement of 50mm.
C. The increment of load carrying capacity pond ash having ordinary stone column to the without stone column that is untreated is 328.57%.
D. Stone column encased with vertical geotextile, the load carrying capacity is 790 N at settlement 50mm.
E. The increase of load carrying capacity of GESC (Geotextile encased stone column) to the untreated (pond ash alone) is 413%, and compare with the ordinary stone column the increment is 19.7% at the 50mm settlement
F. Stone column encased with vertical geotextile plus horizontal geogrid discs at a vertical spacing of D (diameter of column), the load carrying capacity is 1320 N at settlement of 50mm.
G. The increase of load carrying capacity of high confined case is much higher than the all the other cases. The increment level with the comparison of untreated case is 757.14 %.

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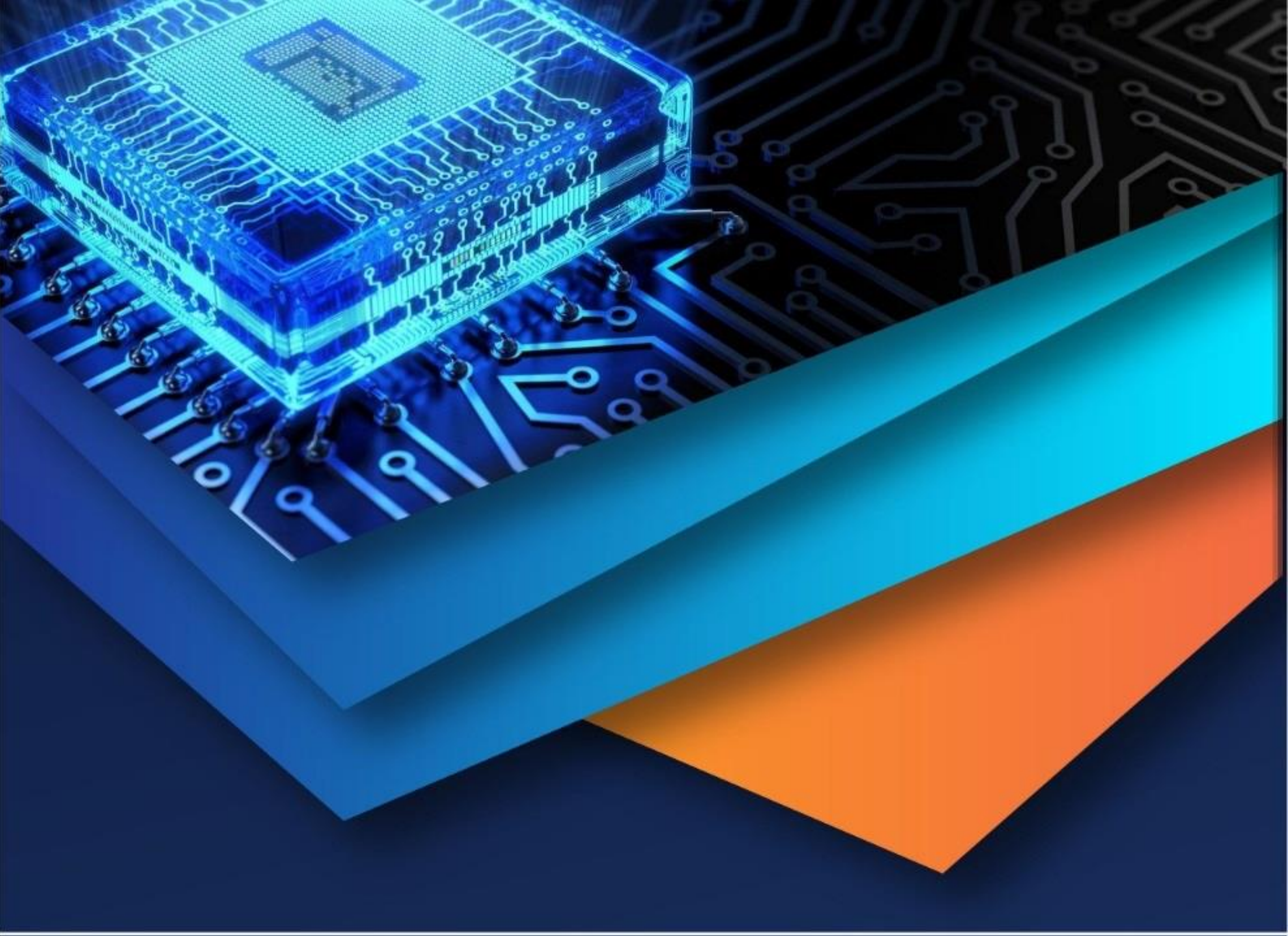

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