07 May 1984, 11:30 am - 6:00 pm

Settlement of a One Floor Building on Soft Clay Beside a Heavy Building

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SYNOPSIS A one floor building was founded on a deposit of normally consolidated soft clay. It was constructed to annex an existing three storey high building founded on piles.

After construction, tilting and settlements of the Annexe were detected relative to the existing building. Recorded absolute and differential settlements, monitored over a period of five years, were considerably high.

It is shown here that this could be caused by the combined effect of high compressibility, confinement of clay layers and variations in pressure distribution below foundations.

INTRODUCTION

The Annexe is a Reception building situated on a deposit of normally consolidated soft clay in the suburb of Alexandira. It was designed as an extension to the existing main building of El-Nozha Airport and attached to it.(See Figures 1,2,and 3). The main building is three storey high supported on piled foundation.

Due to the urgency encountered in the demand for using the Reception Annexe, a shallow foundation design was favoured. This provided worthwhile saving in construction time as well as in cost rather than a comparable piled foundation.

Construction began in August of the same year. Two months later, substantial inclination away of the existing high building as well as settlements were noticed. This was most significant at the joint between the two buildings (see Figurel). However, due to its rigidity, the Reception Annexe was acting as one unit able to accept shearing forces with slight shearing deformations. These deformations.had caused only hair cracks to occur in brick walls (Fig.2) and some doors and windows to be jammed.

Fig. 1. A Front Elevation Photograph showing The Annexe and its Connection with the existing Main Building.

ABOUT THE BUILDING

The building under consideration is one floor high and covers an area of approximately 14.5m by 12.5m plus a 4 m cantilever shed projected from the longer side of the roof. A plan and elevations of the Annexe and the main building are shown in Figures 1 and 2.

The adopted structural system was a reinforced concrete frame construction with brick cladding. The columns carrying the roof rest on inverted T beams strip footings. These beams are 1 m thick and are connected together in two directions to form a hollow raft. The whole system is placed on lean concrete 0.25 m thick which rests directly on the soft clay layer at a depth of 2 m. from ground level (see Figure 2).

THE SUBSOIL

A soil exploration at the site of El-Nozha Airport Reception Annexe was carried out and undisturbed samples were obtained for laboratory testing.The ground water table is situated here at a depth of 1.10 m.

A summary of test result is given in Table 1. A simplified soil profile is shown in Fig.2 and the soil condition can be described in the following way :

Depth 0-1 m. Fill.

Depth 1-6.6 m. Very soft dark grey clay with shells in the upper 2.50 m.
The undrained shear strength of this layer is about 8 kN/m^2. The water content is 114-118 %, the liquid limit is 146-161 % and the plastic limit is 43 to 53; the water content is near to the liquid limit. The bulk unit weight is 14 kN/m^3. One hypothesis is that this layer had been formed by sedimentation of alluvial deposits into stagnant lakes.

Depth 6.60-9.20 m. soft yellowish grey silty clay.
The undrained shear strength is 16.5 kN/m^2. The water content is 26% , the liquid limit is 52% , thus the plasticity index is 26. The bulk unit weight is 20 kN/m^3.

Depth 9.20-15.00 m. Sand, the upper 2.50 m are fine and containing small lenses of silty clay then it is becoming coarser and agglomerated.

