CEMENT GROUTING IN DELHI SILT - A FIELD STUDY

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SYNOPSIS : Loose alluvial silts of Delhi can be successfully grouted using cement slurry. The paper presents a case study wherein the cement grouting was done to strengthen the foundations of a three storeyed building bearing on loose "Delhi Silt". Details of the pressure grouting are presented together with the grout consumptions at various intake points. After grouting, the building was load tested to confirm the efficacy of the ground improvement.

INTRODUCTION

Cement grouting is a technique that has been in use for ground improvement. The paper presents a field report on a project site on grouting to stabilize the loose alluvial silts by permeation and compaction process and proof testing to assess performance of the foundations.

PROJECT DETAILS

Several flats in a three storeyed residential complex in a South Delhi locality had experienced substantial settlement and related cracks. The damage was restricted to a narrow 15 to 25 m wide strip of land which has weak/loose soils underneath. The buildings are supported on continuous brick masonry wall foundation. A layout of the scheme is illustrated on Fig.1.

SITE STRATIGRAPHY

The soil at the site consists of sandy silt of low plasticity and classified as ML to the maximum explored depth of 20 m. The soils are alluvial in nature and are locally called "Delhi Silt".

In the weak zone, SPT values in the vicinity of the damaged flats range between 2 to 8 down to a depth of 5 m below the ground level. Below this depth, SPT values exceed 10. Typical soil profiles from 3 boreholes in the weak zone are illustrated in Fig.2.

Fig.3 presents a plot of corrected SPT values in the weak zone. A plot of dynamic cone penetration tests in this zone is presented

