

Evaluation Of Use of Stone Column in Unengineered Closed Landfill Soil

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ABSTRACT: - In the building industry, ground improvement techniques based on stone column are widely employed. It is a very successful approach for enhancing the engineering characteristics of soil in all aspects, as well as reducing the settling issue in poor-grounded soils including silt, clay, silty sand, and organic soil. The performance of stone columns, is determined by the confining pressure provided by the surrounding soils. Engineering constructions built on thick layers of soft soil strata face issues such as limited bearing capacity, excessive total and differential settlement, lateral spreading, and so on. To address such issues, many ground improvement techniques are available. In exceptionally soft soils, the lateral confining pressure may be inadequate, resulting in column bulging failure. Individual stone column encasement improves lateral resistance to bulging by adding restricting pressure. This research focuses on the geotechnical aspects of building on closed landfill sites. A total of 33 models were tested in a geotechnical engineering laboratory on virgin former landfill soil and stone column with and without encasement in this current study. The increased diameter, length and L/D ratio of the column has demonstrated that the load capacity has increased and soil settling has decreased. When an unreinforced stone column has been installed, the ultimate bearing capacity of landfill soil is increased by 75-112.50 per cent and 87.50-176 per cent respectively, for 10mm and 20mm diameter stone column. Furthermore, when a fully reinforced stone column has been installed, it had increased by 156.25-212.50 per cent and 200-298 per cent for 10mm and 20mm diameters respectively. The stiffness of soil is increased by the stone column, which contributes to increase in the load capacity. The geogrid layer confines an aggregate, which contribute to enhance shear stiffness and bearing capacity.

KEYWORDS: - landfill, stone column, ultimate bearing capacity.

1. INTRODUCTION

The rising of population development, polishing living standards, rapid industrialization and increasing commercial activities are crucial factors for increasing in the quantity of waste produced and reduction of good quality land around the world. More area would be needed to dispose of massive quantity of waste. Waste can be kept in landfill areas. Recyclable materials are to separate before dumping in a landfill. Landfills are the most prevalent and oldest method of waste disposal. Landfill occupies the large areas, resulting in the loss of valuable land.

Landfills are usually designed for a specific time. Once they got reached at the end of their lifespan, they must be closed for decomposition of waste.

Therefore, after decomposition of waste landfill sites are able to use for redevelopment, recreational and others. Sports clubs, Golf courses, natural parks and public tracks for

walking and cycling these are the examples of recreational usage. Because these sites have low bearing capacity that's why stabilization is also necessary.

So, these landfill sites need much attention, for its utilization in civil engineering projects.

The most frequent and oldest method of waste disposal is the landfill. Landfills after reached its full capacity and they are no longer active for use. These are called former landfills. Often repurposed into landfill –to –gas-energy sites, recreational use and other uses. These sites have low bearing capacity, that's why adoption of stabilization or ground improve techniques are significant before starting construction.

2. METHODOLOGY

2.1 Materials: - To conduct the experimental work, landfill soil, aggregates and geogrid were used. Aggregates are primary building materials for stone columns. Geogrid was used to reinforce the stone column.

2.2 Landfill soil: - Soil was collected from village Jainpur, district Ludhiana (Punjab). There is a large landfill that has not been used for about 15 to 16 years. Fig.1 is showing the exact location of landfill soil from where it is collected. 33acre area is covered by landfill. The soil sample was collected from 3 different places. All undesirable matters were removed from the soil. Before conducting all tests, the soil was sieved through a 4.75 mm sieve. Table 2 displays properties of soil.



Fig 1 Former landfill site

2.3Aggregates: - Aggregates used for the construction of stone columns were collected from local building store. Aggregates sieved through a 10 mm sieve for construction of stone columns. Properties of aggregates explains in table no.3.

2.4 Geogrid: - Geogrid used for encasement of stone column purchased online and some of these properties of geogrid were predetermined which are given below. Table no. 1 displays some geogrid properties and figure 2 represents the same geogrid that was used in the experiment.