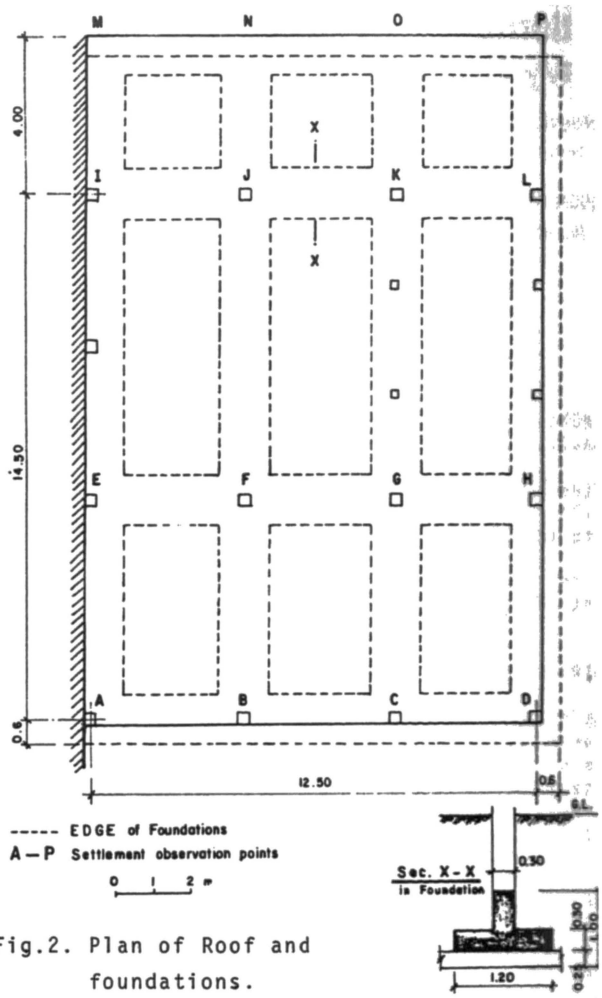
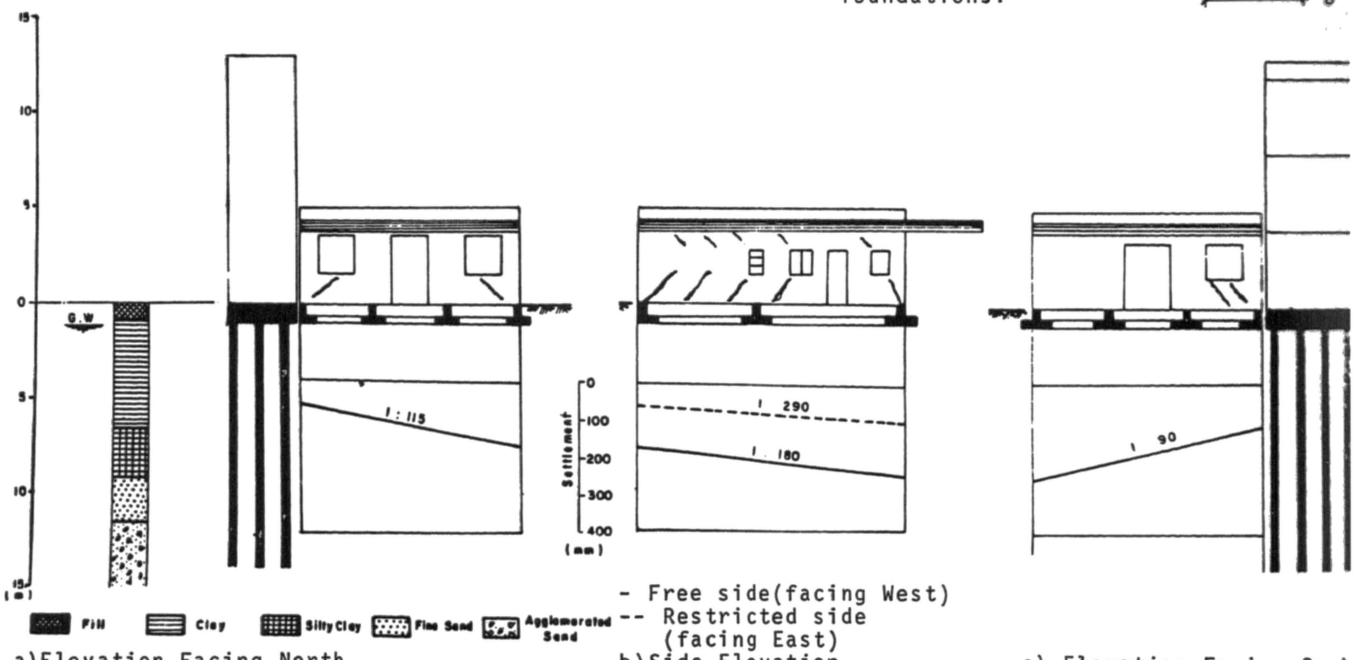


Fig.2. Plan of Roof and foundations.



- Free side(facing West)
-- Restricted side (facing East)

a)Elevation Facing North b)Side Elevation c) Elevation Sout

Fig.3. Soil Profile, Settlements below Foundations and Cracks in the Facades of the Annexe.

TABLE 1. Soil Properties.

