An Innovative Foundation technique for residential building – Case Studies

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Abstract. In recent years, rapid development of urban environment demands large number of residential units which are compounded with scarcity of suitable land. This compelled practicing engineers to find an innovative foundation technique to improve the unsuitable land which are technically feasible and economical. This paper presents case histories of similar conditions where ground improvement techniques using vibro stone columns was chosen to support residential buildings in weak soil strata. The foundation challenges such as bearing capacity, total & differential settlements and mitigation of liquefaction were addressed. Various aspect of subsoil conditions, design aspects, construction methodology, quality control measures are discussed.

Keywords: Vibro stone columns (dry bottom feed method), innovative foundation technique, Post monitoring results.

1 Introduction

Soil improvement techniques are typically implemented as value engineering solutions to classical deep foundations or conventional soil replacement, for wide range of applications such as infrastructure projects, residential buildings, oil & gas facilities, transportation structures [roads, railways and airports], marine structures, power plant structures and storage tanks.

One of the major functions of geotechnical engineering is to design, implement and evaluate the feasibility of ground improvement schemes for unsuitable construction lands. In the last two decades significantly new and advanced technologies and methods have been developed and implemented to assist the geotechnical engineer to provide innovative solutions for construction sites where poor soils exist. The selection of the most suitable and economical soil improvement method for each project depends on the soil conditions (soil type, depth of improvement), type & loads of foundations, project modalities in terms of cost and project schedule and site conditions.

In the current paper, ground improvement using dry vibro stone columns as an innovative and economical solution for residential buildings are discussed with case studies.

2 Case histories

2.1 Low budget residential project at Manali

Project background

Tamil Nadu Slum Clearance Board (TNSCB) proposed to construct a residential project of 7 blocks (G+3) with an area of 5,400m^2 at New Town, Manali in Chennai. The project site consists of soft to firm silty clay (intermediate to high plasticity) for top 11m of with SPT 'N'<10 which is followed by very stiff clay and medium dense sand. The buildings rest on rafts and when loading intensity of 90 kPa is imposed on weak ground (N<10), they induce high settlements (>120mm).

Alternative foundation system

Vibro stone columns (dry bottom feed method) was selected as an innovative foundation to conventional piling method (since there is restriction to go with pile foundation due to environmental and safety issues) to reduce the settlements and to satisfy performance criteria of the project. This project was completed with in 3 months using vibro stone columns where the initially proposed pile foundation was 6 months. There is also a cost optimization when compared to piling and environmentally friendly solution compared to piling.

Design approach

Based on site limitation and performance criteria, dry vibro stone columns with area replacement ratio is of 18% were proposed & executed and the cross section of vibro stone columns is shown in Fig. 1. The quality of the project was ensured by observing the M4 records, conducting plate load tests and post-performance settlement monitoring.

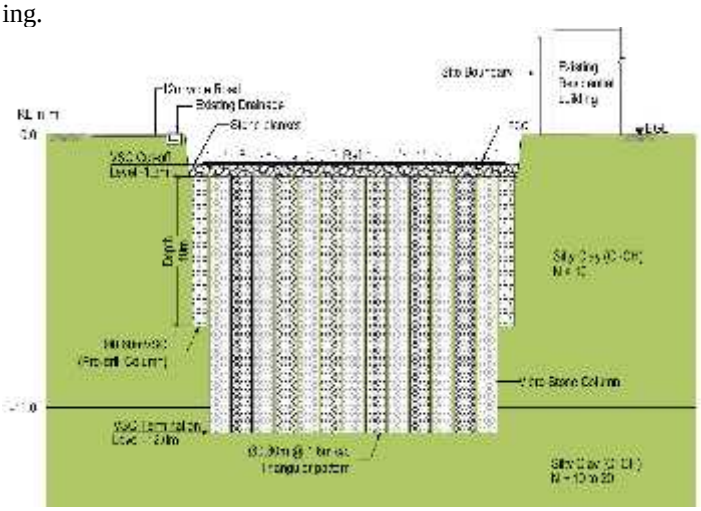

Fig. 1. Cross section of vibro stone columns

Post monitoring results

To understand the post construction performance of the structures, it is planned to conduct field settlement monitoring up to 2 years of the life of structures. The superstructure load is increased from 0 to 90 kPa in 29 weeks and correspondingly predicted settlements (analytical method) increased from the 0 to 72 mm. settlement monitoring results for 1.5 years are of 45mm which is shown in Fig. 2 and almost settlement readings are saturated.

