SMALL DIAMETER RAMMED STONE COLUMNS IN FINE SANDS

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SYNOPSIS The advantage of **small diameter rammed stone columns** is that they can be installed using simple augers and a small compaction winch. Thus, rammed stone columns may often work out as a **cheaper alternative to pile foundations.** It can cause substantial **reduction in foundation settlement**, thus making it an effective ground improvement technique.

The paper illustrates use of the technique for improving performance of foundations on loose alluvial sands. Case studies from two sites are presented wherein the sands to about 3 to 5m depth were loose in condition; hence the allowable bearing pressure for the specified settlement was very low. Rammed stone columns of 300mm diameter and 5 to 6m length were installed which successfully improved the allowable bearing pressure for open foundations by reducing settlements. **Plate load tests** using a **1m** square test plate have been used to demonstrate the efficacy of the method. The **spacing** between the stone columns can be adjusted and **optimized** to match the loading conditions and extent of improvement desired.

INTRODUCTION

"Rammed stone columns" is an effective and economical method of improving the foundation behaviour of loose sands. The technique is particularly effective at sites where the surficial sands to 3 to 5m depth are loose in condition and are underlain by medium dense, compact soils. In such deposits, small diameter stone columns (300 to 400mm dia) of short lengths (not exceeding 5 to 7m) may be successfully used to improve the soil bearing capacity and to control foundation settlements within permissible limits.

The stone columns should penetrate through the loose deposits and should be terminated on the underlying compact soils. Provided that the ramming and compaction is adequate, the net allowable bearing pressure for a specified settlement criteria can increase by over 100 to 150 percent.

BEHAVIOUR OF STONE COLUMNS

Granular piles or stone columns can not be considered as completely rigid elements, although they may be treated as piles with low factor of stiffness. They are not capable of transferring high stresses to the deeper bearing stratum. The load bearing capacity of a single granular pile is a complex soil-pile interaction problem. Under actual loading conditions, the applied load is distributed between the granular pile and the surrounding soils. The stone column acts as a **reinforcing medium** as well as **drainage medium.**

The load applied on the soil-stone column system is resisted by interfacial shear between stone aggregates and soil and in end bearing. The lateral stress mobilized in the stone column will be resisted by lateral compressive strength of the soil. If the strength of the soils is less than the lateral stress in the column, then the column will fail by bulging. The passive pressure developed due to loading of treated ground offers resistance to the bulging of the stone column and thus contributes to its load carrying capacity. As per the various researchers, the critical length of stone column varies from 3D to 5D.

The available mathematical solutions for theoretical prediction of the behaviour are for stone columns in soft clays. These solutions consider the improvement achieved by the drainage and the consequent consolidation of the soils. However, the **ground improvement** by stone columns in loose sands is achieved by **increase in the overall density** of the soil mass as well as by the **ramming process** that tends to squeeze the stone into the surrounding loose soils.

LITERATURE REVIEW

Gopal Ranjan (1988) reports results from several sites where the use of granular piles resulted in significant reduction in foundation settlements. Rao et al (1991) state that the ultimate bearing capacity of the stone column system can be improved by increasing the confining pressure. This may be done by **peripheral restrainment** (provision of additional stone columns outside the loaded area).

Bhandari (1986) reports that effective improvement of the loose sands containing less than 20% fines has been achieved by use of rammed columns. Experimental works carried out in the field suggests that stone columns are **best** suited for large loaded areas. Performance of large diameter storage tanks in particular have been found to be satisfactory by successful use of this technique.

CONSTRUCTION TECHNIQUE

In the rammed stone column technique (Datye, 1982), **granular fill** is introduced in a **pre-bored hole** and **compacted** by a rammer. The borehole may be advanced by conventional methods similar to that used to install augered piles or bored piles.

Sands below water table may be **stabilized** using **bentonite** slurry. The purpose of providing stone columns is for improvement of bearing capacity and reduction in settlement and not as a drainage media. In sands, the increase in strength is achieved by compaction and increase in overall density and not by drainage and consolidation. Therefore, contamination of aggregates by bentonite will not adversely effect the performance of stone columns.