Fig. 2 Geogrid Used for Encasement

2.5 Experimental Setup: -A cylindrical tank made of steel used for all experimental work. This tank is properly braced against expansion. The top view of the cylindrical mould used for the experimental work is shown

in Figure 3. The dimensions of the cylindrical tank are 285.75 mm diameter, 406 mm length and 3mm thickness. The diameter of the test tank is five times greater than that of the footing (plate), as per IS 1888-1962 specifications. The diameter of the stone column is 20mm, and 10mm and different L/D ratios of 4.5, 5, 5.5 and 6 were adopted. A circular metal plate 57 mm in diameter and 4 mm in thickness was used as a footing. In this experiment, a stone column is inserted into a pre-drilled hole in the compacted soil and a circular plate is rested over the stone column.

Table 1 Properties of geogrid

Parameter	value
Stiffness	38.01 kN/m
Thickness	1.5 mm
Ultimate tensile strength	7.96 kN/m
Strain	20.21 %

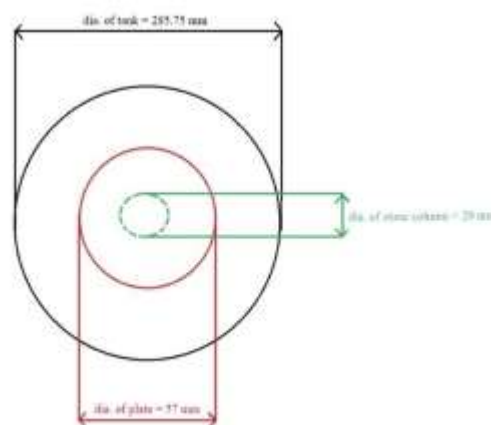


Fig 3 Experimental Arrangement of Stone Column

2.6 Preparation of Stone Column in laboratory: - After sieving, the landfill soil was filled in the tank into several layers. To achieve the maximum dry density, the soil was mixed and compacted at the optimum moisture content. Figure 4 shows the mixture of landfill soil at the optimum moisture content. A 4.9 kg rammer with a free fall height of 450 mm was used for soil compaction. The modified proctor test was

used to determine the required number of blows. After carefully filling the tank with

soil, each layer was properly compacted.

Table 2. Properties of landfill soil

parameter	Value
Cu	6.36
Cc	1.24
Sand content	86%
Silt content	14 %
Type of soil	Well graded sand
Liquid limit and plastic limit	Non plastic
Specific gravity	1.00
Angle of internal friction (ϕ)	5.14°
Cohesion (C)	5.67 kN/m ²
Modulus of elasticity (E)	18 kN
Dry density	12.410 kN/m ³
Bulk density	15.512 kN/m ³
Optimum moisture content	13%
Poisson's ratio (μ)	0.3
Unconfined compressive strength (Q_u)	0.20 kG/m ²
Undrained shear strength	0.10 kG/m ²
Shear strength (kN/m ²)	5.75

Table 3. Properties of aggregates

Parameter	Value
Angle of internal friction(ϕ)	42.8°
Cohesion (C)	3.76 kN/m ²
Saturate unit weight	21.38 kN/m ³
Dry unit weight	20.04 kN/m ³
Specific gravity	2.70
Modulus of elasticity (E)	40000 kN/m ²
Poisson's ratio (μ)	0.3

A 20 mm diameter PVC pipe was placed at the center of the tank, then the soil was filled to the required depth. Figure 6 shows the PVC pipe was inserted into the circular tank. The soil was compacted again around the PVC pipe with a rammer. The PVC pipe was properly lubricated before being placed in the tank. Graduations were marked on the pipe so that the PVC pipe could be inserted at that particular depth or equal to the required length of the stone column. Figure 14 shows the graduation mark on the PVC pipe.

To give reinforcement to the stone column, a layer of geogrid was wrapped over the PVC pipe. Figure 10 shows the geogrid was used to reinforce the stone column. The layer of geogrid at different heights was used to fully and partially reinforce the stone columns. Figures 11,12 and 13 show the length of the geogrid layers provided to reinforce the stone column.

Then the PVC pipe was pulled out gradually when the tank filled at the required height. The layer of geogrid remained in the hole after the PVC pipe was pulled out. A clean and hollow 10mm and 20mm diameter hole was obtained after the PVC pile was pulled out. Fig 7 shows the hole after pulling out the PVC pipe. Aggregates which were sieved through a 10mm sieve filled in this hollow hole in 3 layers. Figure 5 shows the aggregates used for the construction of stone columns. Every layer of aggregates was compacted properly with the help of a rammer to remove the voids. A stone column of the required diameter and length, a stone column was obtained after filling the hole. Fig 8 shows the stone column after filling with aggregates. The top surface of the tank was levelled with the help of hand tools. A steel plate as a footing was placed on the stone column. Fig 9 shows the steel plate over the stone column.