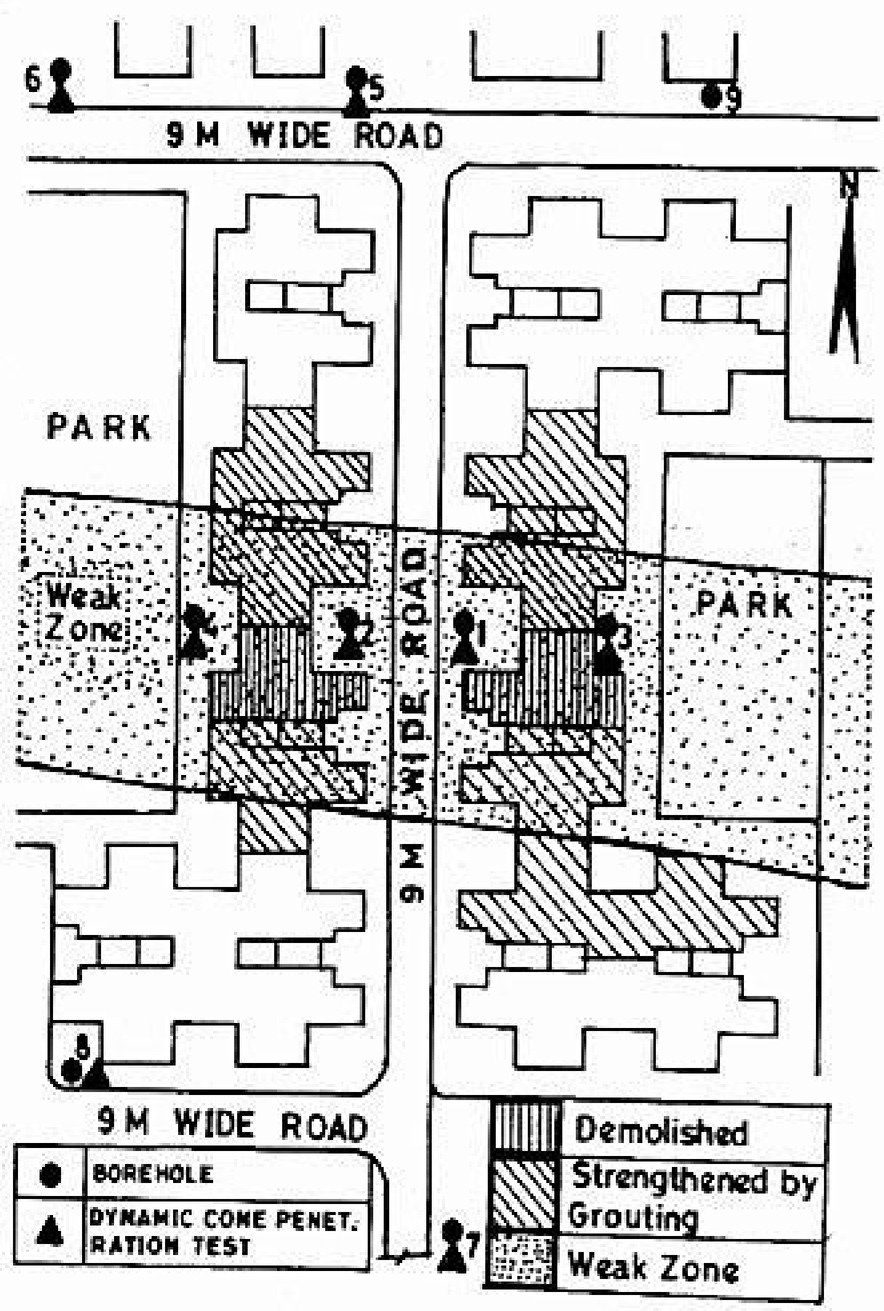

Fig. 1. Layout Plan showing investigation points and extent of weak zone

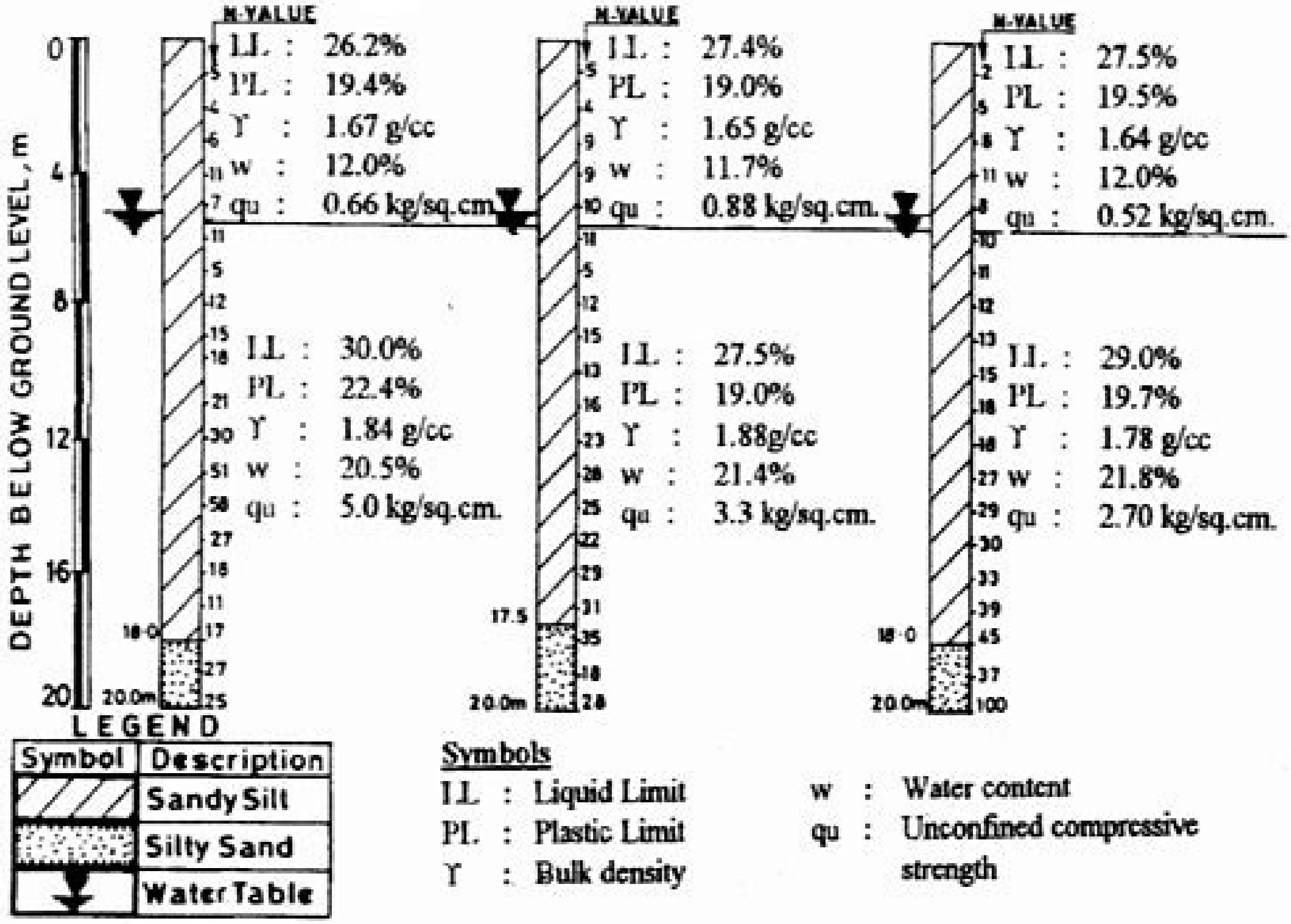

Fig. 2. Borehole data in weak zone

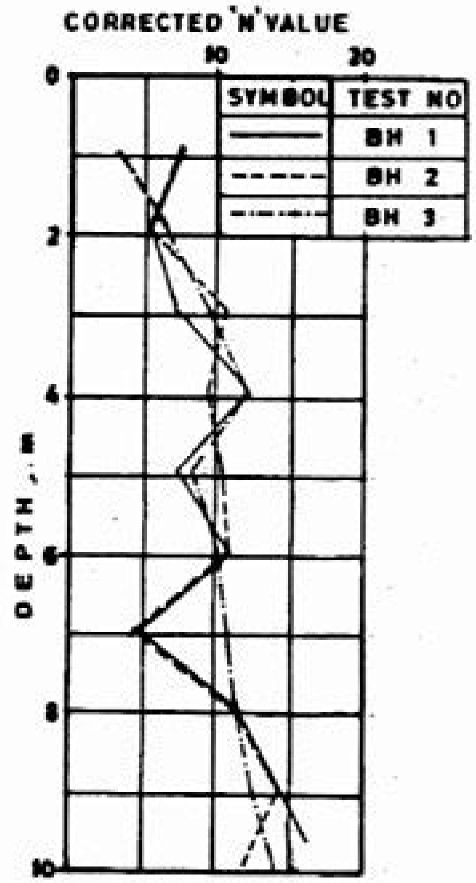

Fig. 3. SPT Values versus depth in weak zone

on Fig.4. To provide a comparison, dynamic cone penetration test results in the soils outside the weak zone are presented on Fig.5. SPT and DCPT tests were conducted as per BIS specifications (IS:2131-1981 and IS:4968 Part-I-1976 respectively).