After boring to the required level, **75mm down stone aggregates** may be placed in the borehole in layers of about 0.3 to 0.5m. The aggregates used should be in suitable proportionof sizes 75mm, 40mm, and 20mm down aggregates so that the mix is **properly graded.** A 0.3 to 0.5m thick charge of sand may be placed over the gravel. Compaction may be done using a 150 to 250 kg weight driving weight operated by a small 0.5 tonne capacity mechanical winch. Thereafter, charge of aggregate and sand should be repeatedly placed in the same sequence and compacted. Careful controlled compaction should be done below the water table to ensure that the bore hole does not collapse.

The quantity of aggregate used for the first few stone columns should be compared with the theoretical volume of the borehole. The aggregate consumed for the trial stone columns may then be taken as guideline for further work.

Over the stone columns, a 200mm thick blanket layer/levelling course may be laid. The blanket should be composed of well graded aggregate, 75mm down, blinded with sand. It should be thoroughly compacted using a heavy roller. Open foundations may then be constructed bearing on this blanket layer.

FIELD STUDIES

Field studies on the efficacy of small diameter rammed stone columns, performed at two sites in the Delhi-Ghaziabad Hapur area, are reported here. Geologically, the area is a part of the **Indo-Gangetic Alluvium.**

At both sites, fine sand, alluvium of the Yamuna River, is encountered. The surficial soils are loose to about 4 to 5m depth below which medium dense sands occur.

The presence of loose sands coupled with shallow groundwater dictated the need for an effective foundation system that would control settlements effectively. After evaluation of several alternative foundation systems (including pile foundations), rammed stone columns were selected as technically acceptable and economical alternative.

Trial Stone Columns : To assess the behaviour in the field, three trial stone columns were installed in a triangular pattern. The centre-to-centre spacing was kept in the range of 4D to 5D. The set of three stone trial columns were installed with different spacings in order to optimize the design.

Load Tests : A levelling course/blanket of 75mm down stone aggregate blinded with sand was placed above the stone columns and a plate load test performed using a 1m by 1m square plate. The test procedure was in accordance with IS:1888. The load test results were interpreted to assess the improvement in soil conditions achieved and the allowable bearing pressure for the specified settlement criterion.

CASE STUDY NO.1

This site is in Delhi near the banks of the Yamuna river. The stratigraphy at the site is presented on Fig.1.