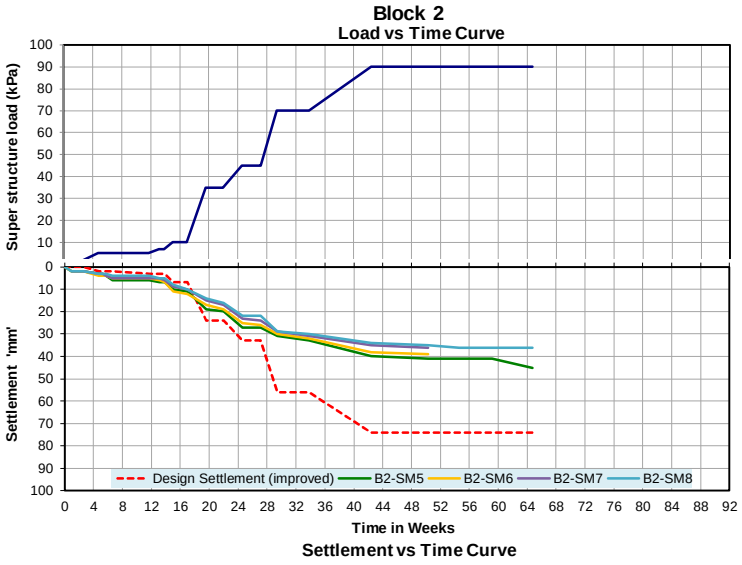

Fig. 2. Post Settlement monitoring data for low budget residential project

2.2 Multistorey structure in Haryana

Project background

A large residential complex comprising of 13 blocks, of each G + 14 floor towers developed in 12 acres in Haryana state. The site consists of silty sand / sandy silt till 30m depth from existing ground level. The percentage of sand varies from 35 to 70 throughout the depth. The project location falls under seismic zone IV with zone factor of 0.24 according to Indian seismic code (IS 1893:2016) and it was required to address liquefaction mitigation and bearing capacity.

Ground improvement using vibro stone columns

Based on the critical review of the subsoil conditions and performance criteria of the project, vibro stone columns was proposed as alternate solution to address liquefaction mitigation and to satisfy the project performance criteria.

Design approach

Area Replacement Ratio of 16% was proposed to mitigate the liquefaction potential, to enhance the bearing capacity of soil. Also, the quality of the project was ensured by conducting large size plate load tests.

Post monitoring results

Field settlement monitoring was monitored up to 2 years of the life of structures. The superstructure load is increased from 0 to 150 kPa in 47 weeks and correspondingly predicted settlements (analytical method) increased from the 0 to 97 mm. Settlement monitoring results for 2.0 years are of 60mm which is shown in Fig. 3.

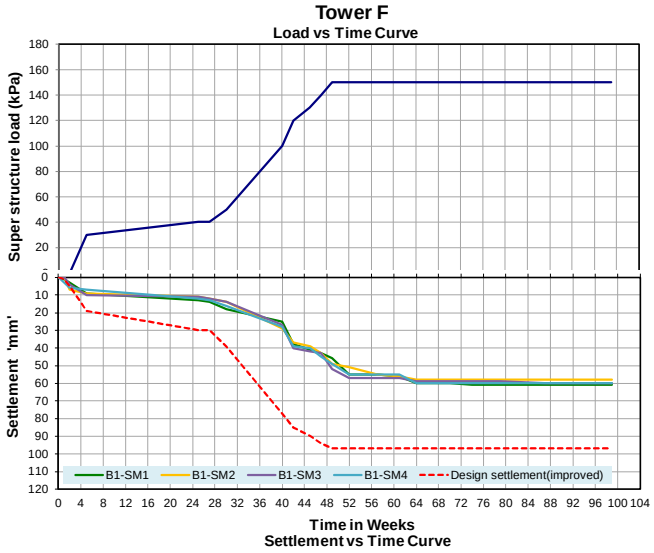

Fig. 3. Post Settlement monitoring data for Multistorey residential project

2.3 Residential project “INFINITY” at Porur

Project background.

Urban Tree Infrastructure Private Limited proposed to develop a residential project comprises of 198 units (Stilt + 4 floors) with an area of 2.5 acres in Chennai. The top 6m of soil profile comprising of thin layers of silty clay and sandy clay with varying consistency. Larger settlements (>100mm) were expected in case of raft foundation due to high structural loads which ranges from 75 to 85 kPa.