Depth (m)	Soil Description	Undisturbed Samples (m)	Water content w %	Liquid Limit L.L. %	Plastic Limit P.L. %	Specific Gravity Gs	Unit Weight b KN/m^3	Cohesion Cu kN/m^2
1.00	Fill							
2.50	Very soft grey clay with shells	1.80	118	161	53	2.76	13.9	8.0
6.60	Very soft dark grey clay.	4.30	114	146	43	2.79	14.0	7.7
9.20	Soft yellowish grey silty clay with fine sand laminations.	7.10	26	52	22	2.71	20	16.5

FOUNDATION BEARING PRESSURES :

The building load distributed by traditional method gives pressures as indicated in Fig.4. These pressures vary between 9.0 and 21 kN/m^2 which are relatively small. The variations are due to the cantilever action on side I-L relative to A-D and the effect of walls near to side D-L relative to I-A.

SETTLEMENT OBSERVATION

The settlements have been recorded at 16 points installed on the roof of the Annexe and the datum was located on the existing building. Levelling commenced in November 1964 and continued for about five years until February 1969. Fig.5 show the plotted time settlement curves for corner observation points. Fig.6 indicates the settlement distribution below Foundations.

SETTLEMENT CALCULATIONS :

Settlements of the Annexe were computed at corner points from Terzaghi (1959) in conjunction with distribution of pressure below foundation and the obtained soil properties.(See Table 1 and Fig.7). These calculatd values of settlements are given in Table 2 together with observed settlements, and the ratio between them.

DISCUSSION

The pressure distribution below foundation and the observed settlement distribution are given in Figures 4 and 5. The show that they follow the same pattern: pressures and settlements below side L-D are greater than those below side I-A: pressures and settlements below side I-L are greater than those below side A-D; and

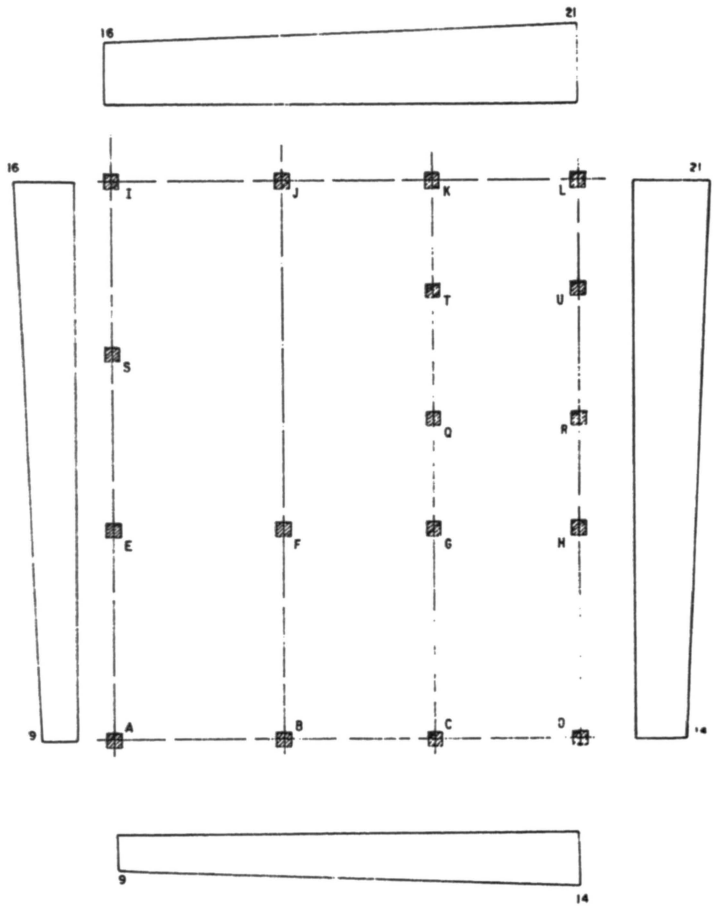


Fig.4 Pressure Distribution at Corner Points below Foundation (in kN/m^2).

