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Foundation Problems at a Residential Complex - A Case History

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SYNOPSIS The paper describes a case history in connection with foundation problems at a residential complex on the adequacy or otherwise of the bearing capacity of foundation soil for raising the existing buildings to double storeyed configuration. The study made possible to raise few existing buildings to double storeyed where safe bearing capacity was found adequate and these buildings could reveal good performance since implementation of suggestions.

INTRODUCTION

Foundation problems are very common and major problems start if addition of more storeyed becomes unavoidable having restriction in expa nsion in horizontal direction due to shortage of land. For raising the existing buildings to double storeyed configuration, the assessment of bearing capacity of foundation soil is of paramount importance. A residential complex of an industrial set up consisting of about 500 numbers of residential accommodations already in occupation by the staff was to be converted into double storeyed configuration. Initially the bearing capacity of foundation soil for a particular spot was reported inadequate for raising to double storeyed configuration. The problem was entrusted to Central Building Research Institute, Roorkee, India to advice on the adequacy or otherwise of the bearing capac - ity of foundation soil for raising the existing buildings to double storeyed configuration. The author undertook the field and laboratory investigations to assess allowable bearing capacity of foundation of the residential complex and advised to raise to double storeyed in the area where the safe bearing capacity was found adequate. The suggestion was also made to add second storeyed with lightweight construction material.

FIELD INVESTIGATION

The residential complex was situated near the foothills of Shiwaliks in scenic backdrop of hills and green landscape. The site plan of residential complex showing locations of plate load test (PLT), standard penetration test (SPT) and dynamic cone penetration test (DCPT) is given in Fig. 1. Five numbers of plate load tests (Plate size 60cm * 60 cm) at excavated depth (1.35 m) were carried out according to IS 1888 - 1982. The load settlement relationship curves in terms of natural and log-log scale were drawn to calculate ultimate and safe stress by adopting double tangent and log-log plot methods. The test results as obtained are shown in Table 1. The safe stresses were calculated by adopting the factor of safety 2 over the ultimate considering controlled tests at site.

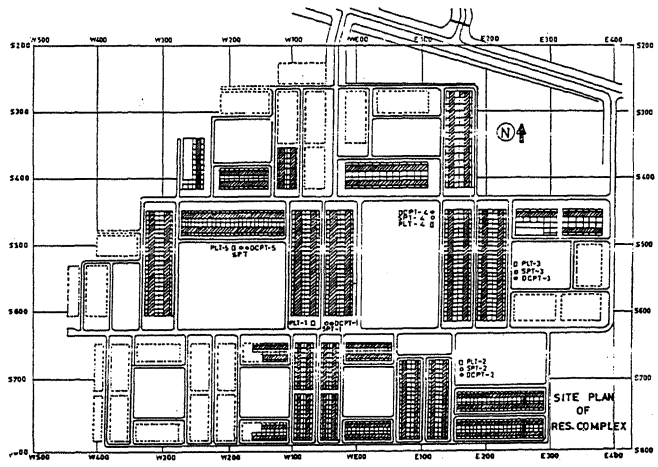

Fig. 1. Location of PLT, SPT and DCPT Tests

TABLE-I Results of Plate Load Tests

Plate Load Test (PLT)	Double Tangent Plot: Ultimate Stress (t/m^2)	Double Tangent Plot: Safe Stress (t/m^2)	Double Tangent Plot: Plate Settlement (mm)	Log - Log Plot: Ultimate Stress (t/m^2)	Log - Log Plot: Safe Stress (t/m^2)	Log - Log Plot: Plate Settlement (mm)
PLT-1	7.4	3.7	19.0	7.4	3.7	20.0
PLT-2	9.0	4.5	11.0	9.0	4.5	11.0
PLT-3	5.0	2.5	9.0	4.8	2.4	8.0
PLT-4	3.8	1.9	14.0	4.8	2.4	16.0
PLT-5	17.6	8.8	23.0	15.0	7.5	19.0

The similar numbers of standard penetration tests (SPT) and dynamic cone penetration tests (DCPT) were carried out upto 10 m. depths according to IS 2131 -1981 and IS 4968 (Pt-1) -1968 respectively. The test results as obtained are shown in Fig. 2(a-e).

LABORATORY INVESTIGATION

The disturbed soil samples collected during conducting SPT at various locations and depths were analysed in laboratory to determine particle size distribution and atterberg's limits for the classification of soil layers below foundation. The test results as obtained are tabulated in Table - II. The bore logs with the results of SPT value, DCPT value, Atterberg's limits and classification of soil layers are also shown in Fig. 2(a-e).