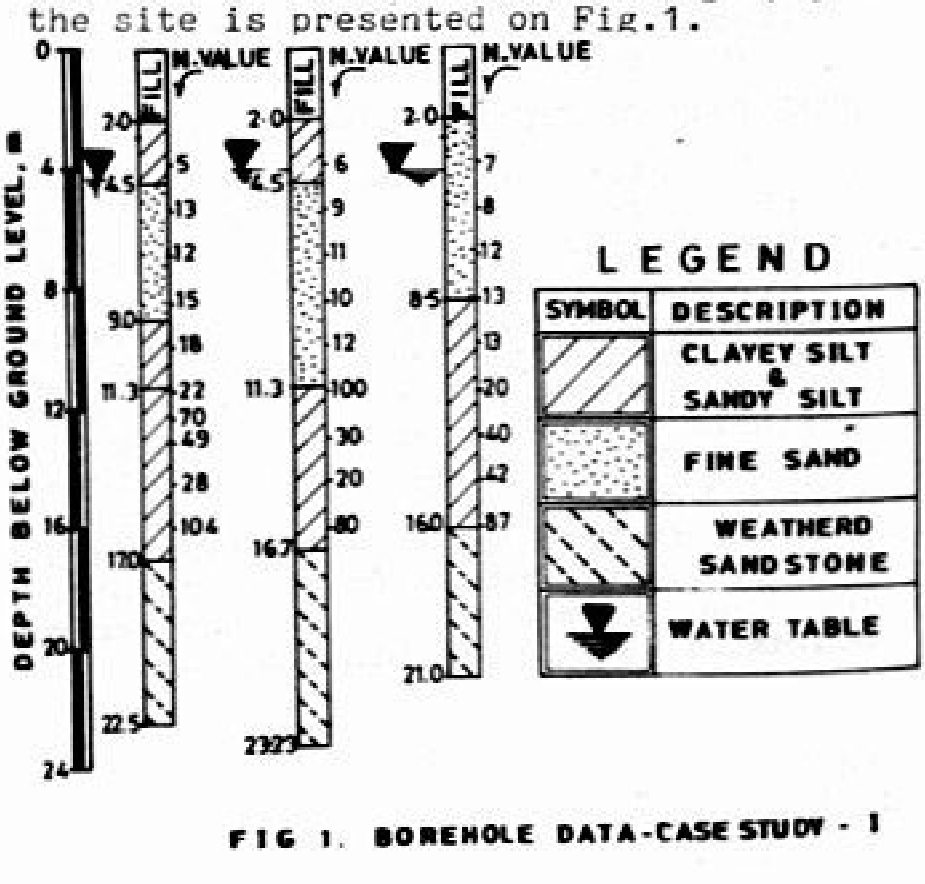

FIG 1. BOREHOLE DATA-CASE STUDY - 1

Results of one plate load test conducted on the fine sands in their natural state are presented on Fig.2.

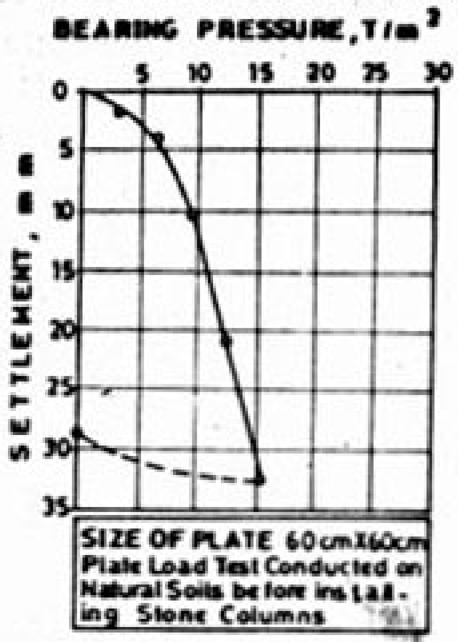

FIG 2. PLATE LOAD TEST ON UNIMPROVED SOILS

At this site, a long retaining wall was to be built for a road bridge. The applied bearing pressure on the 3.5m wide RCC strip foundation was 12 Tonnes per sq.m. Due to the fill and the low N-values, the estimated settlement based on N-values and the plate load test results exceeded the tolerable total settlement of 50mm.

Rammed stone columns of 300mm dia and 5m length (below cut-off-level of 2m) were planned to be installed. Two sets of trial stone columns using centre to centre spacings of 1.2m and 1.5m were installed at the project site. The test plate was placed centrally over a compacted levelling course of stone aggregate blinded with sand was placed. Results of the load test performed are presented on Figs. 3 and 4.