Innovative & Alternative solution to pile foundation

Driven cast-in-situ piles resting in hard clay layers below 25m were adopted by client and the construction of piles were stopped due to environmental issues. Considering

the project boundary conditions, vibro replacement (stone columns with dry bottom feed method) was selected as a viable innovative method to reduce settlement and to satisfy performance criteria of the project. The selected method of ground improvement satisfied in addressing environmental issues and the stone columns were installed by displacement technique (without removing any soil) which makes the environment would be comparatively clean and tidy. The ground improvement works were completed within 6 weeks (as against 6 months to that of pile foundations) that was made possible through effective project management.

Design approach.

Ground improvement using vibro stone columns (dry bottom feed method) with area replacement ratio of 18% is used as a treatment scheme. Typical cross section of vibro stone columns using dry bottom feed method adopted for the present project is illustrated in Fig. 4.

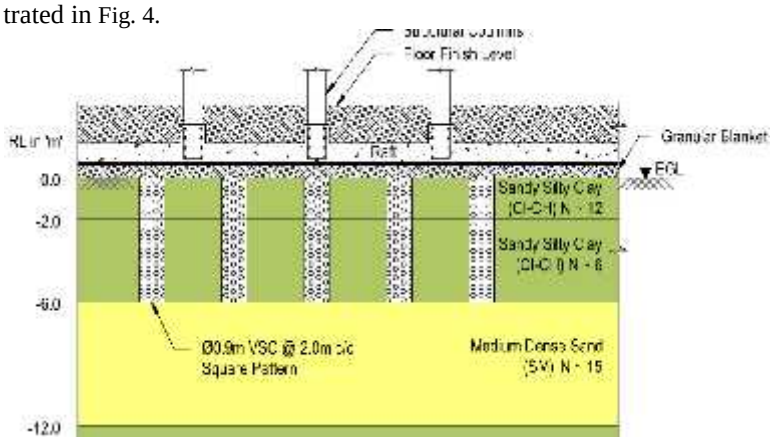

Fig. 4. Typical soil profile showing ground improvement

In order to measure and assure the quality of installed stone columns, real time monitoring (M4 Graph) was carried out in addition to routine single column load tests to ascertain the effectiveness of the design and performance of the ground improvement works.

Post monitoring results

The superstructure load is increased from 0 to 80 kPa in 20 weeks and correspondingly predicted settlements (analytical method) increased from the 0 to 64 mm (Fig. 5). However, the observed settlements are considerably less than the predicted settlements as well as the allowable settlements of 75 to 100 mm for raft foundations resting in clayey soils. It is suggesting that the long-term settlements will be of much smaller range than that was expected.

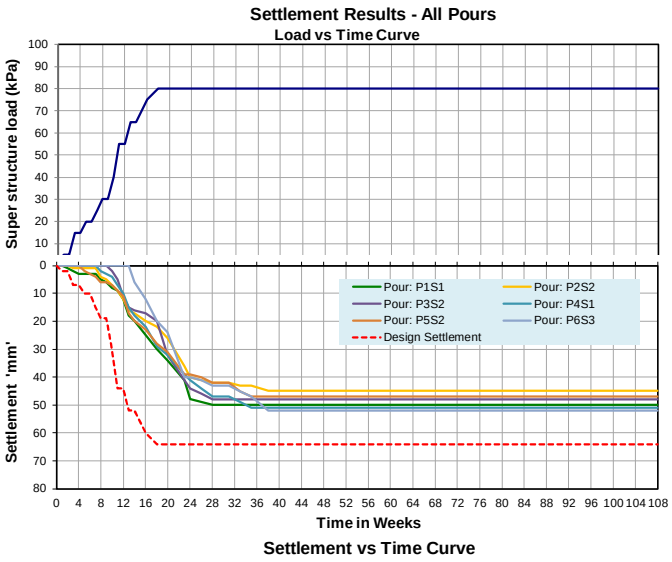

Fig. 5. Post Settlement monitoring data for INFINITY residential project

3 Conclusion

Vibro stone columns proved to be an innovative ground improvement solution to support residential buildings on weak soil deposits and best alternative to conventional piling foundation. It is also proven from the results of extensive monitoring that the required performance was achieved. In addition to improving shear strength and compressibility parameters, the ground improvement technique offered acceleration in the overall construction schedule and enabled the project to be completed within stipulated duration.

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