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Assessment of Group of Stone Column under Sesmic Condition

S. D. Futane, A. I. Dhatrak, S. W. Thakare

Abstract: The study of group of stone column is concerned with evaluation and comparison of the behaviour of group of encased stone column and ordinary stone column for static and seismic load condition. Stone column system with specified geometry is modelled and analysed in FEM software program MIDAS GTS 3D. Analysis is categorised into four cases. Pseudo-static method is used for seismic load calculation. The objective of research is to analyse the performance of stone column by considering the effect of various parameters such as diameter of stone column, static and seismic load condition in cohesive clay and silty clay. Effect of encasement is also observed for static loading condition and seismic loading condition. Result shows that encased stone column reduces the settlement and length of stone column.

Keywords- Encased stone column, ordinary stone column, static load and seismic load.

I. INTRODUCTION

Stone column is a suitable technique of ground improvement for foundations on soft clay. Stone column is a method of soil reinforcement in which soft cohesive soil is replaced by gravel or crushed rock in pre-bored vertical holes to form columns within the soil. Stone column has two basic functions that provide strength, reinforcement to the soil and acts as vertical drains to allow subsoil rapid consolidation under any given load. Stone columns are used to accelerate the rate of consolidation by reducing the length of the drainage path, to reduce the settlement of soft clays and increase the load bearing capacity. It mitigates damage due to the build-up pore pressure, by providing a drainage path and increasing the strength, stiffness of ground and potential for liquefaction. There are two types of stone column installation techniques viz., non-displacement method (rammed stone column) and displacement method (vibro-replacement method). Stone columns are used for the foundations of rail and road embankments, bridge approaches and abutments, offshore bridge abutments, airport runway and taxiways, storage tank (LNG, Crude Oil, LPG etc.) and power plants.

Testing was conducted on stone column to determine performance as liquefaction countermeasure in non-plastic silty soil. Stone columns were effective remediation technique for liquefaction induced settlement of non-plastic silty soil [1].

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Behaviour of stone column was studied when subjected to cyclic loads installed in marine clay. Settlement was increased with increase in number of cycles [2]. Geosynthetic encased stone columns and ordinary stone columns were installed in kaolinite clay bed to study and behaviour was compared during and after seismic excitation. Experimental setup was subject to large-scale shaking table test to simulate seismic behaviour of columns [3].

II. METHODOLOGY

Stone column system with specified geometry was modelled and analysed in FEM software program MIDAS GTS 3D. For the analysis, a 3D model of stone column foundation with a soil block was modelled. The group of stone column embedded in clay was subjected to static and seismic loading condition. Pseudo-static method was used for the calculation of seismic load. Stone columns were designed for actual site condition for analysis purpose, in which one oil tank was considered. Uniformly distributed load was applied by oil tank; therefore analysis was performed on a group of 4 x 4 stone columns as shown in Fig.1. Analysis was carried out by varying diameters of stone column. Number of stone columns, spacing and length of stone columns were varied for each diameter. The material properties used for the study are given in Table I.

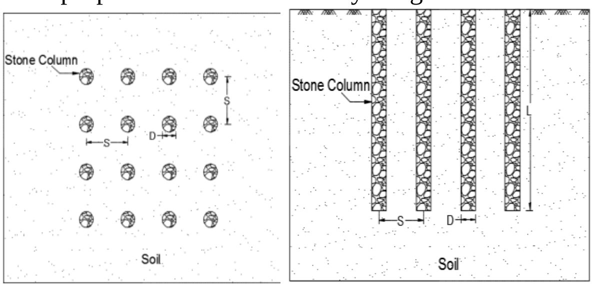

Fig. 1: Typical stone column model with various parameters.

Table I. Material Properties selected for analysis of stone column

Property	Unit	Soil	Stone Column	Geogrid
Material Model	-	Mohr-Columb	Mohr-Columb	Elastic
Elastic Modulus	kPa	5500	55000	500000
Angle of Internal Friction (Ø)	degree	-	43˚	-
Cohesion (c)	kPa	30	-	-
Poisson's Ratio (μ)	-	0.42	0.3	0.3

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III. NUMERICAL ANALYSIS

Analysis was carried out to evaluate settlement of stone column and results were compared for encased stone column and ordinary stone column under static and seismic loading condition. Analysis of group of stone column was divided in four cases:

i. Analyses of stone column for static loading -
Analyses were carried out for stone column group subjected to static loading only.

ii. Analyses of stone column group for seismic loading -
Analyses were carried out for the stone column subjected to seismic load by pseudo-static method.

iii. Analyses of encased stone column group for static loading-
In this case analyses were carried on encased stone column under static load.

iv. Analyses of encased stone column group for seismic loading-
In this case analyses were carried on encased stone column under seismic load condition.