2.7 Experimental procedure: - This procedure was performed in the geotechnical engineering laboratory. The machine used for the experiment is represented in fig 15. The testing tank was gently placed under the penetration piston of the testing machine after filling and

compacting the soil. A steel plate was placed on a stone column at the center of the tank. It also ensures that the top surface of the filled tank is properly level. The load testing machine can be operated manually or electrically.

For required amounts of penetration, corresponding load values were recorded. Later, the stress v/s penetration values curve is drawn by using these values.



Fig 4. Mixed Soil at OMC



Fig 5. Aggregates Used for Construction of SC



Fig 6. PVC Pipe Inserted in The Tank



Fig 7. Hole After Pulled Out PVC pipe



Fig 8. SC After Filling the Aggregates



Fig 9. Steel Plate Over SC



Fig 10. geogrid R/F



Fig 11. R/F @ length L



Fig 12. R/F @ L/2 length of SC



Fig 13. R/F @ L/3 length of SC



Fig 14. Graduated PVC Pipe



Fig 15. Experimental Set Up testing machine in The Laboratory

3. RESULTS AND DISCUSSIONS

In this experimental work total 33 number of models were tested. It includes tests on virgin soil, stone column with or without encasement and partial reinforcement by adopting various L/D ratios and diameter of stone column. Graphs were plotted for each model between load (kN) and settlement (mm). The double

tangent method was used to determine the ultimate bearing capacity of soil.

3.1 Ultimate bearing capacity of landfill

soil: - Table 4.1 represents the ultimate carrying capacity of soil using stone column with diameters of 10mm and 20mm and L/D ratio of 4.5, 5, 5.5, and 6 with or without encasement.

Table 4.1 Ultimate bearing capacity of soil

SR. NO	TYPE OF ENCASEMENT	ULTIMATE BEARING CAPACITY (kN/m ²)							
		DIAMETER=10mm				DIAMETER=20mm			
		L/D Ratio				L/D Ratio			
		4.5	5	5.5	6	4.5	5	5.5	6
1	W-EN	548.65	587.84	666.22	627.03	587.84	705.41	866.08	783.79
2	L/3-EN	627.03	685.81	744.60	705.41	705.41	822.98	999.33	90.35
3	L/2-EN	744.60	783.79	862.17	822.98	842.57	979.73	1071.71	1018.92
4	L-EN	803.39	862.17	979.73	940.54	940.54	1136.49	1250.14	1175.86

3.2 Effect of length of encasement on ultimate bearing capacity: - The effect of length of encasement on ultimate bearing

capacity (UBC) is examined when a stone column with a diameter of 20 mm & 10 mm and a length-to-diameter ratio(L/D) of 4.5, 5,

5.5 & 6 is used. There are three types of encasements: L/3 length of encasement, L/2 length of encasement and L- length of encasement of stone column.

3.2.1 10 mm & 20mm diameter of stone column with different L/D ratios.

Fig. 16 describes the effect of diameter and length of encasement of a stone column with an

L/D ratio of 4.5 on the UBC of the soil. Due to encasement and without encasement of the stone column, the UBC of soil as increases as increase diameter of the stone column from 10mm to 20mm. Also, the UBC of soil increases as increases the length of encasement from L/3-EN to L- length of the encasement.