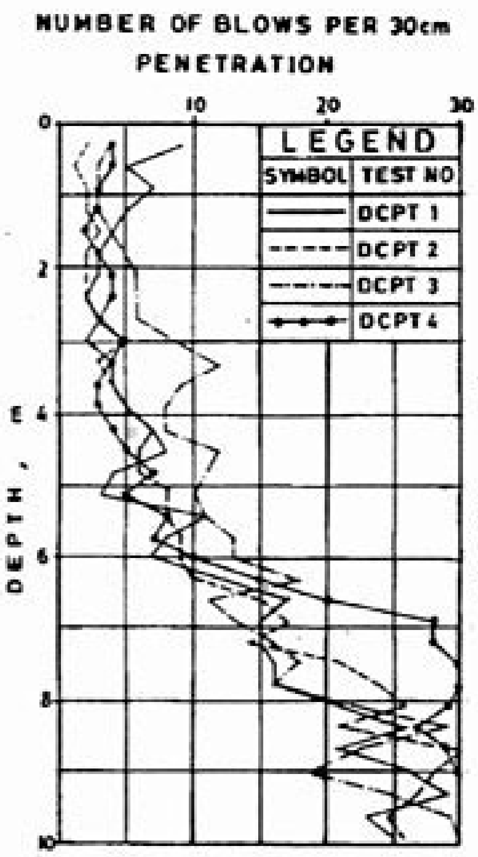

Fig. 4. Dynamic Cone Penetration Test Results in weak zone

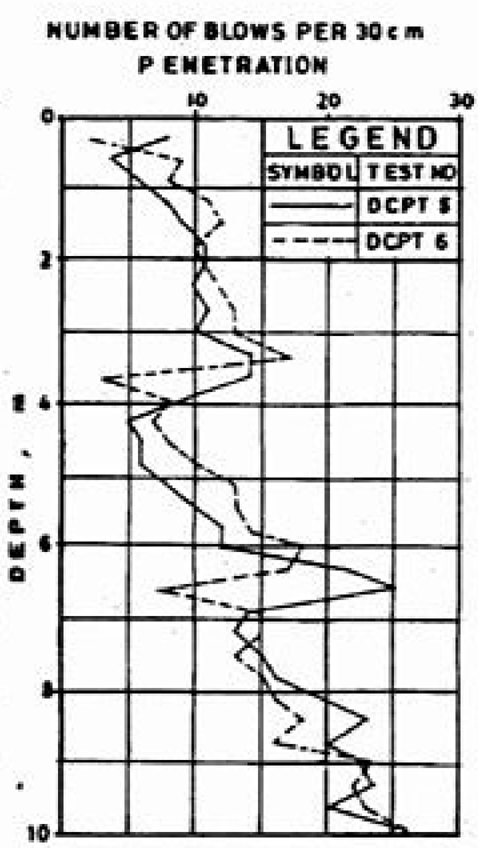

Fig. 5. Dynamic Cone Penetration Test Results outside weak zone

MECHANISM OF GROUTING IN SILTY SOILS

The cement grout does not fully permeate through silt/silty sands under pressure; it compresses the surrounding soil, opens up cracks and fills them. Micro-fine level cement permeates and binds the particles. The cement grout in such soils essentially works as compaction grout.

PROPOSED SYSTEM FOR STABILIZING FOUNDATIONS

Two of the blocks that had been very severely damaged (See Fig.1) had to be demolished. At locations where the damage to the structure was not severe, it was decided to stabilize the foundations by cement grouting. The grouting was proposed to be done to about 2 times the foundation width below the footing level. The flats taken up for the strengthening by grouting are marked on Fig.1.

Trial grout hole indicated the extent of penetration of grout would be about 50 to 60 cm. Accordingly, it was decided to keep the centre-to-centre spacing between the grout holes as 1.0 m.

GROUTING PROCEDURE

The grout was prepared by mixing 50 kg (1 bag) of cement in 100 litres of water (1:3 by volume). The grout holes of 75 mm diameter were made using auger to about 4 to 4.5 m depth depending upon the foundation size and its embedment depth. A 20 mm diameter conduit pipe was placed in the hole. A concrete plug was placed in the grout hole at foundation level to seal the hole and to ensure that only the soil below foundation level is grouted.

Before injecting the cement grout, about 15-20 litres of water was pumped in for creating passages/openings for easy movement of grout. The cement slurry was then pumped into the hole, initially under a pressure of 0.5 to 1 kg/sq.cm. and gradually increased to 2 kg/sq.cm. The injection of the cement slurry was continued until refusal to further grout intake was met under a steady pressure of 2 kg/sq.cm. A typical section of the grout hole is presented on Fig.6.

As a precautionary measure, only alternate holes were taken up for grouting. Boring for the intermediate point was taken up only after the adjacent holes were grouted.

To strengthen cracks in walls, plastering was done on one of the faces of the wall. On the other face, two nipples ($\approx$10 mm dia) were inserted, one at each end of the crack. The crack portion between these two nipples was then plastered. The cement grout was then pumped under low pressure (<0.5 kg/sq.cm) through the lower nipple and allowed to come under pressure through the upper nipple. After ensuring that the grout has spread out in the entire crack length, both nipples were sealed.

Where grout did not flow out of the nipple at higher end due to obstructions to its passage, a 1 m long chase was cut across the crack. A 8 mm diameter steel reinforcement bar was placed in the chase and set in rich cement mortor. This assisted in stitching the crack to restrict it from widening under stress.

FIELD RESULTS

In areas of distress, the foundations were strengthened by pressure grouting from either side of the wall. the grout holes were spaced 1 m apart, drilled about 10-15 cm from the outer edge of the brick masonry wall foundations. The holes were staggered on either side of the wall for maximum grout intake. Where distress was minor/insignificant, grouting was done only from one side of the wall.

A layout plan of one typical ground floor flat showing locations of the grout holes together with the grout consumption (in bags of cement per hole) is presented on Fig.7.