TABLE-II Physical Properties of Soil Layers

Bore Log	Depth (m)	% Passing 4.75 mm	% Passing .425 mm	% Passing .075 mm	% Clay content < .002mm	Atterberg's limit % L.L.	Atterberg's limit % P.I.
SPT -1	0.00- 0.80	98	88	59	12	18	NP
	0.80- 3.50	100	98	85	25	25	6
	3.50- 4.50	91	58	4	1	NP	NP
	4.50- 8.50	100	97	86	28	32	12
	8.50-10.00	99	95	66	15	21	5
SPT -2	0.00- 1.80	100	99	79	17	19	NP
	1.80- 3.10	100	100	80	23	26	7
	3.10- 3.60	100	99	48	7	NP	NP
	3.60- 5.60	89	49	1	NIL	NP	NP
	5.60- 7.25	99	90	5	NIL	NP	NP
	7.25- 8.30	100	99	96	32	40	16
	8.30- 9.80	100	100	48	10	31	9
SPT -3	0.00- 3.00	100	99	74	17	23	5
	3.00- 5.60	98	93	85	30	33	11
	5.60- 7.15	100	83	3	1	NP	NP
	7.15- 8.50	73	53	1	NIL	NP	NP
	8.50-10.50	100	99	96	33	36	15
SPT -4	0.00- 1.80	98	97	93	28	29	8
	1.80- 3.00	99	98	97	32	44	19
	3.00- 4.10	100	99	87	25	32	10
	4.10- 7.00	78	66	6	1	NP	NP
	7.00- 8.00	99	94	87	27	32	10
	8.00- 8.50	100	99	97	33	47	22
	8.50-10.05	99	94	93	28	28	8
SPT -5	0.00- 2.60	98	94	8	1	NP	NP
	2.60- 3.50	100	97	91	15	32	7
	3.50- 7.00	99	98	95	31	37	14
	7.00- 8.50	99	97	82	25	30	8
	8.50-10.00	100	97	92	28	31	9

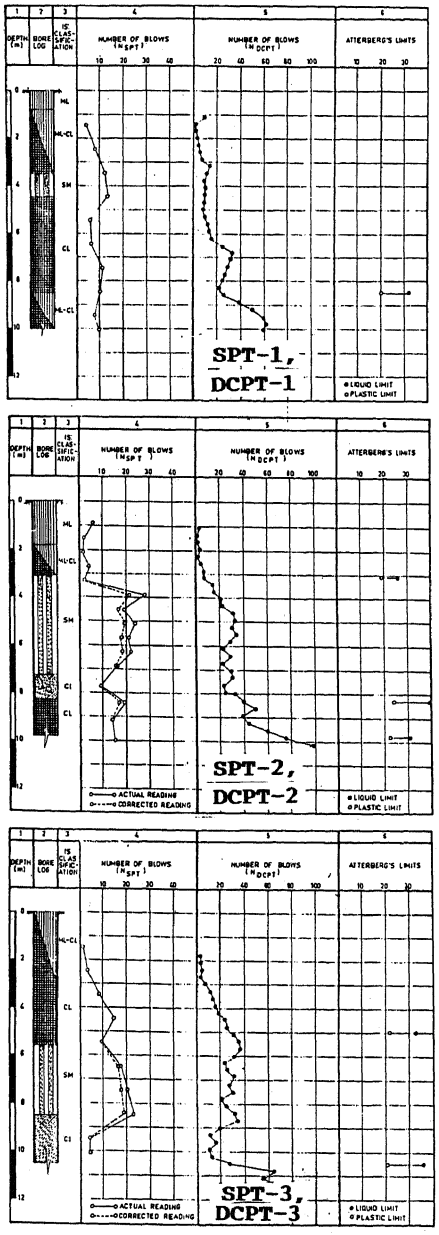

Fig. 2(a-e). Borelog Showing N-Value and Atterberg's Limits

ASSESSMENT OF BEARING CAPACITY OF FOUNDATION SOIL

The safe bearing capacity of foundation soils were calculated from the consideration of settlement for various footing sizes as incorporated by the user organisation. The magnitude of settlement of soil considering various footing sizes was worked out using the following equations.

$$S_f = \frac{B_f}{B_p} * S_p \quad \text{(for cohesive soil)} \qquad (1)$$

$$S_f = \left[\frac{B_f (B_p + 0.3)}{B_p (B_f + 0.3)}\right]^2 * S_p \quad \text{(for non-cohesive soil)} \qquad (2)$$

Where,

S_f = Settlement of footing in m.
S_f = Settlement of plate in m.
B_p = Size of footing in m.
B_f = Size of plate in m.
B_p

The bearing capacity of foundation soils were also worked out considering permissible maximum settlement of 60 mm according to IS: 1904-1978. The ultimate and safe bearing capacity of foundation soils calculated referring the load - settlement relationship curves and the magnitude of the settlement evaluated following the equations 1 and 2, are tabulated in Table-III.