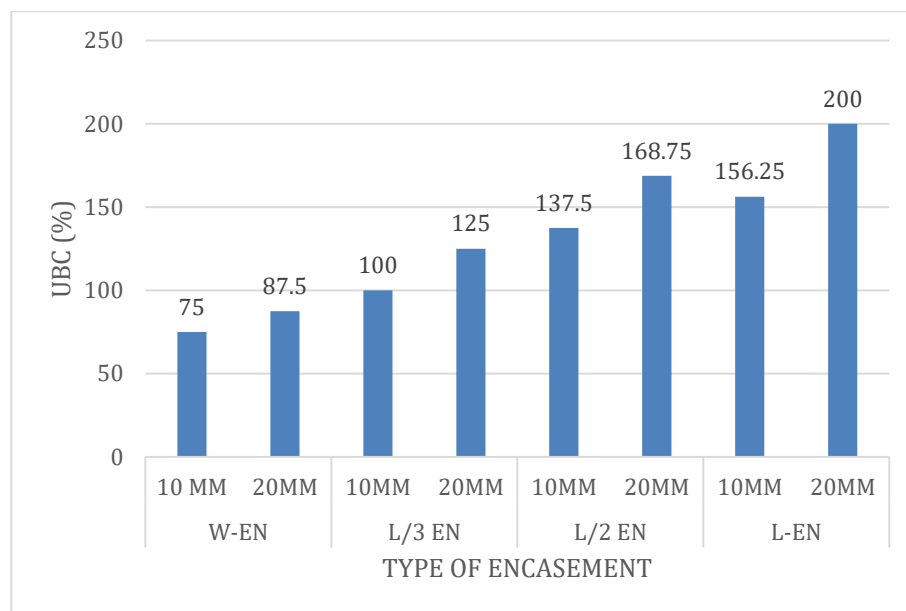


Fig. 16. Effect of length of encasement using L/D = 4.5

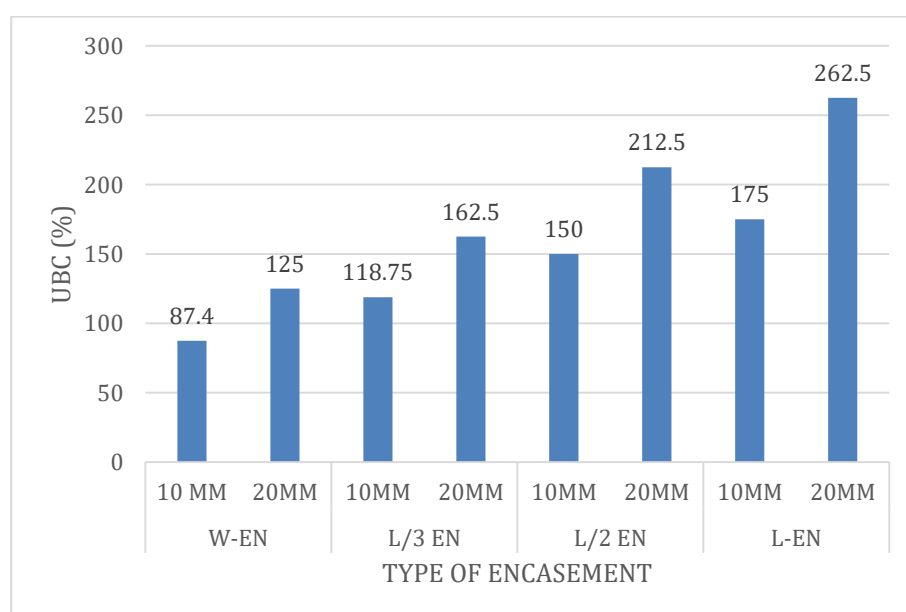
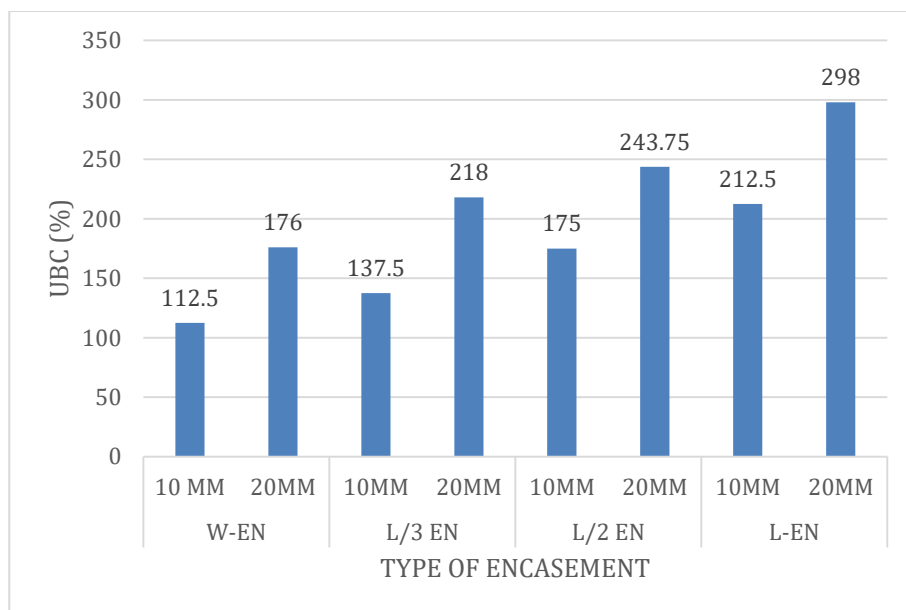
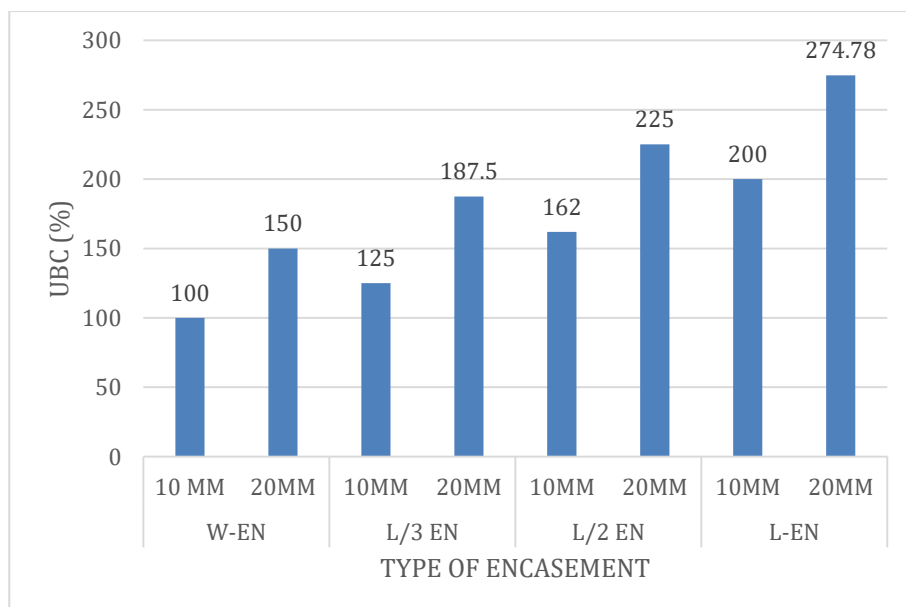