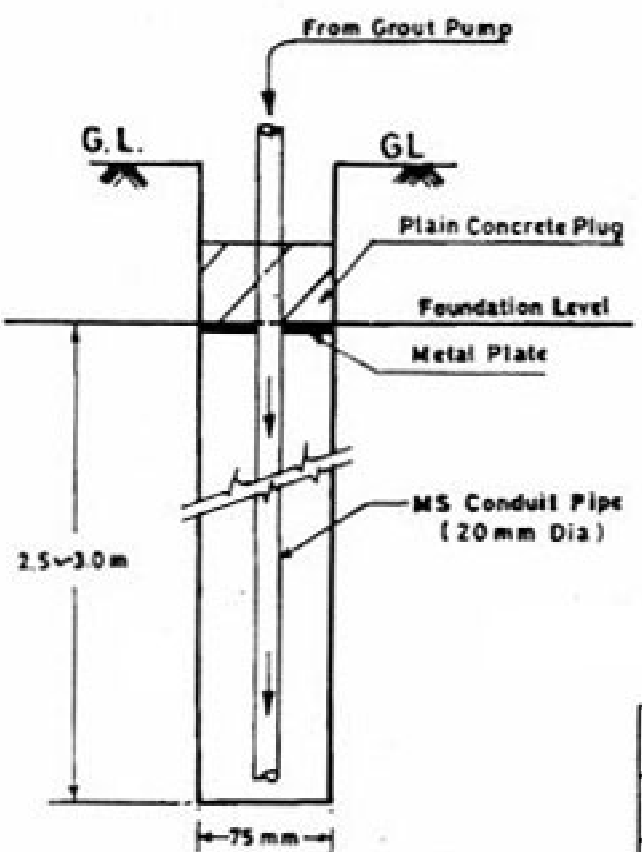

Fig. 6. Typical section of grout hole arrangement

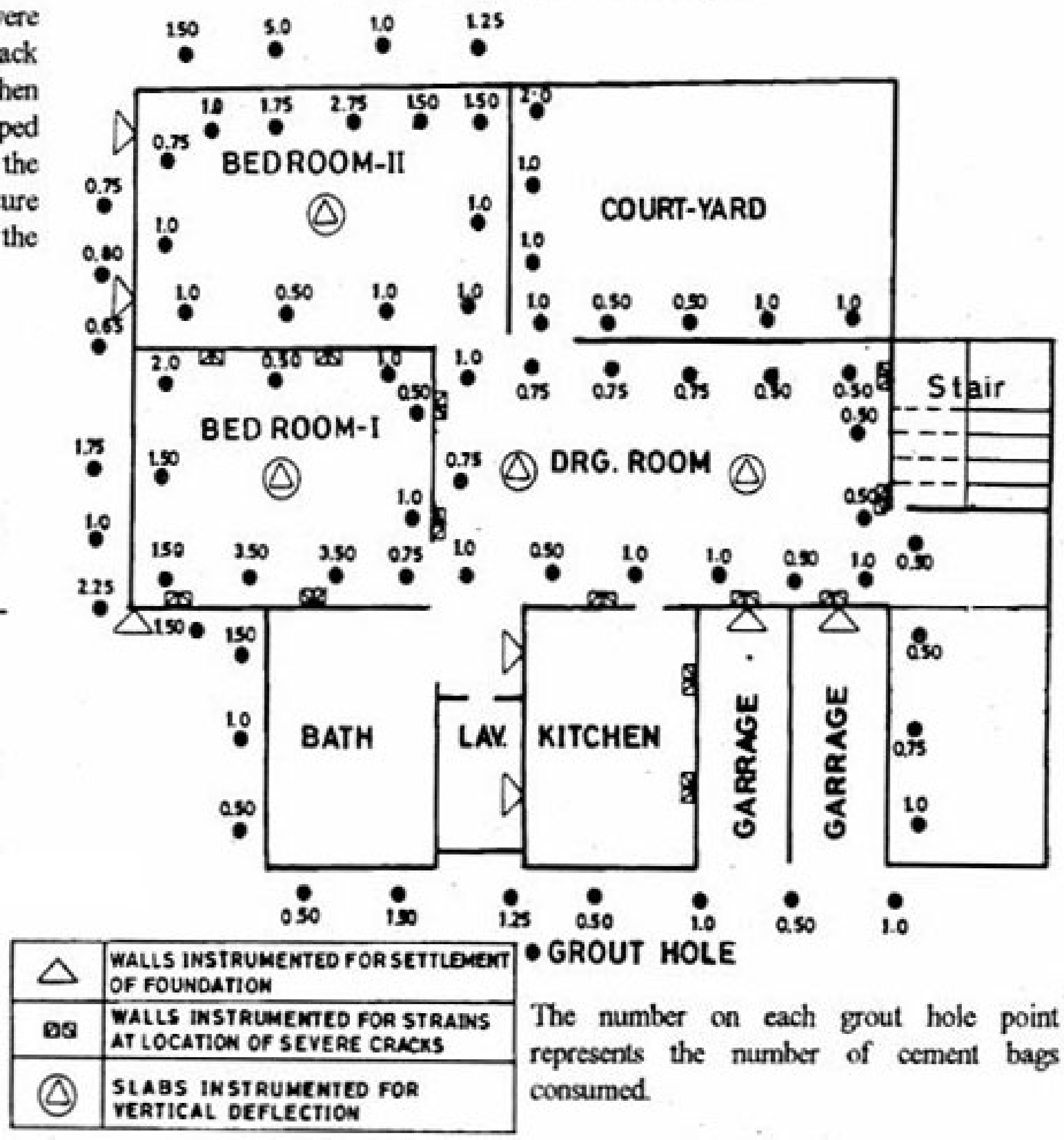

Fig. 7. Ground floor layout plan showing grout hole points, grout intake and instrumentation

LOAD TEST

To assess the structural stability of the rehabilitated foundations, gravity load equal to 1.25 times the live load was applied on all the floors. The live load was considered as 200 kg/sq.m. on floor slabs, 150 kg/sq.m. on roof slab and 300 kg/sq.m. on stair case. The load testing was done for two adjacent blocks simultaneously, i.e. from one expansion joint to the other.

Vertical deflections of slabs, strains in wall at critical locations where cracks were severe and settlement of walls that had cracked excessively were measured. Vertical deflections at the centre of slabs were measured using dial gauges. The settlement of walls subjected to severe cracks were measured using dial gauges fixed at ground floor level. Strains in walls at locations of severe cracks were measured using demace gauges. The instrumentation was referenced to a stable datum. After recording the initial readings, dial gauges and demace gauge readings were taken under full test load after it was sustained for 24 hours. The final set of readings were taken 24 hours after removal of load. The test procedure was in accordance with Clause 16.5 of IS:456-1978 (Load Tests on Parts of Structures).

The following Table 1 presents the measured deflection of the slabs at one typical block location under the test loading.

TABLE 1: MEASURED AND PERMISSIBLE DEFLECTIONS

Slab	Measured Deflection of Centre of slab slab under the applied live load, mm at			Permissible Value, mm