Cohesive soil was used for analysis. Various diameters of stone columns were used viz. 0.6 m, 0.8 m, 1.0 m and 1.2 m

Table II. Settlement and effect of encasement of stone column for static loading condition in cohesive clay

Diameter of stone column (m)	Settlement of ordinary stone column for static load condition in cohesive clay (mm)	Settlement of encased stone column for static load condition in cohesive clay (mm)	S.R.R. in static loading (%)	L.R.R. in static loading (%)
0.6	183.11	149.90	18.13	20
0.8	342.01	292.29	14.53	17.14
1.0	460.93	401.68	12.85	26.25
1.2	711.239	646.33	9.12	9.6

IV. RESULTS AND DISCUSSION

Analysis was carried out for 0.6 m, 0.8 m, 1.0 m and 1.2 m diameter of ordinary stone column and encased stone column subjected to static and seismic loading. Settlement obtained from the analysis of group of stone columns and effect of encasement on settlement and length reduction for cohesive clay are given in the table II and table III. Settlement and length reduction were observed for static loading condition and seismic loading condition due to encasement of stone column. Fig. 2 and Fig. 3 shows settlement reduction ratio (S.R.R.) and length reduction ratio (L.R.R.) for different diameter of stone column in cohesive clay.

Table III. Settlement and effect of encasement of stone column for seismic loading condition in cohesive clay

Diameter of stone column (m)	Settlement of stone column for seismic load condition in cohesive clay (mm)	Settlement of encased stone column for seismic load condition in cohesive clay (mm)	S.R.R. in seismic loading (%)	L.R.R. in seismic loading (%)
0.6	284.88	228.60	19.75	9.83
0.8	543.50	440.55	18.94	24.54
1.0	805.89	619.17	23.16	10.12
1.2	1070.03	956.84	10.57	12.72

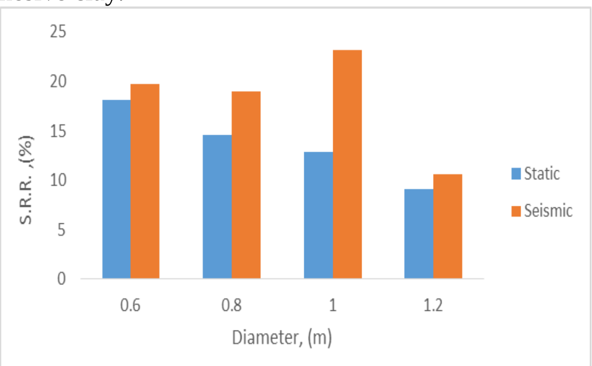

Fig. 2: S.R.R. for different diameter of stone column in cohesive clay

Table IV shows effect of seismic loading on settlement of stone column in cohesive clay. Settlement was increased due to seismic loading. Percentage increment was determined for stone column without encasement and for encased stone column.

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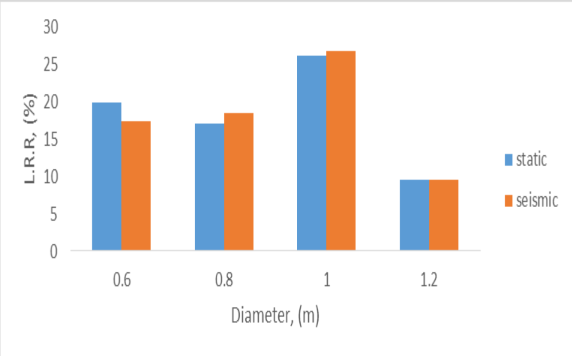

Fig. 3: L.R.R. for different diameter of stone column in cohesive clay

Table IV. Effect of seismic loading on settlement of stone column in cohesive clay

Diameter (m)	Increment in settlement of stone column without encasement due to seismic loading (%)	Increment in settlement of stone column with encasement due to seismic loading (%)
0.6	55.57	52.50
0.8	58.9	50.7
1.0	74.83	54.14
1.2	50.44	48.40

Table V. Settlement and effect of encasement of stone column for static loading condition in silty clay

