Investigation Of Foundation Failure Of A Residential Building

D. Nagarajan, K. Premalatha

Abstract: Movement and distress in low rise residential buildings most commonly occur as a result of interactions between the footing system and the ground. This paper summaries the study that is carried out to evaluate the possible causes of distress in the G+2 Residential building founded on shallow foundation at Velacherry, Chennai, TamilNadu by detailed investigation. Disturbed and Undisturbed samples are collected by drilling borehole using auger. Laboratory test are carried out on disturbed and undisturbed soil samples obtained from the site of distressed building. The causes of failure of the structures are identified by considering the soil properties, intensity of loading, nature of foundation and pattern of cracks developed. Based on the degree of distress, the suitable measures are also recommended.

Index Terms: consolidation, distress, foundation, investigation, recommendations, settlement, tilt

1 INTRODUCTION

THE investigation of a building where a failure has occurred is often necessary to establish the causes of the failure and to obtain the information required for the design of remedial measures. Observations and measurements of the feature of the structure to determine the mode of mechanism of failure are first needed, and these will often suggest the origin of the trouble, or at least indicate whether the ground conditions were partly or wholly responsible.

2 DETAILS OF THE DISTRESSED BUILDING

The G+2 Residential Building which was built in 2005 is located in Velachery, founded on shallow foundation had distressed to varying degrees. The Tilting of the structure was observed from 2008 onwards. The area elevation is lower than that of the surrounding area, which results in Water accumulation. Now, the building is tilted at an angle of 7^{o} 24' in North West and $5^{o}25'$ in North East side with respect to vertical.

3 FOUNDATION DETAILS

The type of foundation is column footing and the depth of foundation of the building is 1.5 m from the existing ground level. The foundation details and building plan are collected from the resident during the site inspection. The foundation details and depth of the foundation from the ground level as shown in Fig 1.

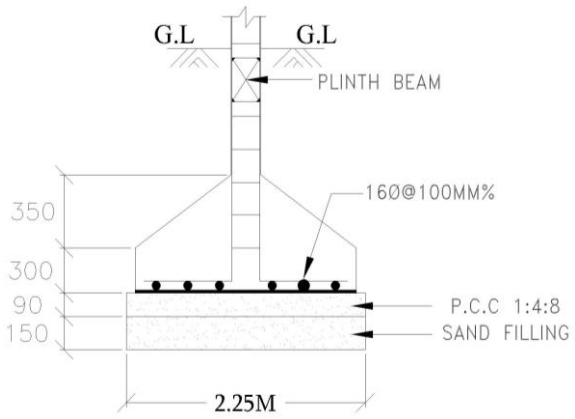

Fig.1 Foundation Details

4 SOIL EXPLORATION

The Soil condition at the site was explored by drilling two boreholes. Drilling of the bore hole was terminated at 3m below existing ground level after encountering the ground water table. Disturbed samples were collected at every one feet of bore hole. Undisturbed samples were collected from borehole 1 at 1.5m from the ground level at the time of soil exploration. Bore hole 2 was terminated at 0.5m due to the seepage of nearby stagnant water.

5 LABORATORY TEST RESULTS

The routine laboratory tests such as grain size distribution, Atterberg's limits, UCC, and One Dimensional Consolidation were conducted on the disturbed and the undisturbed samples collected from the two bore holes. All the tests were done as per relevant I.S. Codes.

5.1 Variation of Liquid Limit, Plastic Limit and Natural Moisture Content

The results of moisture content tests performed on disturbed samples recovered from the borehole 1. In bore hole 1, there is a increase in moisture content with depth, from 18.35 % at 1.2m to 46.2 % at 2.4 m. The variation of liquid limit, plastic limit and natural moisture content with depth for bore hole1 as shown in Fig. 2. The water content profile of 0.5 liquid limit is also shown in Fig. 2.