DISCUSSION AND SUGGESTION

Based on the evaluation of the bearing capacity of foundation soils carried out considering the failure of foundation soils due to shear strength and maximum allowable settlement for various footing sizes (Table-III), the allowable bearing capacity of foundation soil was considered lower of two and accordingly the area covering PLT-5 was considered adequate for raising residential accommodation to double storeyed configuration. The area covering PLT-1 3 and 4 revealed very low allowable bearing pressure and were considered inadequate for even single storeyed buildings.It was suggested that the existing buildings located in the area should be strengthened. The area covering PLT-2 could reveal very marginal allowable bearing pressre and did not have desired margin safety hence it was suggested for undertaking strengthening measure. However considering the bearing pressure on maximum settlement criteria, it was suggested to raise the existing buildings for the area covering to PLT-5 to double storeyed configuration using normal building materials. The area covered by PLT-1, 2 and 3 revealed bearing pressure very near to desired bearing pressure and it was suggested to raise to double storeyed configuration using lightweight building materials for walls and roof to avoid excessive loading and performance be observed regularly. The area covering PLT-4 revealed inadequate bearing pressure even on the basis of settlement and it was suggested to undertake strengthening measure for existing buildings.

HISTORY OF PROBLEM AND PERFORMANCE

On evaluation of bearing capacity of foundation soils, the residential complex having 500 numbers of residential accommodation already in occupation by the staff, was visited and the residential accommodation covering in the area where bearing pressure was not adequate showing cracks at roof level in horizontal, vertical and diagonal directions on outer & inner walls and it was reported that the initial distress was glaring but after remedial measure it could be controlled. The user organisation raised the

TABLE-III Bearing Capacity of Foundation Soils

Type of combination	Location of PLT	Footing Number	Width of Footing (m)	Tangent Method: Ultimate (t/m^2)	Tangent Method: Safe (t/m^2)	Tangent Method: Calculated Settlement (mm)	Log-Log Method: Ultimate (t/m^2)	Log-Log Method: Safe (t/m^2)	Log-Log Method: Calculated Settlement (mm)	Settlement Criterion: Calculated Settlement for 60cm*60cm plate (mm)	Settlement Criterion: Bearing Capacity (t/m^2)
I	PLT-2	F2,3,4	1.22	10.2	5.1	32	10.2	5.1	32	30	11.1
		F5	0.99	9.2	4.6	18	9.2	4.6	18	36	11.9
	I	F6	1.45	10.4	5.2	27	10.4	5.2	27	25	10.6
II	PLT-1	F2,3,4	1.22	7.8	3.9	22	7.8	3.9	22	30	8.4
		F5	0.99	7.4	3.7	18	7.4	3.7	18	36	9.3
		F6	1.45	8.2	4.1	27	8.2	4.1	27	25	7.9
	PLT-5	F2,3,4	1.22	21.0	10.5	33	19.0	9.5	28	41	20.1
		F5	0.99	20.0	10.0	31	18.0	9.0	25	45	22.5
		F6	1.45	22.0	11.0	35	22.0	11.0	39	39	23.5
II	PLT-3	F2,3,4	1.22	6.6	3.3	18	6.0	3.0	18	30	8.4
		F5	0.99	6.0	3.0	15	5.8	2.9	15	36	9.4
		F6	1.45	7.0	3.5	22	7.0	3.5	22	25	7.7
	PLT-4	F2,3,4	1.22	4.4	2.2	20	4.2	2.1	20	30	5.6
		F5	0.99	4.0	2.0	17	3.8	1.9	16	36	6.4
		F6	1.45	5.0	2.5	24	5.8	2.9	24	25	5.0

buildings to double storeyed configuration for the area covering at PLT-5 and over all 96 type II accommodations were converted into double storeyed in three phases (24+48+24). The extension was undertaken in October 1986 and the last block was completed in November 1989. The completed view of residential accommodation is shown in Fig. 3. As reported by the user organisation the accommodation could not reveal any sign of distress viz. settlement, cracks, pealing off plasters etc. The conventional building materials were used and the accommodations are

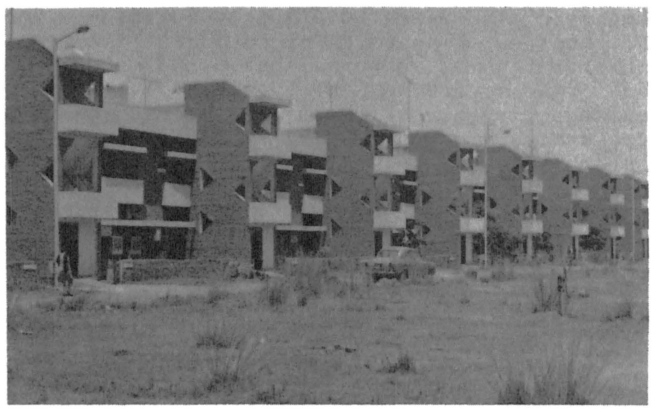

Fig. 3. View of Completed Accommodations

in occupation after completion of construction work. The investigation could reveal confidence in them for raising the buildings to double storeyed configuration successfully.

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