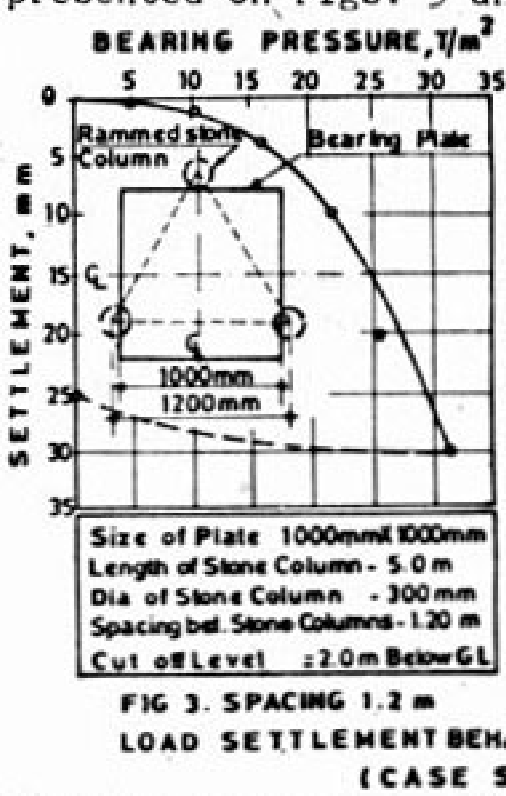

FIG 3. SPACING 1.2 m

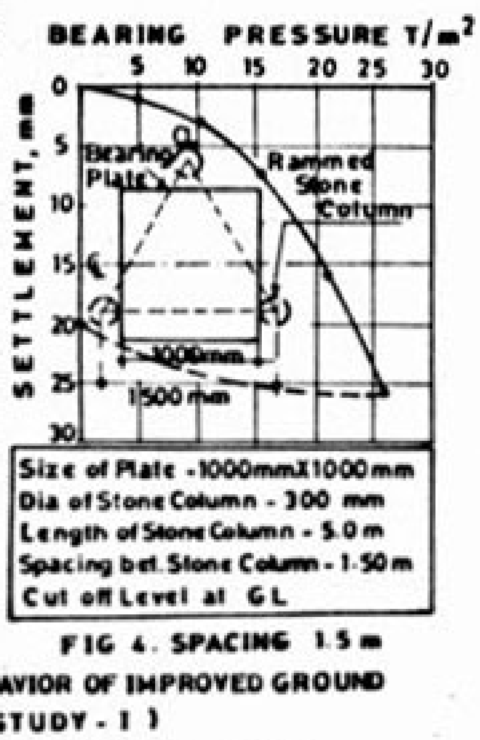

FIG 4. SPACING 1.5 m

LOAD SETTLEMENT BEHAVIOR OF IMPROVED GROUND
(CASE STUDY-1)

Spacing Between Stone Column, m	Settlement, mm 10T/m²	12T/m²	15T/m²
1.2	1.5	2.0	3.3
·.5	3.0	4.0	6.3

It may be seen that before the installation of the stone columns, the extrapolated settlement for a 1m square plate is 14.6mm at 10T/m² and 20mm at 12T/m². The load tests amply demonstrate the extent of improvement achieved.

CASE STUDY NO.2

The site of this study is in Distt. Ghaziabad (U.P.) near Hapur town. A 30m diameter steel digestor tank was proposed to be installed for a distillary unit. The tank was designed for a net bearing pressure of 11T/m² and the tolerable total settlement was specified as 75mm. The stratigraphy at the site is shown on Fig.5.