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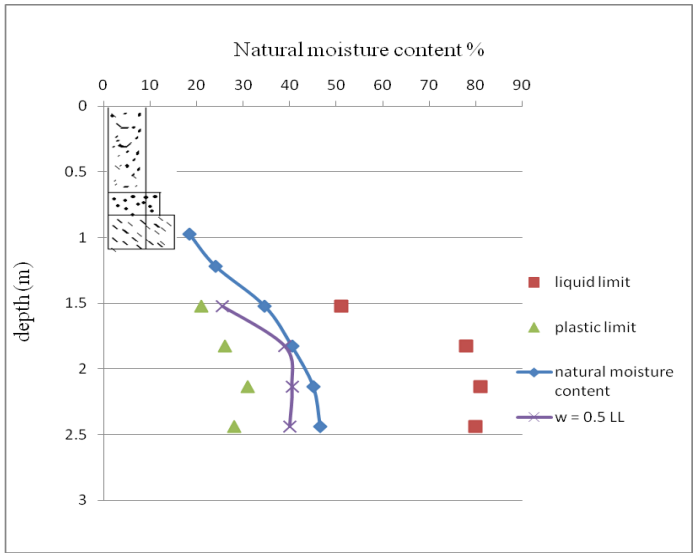

Fig. 2 Variation of Liquid Limit, Plastic Limit and Natural Moisture Content

5.2 Variation of Plastic Index with respect to depth

In bore hole 1, there was a general increase in plastic index with depth, from 30 % at 1.5 m to 52 % at 2.4 m. It shows that the soil up to 2.40 m depth is CH type of clay with possible volume – change characteristics. The variation of plasticity index with depth for BH1 is shown in Fig 4.3.

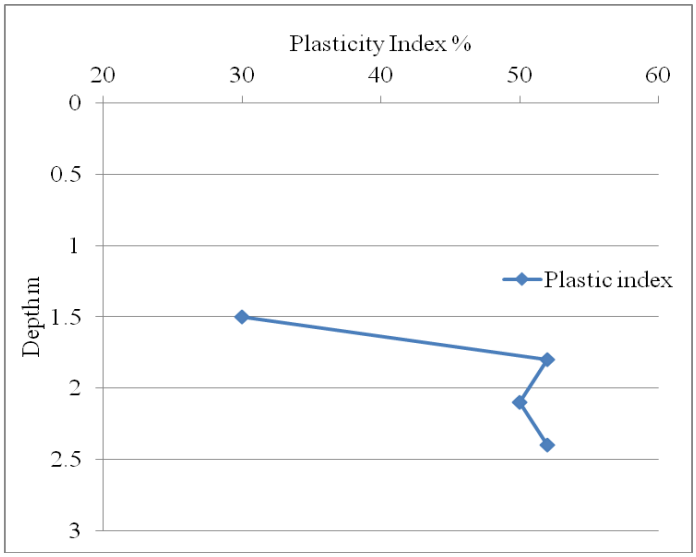

Fig. 3 Variation of Plastic Limit with respect to depth

5.3 UCC Test

Undisturbed samples were collected from Borehole 1 at 1.5m collected. The UCC test also carried for remolded sample at 1.8m with natural moisture content. The stress-strain curve obtained from the unconfined compression tests are shown in Fig.4 and Fig.5.