	First Floor	Second Floor	Roof Level	
Drawing Room	0.69	0.73	0.86	4.90
Bed Room I	0.47	0.48	0.73	3.60
Bed Room II	0.45	0.59	0.59	3.60

The permissible deflection value given in the above table is computed as 40 ℓ^2/D where ℓ is the effective span in metres and D is the overall depth of section in mm.

During the test no visual cracks were observed. The recovery of the slabs 24 hours after removal of load was more than 80 percent of the measured deflections. Value of strain measured in the walls after load was maintained for 24 hours was less than 0.0005. Measured settlement of the walls was less than 1 mm. The settlement and strains were well within the permissible limit. Hence the structure was judged to be safe.

CONCLUSIONS

In silty sand and sandy silt loose deposits, cement grouting could be adopted with reasonable success in improving the bearing capacity/minimising the settlements of foundations. The grout essentially compresses the surrounding soil and improves the density and leaves columns of cement grout. Before using such grouts, trials must be made to analyse their efficacy. Distressed buildings with cracks as wide as 6 mm have been restored and their stability was verified by load tests.

REFERENCES

IS:2131-1981 *"Method for Standard Penetration Test for Soils"* (First Revision), Bureau of Indian Standards, New Delhi.

IS:4968 (Part-I)-1976 *"Method for Subsurface Sounding for Soils"* - Dynamic Method using 50 mm cone without Bentonite slurry (First Revision), Bureau of Indian Standards, New Delhi.

IS:456-1978 *"Code or Practice for Plain and Reinforced Concrete"* (Third Revision), Bureau of Indian Standards, New Delhi.