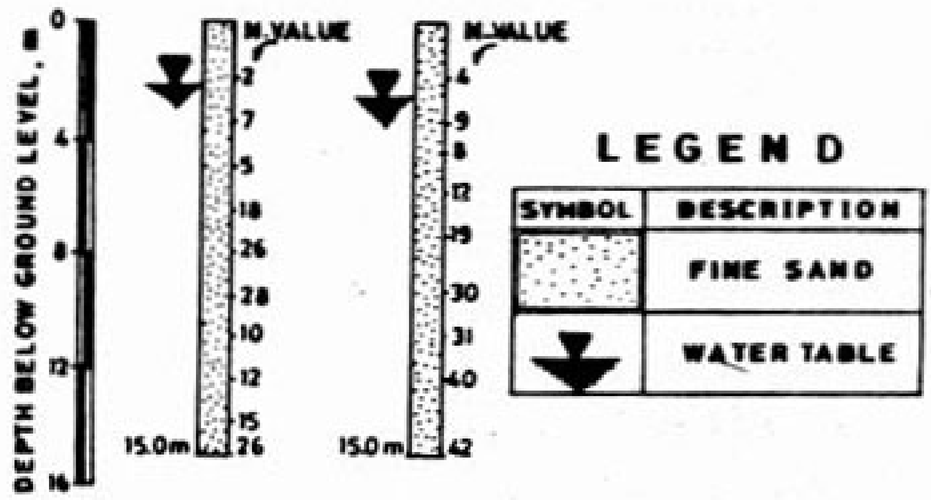

FIG 5. BOREHOLE DATA - CASE STUDY - 2

Trial stone columns (30cm diameter, 5.5m long, cut-off-level at ground surface) were installed using centre-to-centre spacings of 1.2, 1.3 and 1.5m. Test results are presented on Figs. 6 to 8.

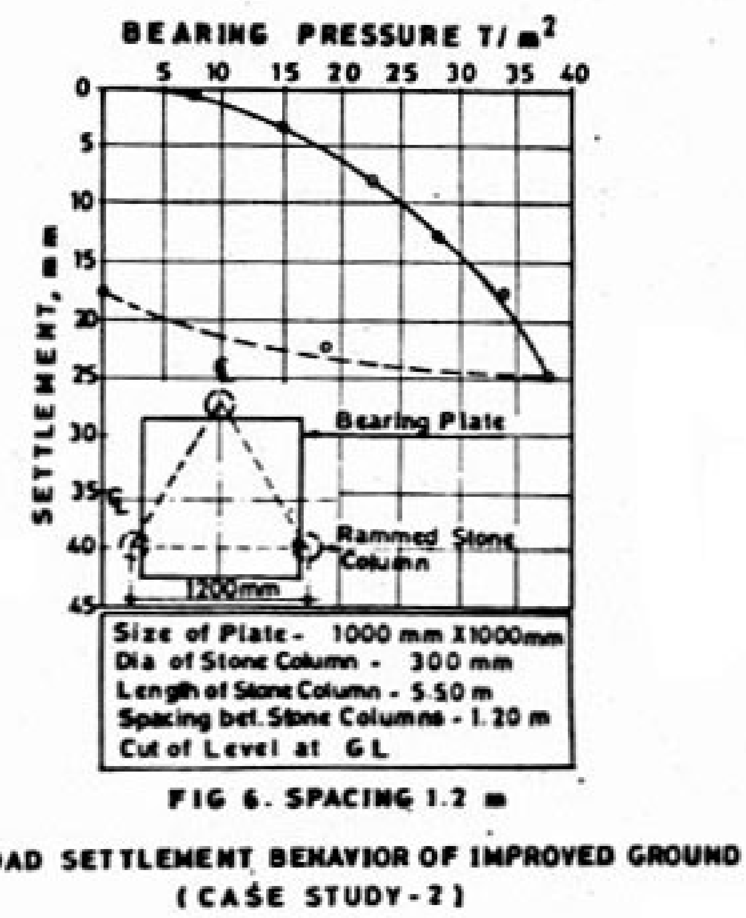

FIG 6. SPACING 1.2 m

LOAD SETTLEMENT BEHAVIOR OF IMPROVED GROUND
(CASE STUDY-2)