Diameter of stone column (m)	Settlement of ordinary stone column for static load condition in silty clay (mm)	Settlement of encased stone column for static load condition in silty clay (mm)	S.R.R. in static loading (%)	L.R.R. in static loading (%)
0.6	121.48	95.39	21.47	9.83
0.8	193.16	138.49	28.30	24.54
1.0	268.5	199.72	25.61	10.12
1.2	340.30	256.17	24.72	12.72

Table VI. Settlement and effect of encasement of stone column for seismic loading condition in silty clay

Diameter of stone column (m)	Settlement of stone column for seismic load condition in silty clay (mm)	Settlement of encased stone column for seismic load condition in silty clay (mm)	S.R.R. in seismic loading (%)	L.R.R. in seismic loading (%)
0.6	151.85	117.77	22.44	9.83
0.8	252.4	188.62	18.94	24.54
1.0	329.4	245.31	23.16	10.12
1.2	443.4	322.18	10.57	12.72

Table V and table VI shows settlement obtained from the analyses of group of stone columns and effect of encasement on settlement reduction and length reduction for silty clay. It was observed that, length reduction in static loading condition and seismic loading condition was same in case of silty clay. Fig 4 and 5 shows variation in settlement reduction ratio (S.R.R.) and length reduction ratio (L.R.R.) for different diameter of stone column in silty clay.

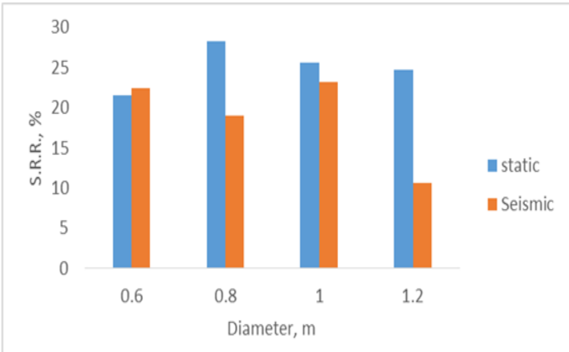

Fig.4: S.R.R. for different diameter of stone column in silty clay

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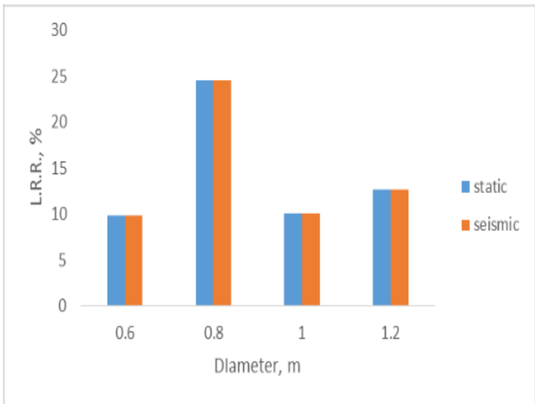

Fig.5:L.R.R. for different diameter of stone column in silty clay

Table VII shows effect of seismic loading on settlement of stone column in silty clay. Increment in settlement of stone column without and with encasement due to seismic loading was calculated.

Table VII. Effect of seismic loading on settlement of stone column in silty clay

Diameter (m)	Increment in settlement of stone column without encasement due to seismic loading (%)	Increment in settlement of stone column with encasement due to seismic loading (%)
0.6	25	23.46
0.8	30.66	36.19
1.0	22.68	22.82
1.2	30.29	25.76

CONCLUSIONS

A study was conducted using a FE analysis to discuss the effect of static and seismic loading on the ordinary stone column and encased stone column. From this study following conclusions are drawn:

1. Settlement of group of stone column is less in silty clay than cohesive soil.
2. For seismic load, in case of cohesive clay settlement of stone column without encasement found out to be 74% and settlement of encased stone column is 54 % i.e. encasement of stone column reduces the settlement due to seismic load condition.
3. Settlement of group of stone column is reduced by providing encased stone column. In cohesive clay, settlement of group of stone column for static load condition reduces upto 18 % and for seismic load condition reduces upto 23 %.
4. Settlement of group of stone column in silty clay reduces upto 28.30 % in case of static load condition and upto 23.16 % in case of seismic load condition.
5. The length of stone column can be reduced by providing encased stone column. In cohesive clay, length of stone column reduces up to 26.25 % for static load condition and for seismic load condition it reduces up to 26.8 %.
6. In case of silty clay length of stone column reduces upto 24.54 % for static as well as seismic load condition.

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AUTHOURS PROFILE

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