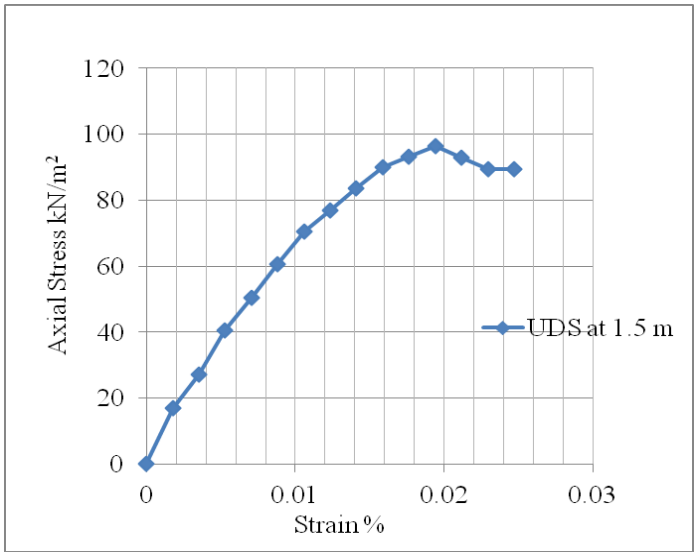

Fig. 4 Stress- Strain Curve for UDS of Borehole 1

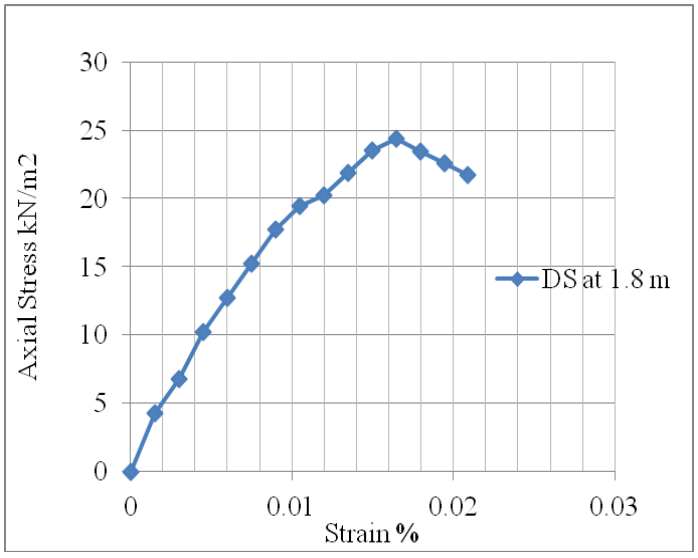

Fig. 5 Stress- Strain for Remolded Sample of Borehole 1

The values obtained from the UCC test shows that the clay as consistency of medium stiff, highly compressible in nature. The Values of Unconfined compressive strength from UCC test is presented in the Table 1.

Table. 1 Values of Maximum UCS for Borehole 1

Description	Depth m	Water Content %	Unconfined compression strength q_u kN/m^2	Undrained Cohesion c_u kN/m^2
UDS 1	1.5	34.38	96.45	48.23
Remolded sample 2	1.8	28.42	24.34	12.16

5.4 One Dimensional Consolidation Test

The consolidation test has been conducted as per IS: 2720 - 1986. The specimen has been prepared in orientation direction same in the consolidation apparatus as they were oriented in field. Specimen has prepared in the liquid limit water content to obtain Cc and C_R. The test was conducted for the pressure range of 0 to 1.6 kg/cm^2.

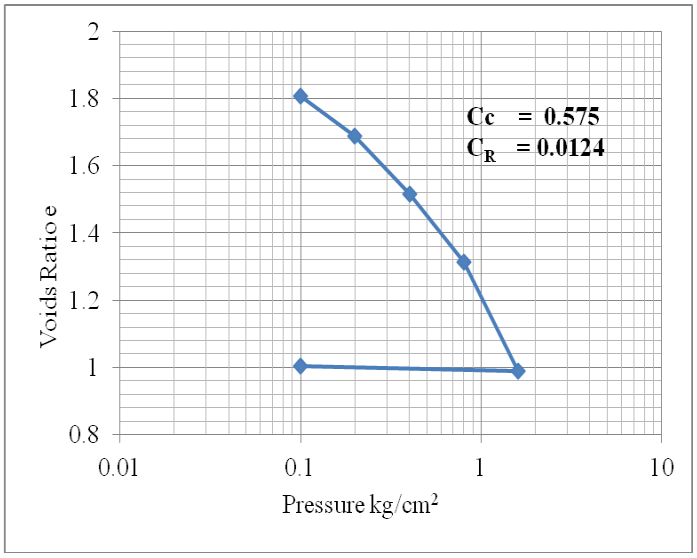

Fig. 6 Semi-log Plot of Pressure-Voids Ratio Relationship

Table 2. Values coefficient of volume Change

Pressure kg/cm^2	a_v cm^2/kg	Coefficient of volume Change mv cm^2/kg	Cc	Cs
0-0.05	1.32	0.449	0.575	0.0124
0.1- 0.2	1.18	0.420		
0.2-0.4	0.865	0.322		
0.4-0.8	0.5025	0.199		
0.8-1.6	0.202	0.087		

6 DYNAMIC CONE PENETRATION TEST

The Dynamic cone Penetration test has been carried at borehole 1 at 1.5 m below the existing ground level of the building. The Dynamic Cone Penetrometer, or DCP (Illinois Test Procedure 501), is primarily used to determine the immediate bearing value (IBV) and also used to determine the unconfined compressive strength (Qu) of foundation materials. Correlation between Penetration Rate, IBV and qu

(Illinois Test Procedure 501)

IBV = 10 (0.84 - 1.26 × LOG [Rate])

where Rate is in units of inches/blow

Qu = 0.32 x IBV

The rate of penetration decreases with increase in depth and also Qu value decreases with increase in depth. The Shear Strength of soil also decreases with increase in depth as shown in Fig. 6.