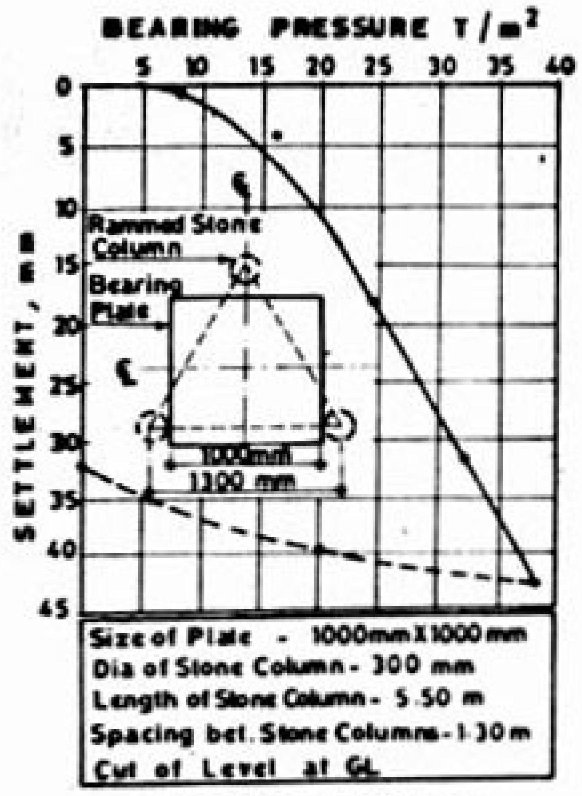

FIG 7. SPACING 1.3 m

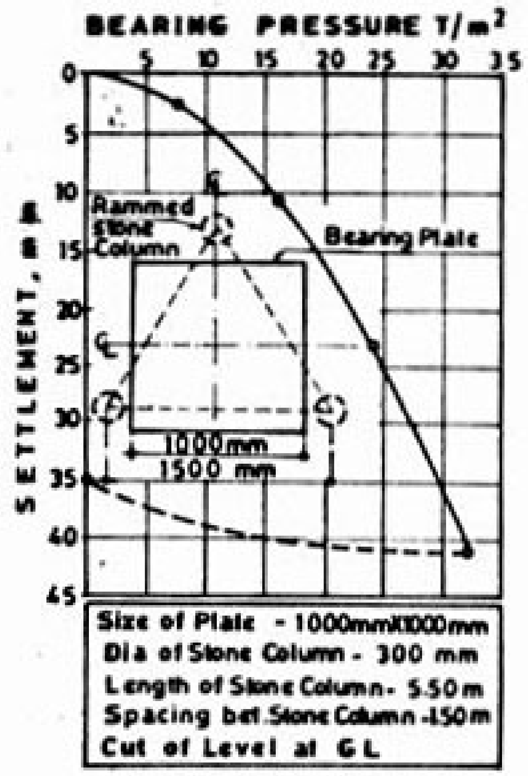

FIG 8. SPACING 1.5 m

LOAD SETTLEMENT BEHAVIOR OF IMPROVED GROUND (CASE STUDY-2)

Spacing Between Stone Column, m	Settlement, mm 10T/m²	12T/m²	15T/m²
1.2	1.3	2.0	3.8
1.3	1.5	2.6	5.0
1.5	4.7	7.0	9.5

The load test results confirm that the loose soils to 5.5m depth have been successfully strengthened. The soils data and the load test data used in conjunction to predit the tank centre and edge settlements. The load test data was used to optimize the spacing between the columns for the most economical design.

POINTS OF CAUTION

Soil conditions and loading conditions that are suitable for installation of rammed stone columns should be selected with caution. Key points are listed below :

1. Stone columns are more effective for large loaded areas. For individual foundations, they yield less advantage.
2. For very heavily loaded foundations and where settlement criteria is stringent/restrictive, stone columns are not recommended.
3. If loose soils occur below the termination level of the stone columns, excessive/uneven/differential settlement or tilt of foundations may occur.
4. Field control and experienced supervision personnel is essential for successful installation of stone columns.

REFERENCES

Gopal Ranjan (1988), "Ground Treated with Granular Piles and its Response under Load", Eleventh IGS Annual Lecture, Indian Geotechnical Journal 19(1) 1989.

Rao, P.J., Kumar, S., and Bindumadhava (1991), "Experimental Studies on Stone Columns", Proceedings, National Workshop on Ground Improvement - 1991, Indian Geotechnical Society Delhi Chapter.

Bhandari, R.K.M. (1986), "What Foundation Systems are appropriate for Large Diameter Oil Storage Tanks Resting on Weak Soils", Synthesis Paper, Indian Geotechnical Conference 1986, Vol. III, pp 121-128.

Datye, K.R. (1982), "Simpler Techniques for Ground Improvement",Indian Geotechnical Journal, Vol. 12(1).