Fig. 17. Effect of length of encasement using L/D = 5

Fig. 18. Effect of length of encasement using $L/D = 5.5$ Fig. 19. Effect of length of encasement using $L/D = 6$

An influence of the diameter and length of encasement of a stone column with L/D ratio of 5.6 on the UBC of soil is depicted in Fig. 19. when SC used with L/D ratio 6, the UBC of soil increases but slightly less than that of L/D ratio 5.5. For obtaining maximum UBC of soil a stone column with L/D ratio 5.5 is sufficient. This experimental work identified that if L/D ratio of Sc further increase form 5.5, the UBC of soil starts decreasing.

3.3 Effect of L/D ratio on ultimate bearing capacity: - It explains the effect of different L/D ratios and diameter of stone

column (SC) on ultimate bearing capacity of soil. An influence of L/D ratio on UBC is investigated by using a stone column with diameters of 20 mm and 10 mm and length-to-diameter ratios (L/D) of 4.5, 5, 5.5, and 6.

3.3.1 10 mm & 20mm diameter of stone column using different L/D ratios.

Fig. 20 and 21 explains the effect of the L/D ratio on UBC when the stone column of diameter 10mm and 20mm was used. As encasement is applied, the UBC of the soil increases. In this experimental work, different

L/D ratios of 4.5, 5, 5.5, and 6 were adopted. The ultimate bearing capacity of soil increases the L/D ratio to 4.5, 5 and 5.5. But, When the L/D ratio increases from 5.5 to 6, the UBC of soil decreases in both cases, i.e., encasement or without encasement of stone column. A reason behind the decrement of

UBC of soil for the L/D ratio of 5.5 to 6 is that as the length of column increases, it starts bulging and fails. When stone column is installed in soil, a stiffness of soil rises and the geogrid layer confines an aggregate. That's why it contributes to increase the ultimate bearing capacity of soil.