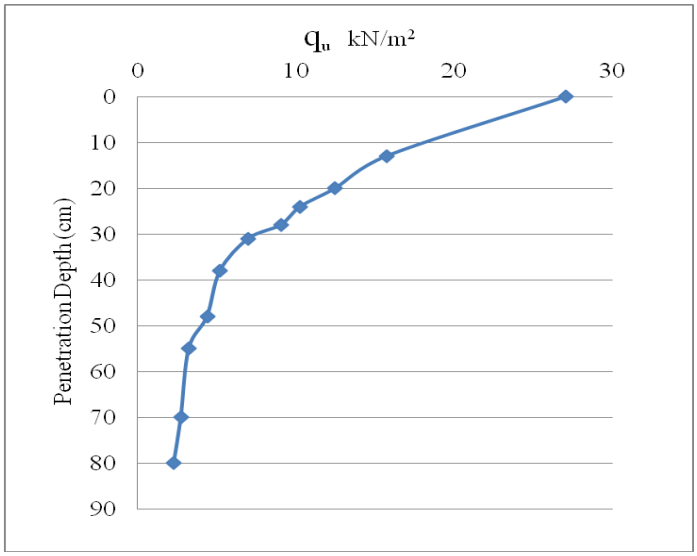

Fig.6 Variation f Qu with respect to Depth

Table 3. Values of Penetration Rate, IBV and Qu

No of blows	Penetration cm	Penetration Rate (inches/ Blow)	IBV	Qu kN/m2
1	13	5.122	0.883	27.067
2	20	3.941	0.513	15.729
3	24	3.152	0.407	12.500
4	28	2.758	0.335	10.294
5	31	2.442	0.295	9.055
8	38	1.871	0.228	7.006
10	48	1.891	0.170	5.219
14	55	1.547	0.143	4.396
21	70	1.313	0.105	3.244
27	80	1.167	0.089	2.742
31	92	1.169	0.075	2.299

7 INTERPRETATION OF RECONNAISANCE SURVEY

The type of foundation of the residential building is individual column footing and it is placed at 1.5m depth. The Building is situated in the water stagnant area. The water table is located at a depth of 0.5m. The thickness of Clay layer is around 10m. It is understood that the existing foundation is resting over soft clay. During the reconnaissance survey, it was noticed that the building were tilted at an angle of 7^{o} 24' in North West and 5^{o}25' in the North East side with respect to vertical. The offset between the sunshades of the adjacent building is very and even crushed due to settlement.

8 INTERPRETATION OF SOIL EXPLORATION

From bore hole 1, the soil up to 2.80m depth is a CH type of clay with possible volume- change characteristics. The plasticity index and the natural water content are in the same range indicating the possibility of the soft nature of the clay. Bore log 1 reveals that the foundation of residential building was laid over CH type of clay thickness 3 m. In bore hole 2, water table presented at a depth of 0.5 m.

9 REASONS FOR DISTRESS IN THE BUILDING

The reasons attributed for the distress of a building selected in the present investigation are detailed below:

- **i)** The differential settlement of footing due to variation in the column load and variation in the soil profile in the building area.
- **ii)** Most of the heavily loaded columns are located in the tilted region.
- **iii)** Footing of an adjacent building is very close to the footing of tilted building and its placed at same depth caused interference of pressure bulb of footings. This interference made the building undergoes differential settlement.
- **iv)** The tilt of the building was not uniform, because it is resting on the individual footing. Since the angular distortion of the adjacent footing are within permissible limit to the distress on the structure is repairable.

10 REMEDIAL MEASURES

1. There is no distress in the structures which are resting on the pile foundation in this area, because the piles are resting on the soft rock at 10m depth. So it is advised to strength the foundation system by Underpinning method
2. Since the distress where due to the interference of the pressure bulb of footing, non-uniform loading and non-uniform soil. So it is recommended minimizing the variation of load in this building area.
3. To arrest the tilting of existing building, it is recommended improving the strength of soil in the tilted area by grouting. The method of grouting and chemical is to be decided based on detailed investigation in the laboratory.

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