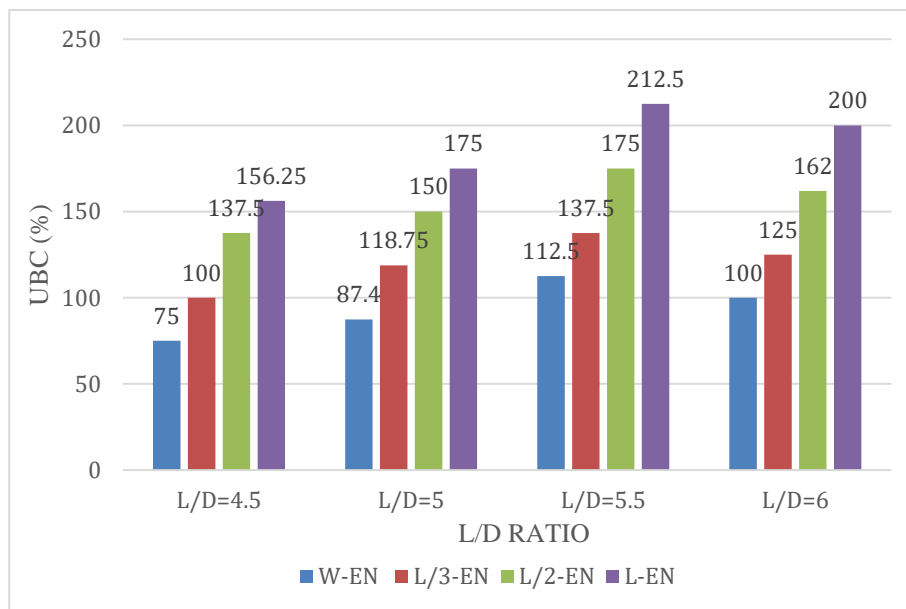


Fig. 20. Effect of L/D ratio on UBC using 10mm diameter of stone column

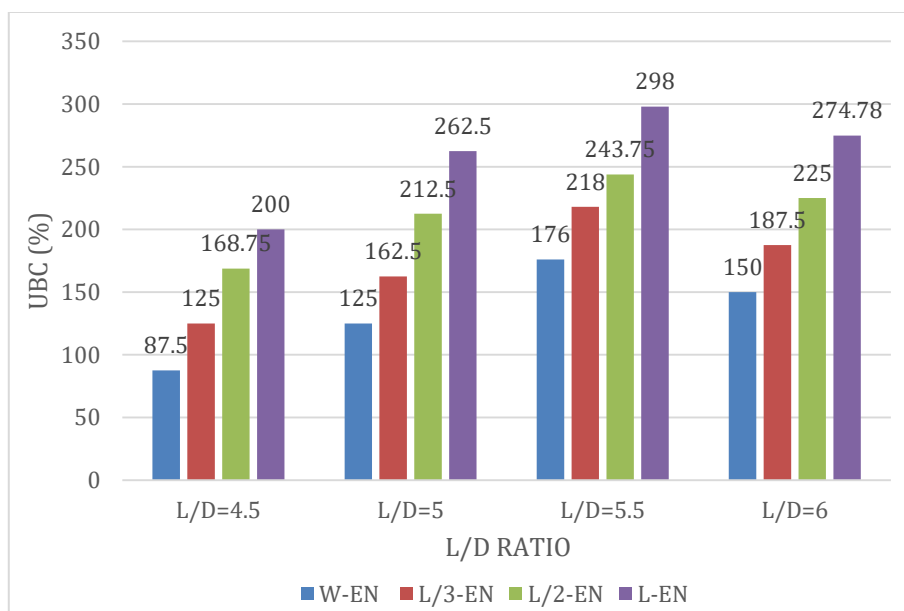


Fig. 21. Effect of L/D ratio on UBC using 20mm diameter of stone column

4. CONCLUSIONS

From the results, it has been concluded that the landfill soil has low bearing capacity. When the stone column has been installed

without and with geogrid encasement or partial encasement the bearing capacity value has multiplied by the number of times than that of virgin landfill soil. To conclude of all experimental work are defined below: -

1. The ultimate bearing capacity of landfill soil is increased by 75-112.5% when an unreinforced stone column is installed. When increasing the diameter of the stone column at same L/D ratio, the bearing capacity of soil increases by 87.50-176 %.

2. The bearing capacity of landfill soil increased by 156.25-212.50% when fully reinforced stone column was installed in the virgin soil. When a diameter of the stone column is increased a same L/D ratio, the ultimate bearing capacity increases by 200-298%.

3. The bearing capacity of virgin landfill soil is increased by 137.50-175% when geogrid reinforcement provided at L/2 length of stone column. The ultimate bearing capacity improved by 168.75-243.75 % when diameter of the stone column was doubled at same L/D ratio.

4. The bearing capacity of virgin landfill soil increases by 100-137.5% when geogrid reinforcement is provided at L/3 length of stone column. When the diameter of stone column was doubled while maintaining same L/D ratio, the ultimate bearing capacity increased by 125-218%.

5. There is a significant increase in soil bearing capacity with an increase in L/D ratio of the stone column upto 5.5. This experimental work identified that for landfill soil the optimum value of L/D ratio of SC is 5.5.

REFERENCES

- (1) Pohland, Frederick G. (1973) *Sanitary Landfill Stabilization with Leachate Recycle and Residual treatment*. Washington, D.C.: Georgia Institute of Technology, pp. 6-71
- (2) J.R., Emberton, and J Parker. (1986) "the problems associated with building on landfill sites." *waste management & research* pp. 473-482.
- (3) D. Snethen & M. Homan (1991). Dynamic Compaction/Stone Columns - Test Sections for Construction Control and Performance Evaluation at an Uncontrolled Landfill Site. In M. Esrig & R. Bachus (Eds.), *STP1089-EB Deep Foundation Improvements: Design, Construction, and Testing* pp. 199-211.
- (4) Odud, Claire. (2000) "Current State of the Practice of Construction on Closed Landfill Sites." *16th International Conference on Solid Waste Technology and Management*. PA, USA.
- (5) Asadi, J.B. Wiley and B. (2002) "Redevelopment potential of landfills. A case study of six New Jersey projects." *Browtzfield Sites: Assessment, Rehabilitation and Developpment* pp. 42 - 55.
- (6) IS 15284-1 (2003): Design and construction for ground improvement - Guidelines, Part 1: Stone columns [CED 43: Soil and Foundation Engineering]
- (7) Guetif, Z., Bouassida, M., & Debats, J. M. (2007). Improved soft clay characteristics due to stone column installation. *Computers and Geotechnics*, 34(2), pp.104-111.
- (8) Black, J. A.; Sivakumar, V.; Madhav, M. R. and Hamill, G. A. (2007) "Reinforced stone column in weak deposit: laboratory modal study", *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE Vol. 133, (9).
- (9) Wang, G. (2009) "Consolidation of soft clay foundation reinforced by stone columns under time-dependent loading", *Journal of Geotechnical and Geoenvironment Engineering*, ASCE, Vol.135, (12): pp.1922–1931.
- (10) Murugesan, S. and Rajagopal, K. (2010) Studies on the behaviour of single and group of geosynthetic encased stone columns", *Journal of Geotechnical and Geo Environmental Engineering*, ASCE, Vol.136(1): pp.129-139.
- (11) Piotr KANTY, Jerzy SĘKOWSKI. (2011) "model tests of phenomena occurring during stone column." *architecture civil engineering environment* pp. 44-100.
- (12) Dr. Purushothama. (2011) *ground improvement techniques*. Lakshmi publications (P) limited
- (13) Tarantino, Davide Forcellini and Angelo Marcello (2014) "Assessment of Stone

Columns as a Mitigation Technique of Liquefaction-Induced Effects during Italian Earthquakes." *Hindawi Publishing Corporation* 1-8.

(14) Samuel Thanaraj. M1, Freeda Christy. C2, Brema.J3. (2015) "Performance of Different Types of Stone Columns in Soil Stabilization – A Review." *International Journal of Engineering Technology Science and Research* pp. 73-82.

(15) Pa. Suriya, P. Subathra, P. Gopiprasath, Vemuri Lakshminarayana. (2017) "Stabilization of Soft Soil Using Stone Column – The Review." *Jr. of Industrial Pollution Control* pp 1214-1217.

(16) Ali Chabuk, Nadhir Al-Ansari, Hussein Musa Hussein, Suhair Kamaledin, Sven Knutsson, Roland Pusch and Jan Laue. (2017) "Soil Characteristics in Selected Landfill Sites in the Babylon Governorate, Iraq." *Journal of Civil Engineering and Architecture* 11 pp. 348-363.

(17) N. Hataf, N. Nabipour and A. Sadr. (2020) "Experimental and numerical study on the bearing capacity of encased stone columns." *international journal of geo-engineering* pp. 1-19