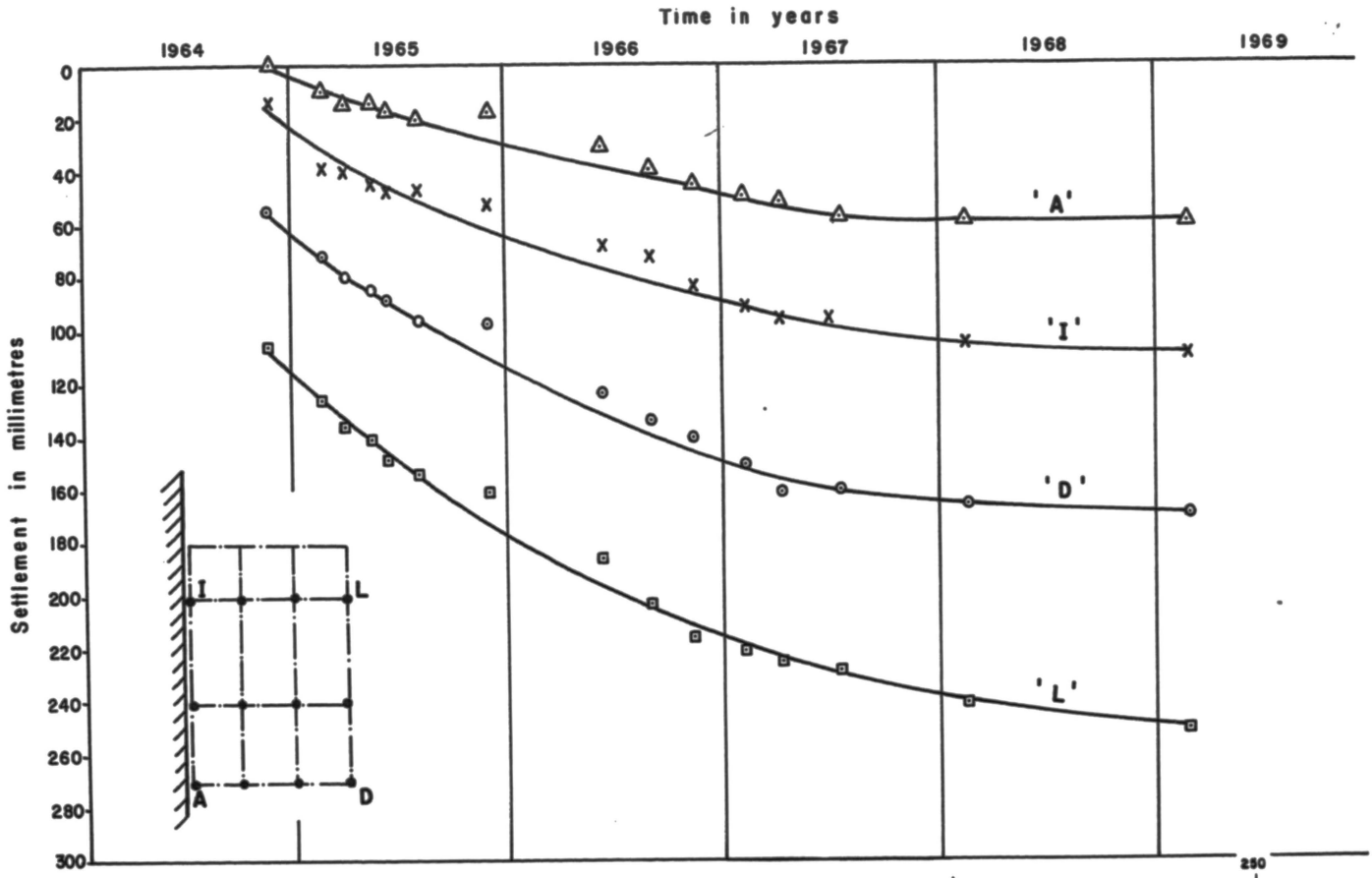


Fig.5.Time-Settlement Curves at Corner Point

TABLE 2 Settlement Values at Corner Points

Settlement Point Numer.		Settlements in millimeters	
Side adjacent to Existing Building	A	Observed So	60
		Calculated Sc	182
		Ratio (So/Sc)	100
	I	Observed So	100
		Calculated Sc	311
		Ratio (So/Sc)	0.35
Free Side	L	Observed So	250
		Calculated Sc	280
		Ratio (So/Sc)	0.65
	D	Observed So	170
		Calculated Sc	264
		Ratio (So/Sc)	0.65

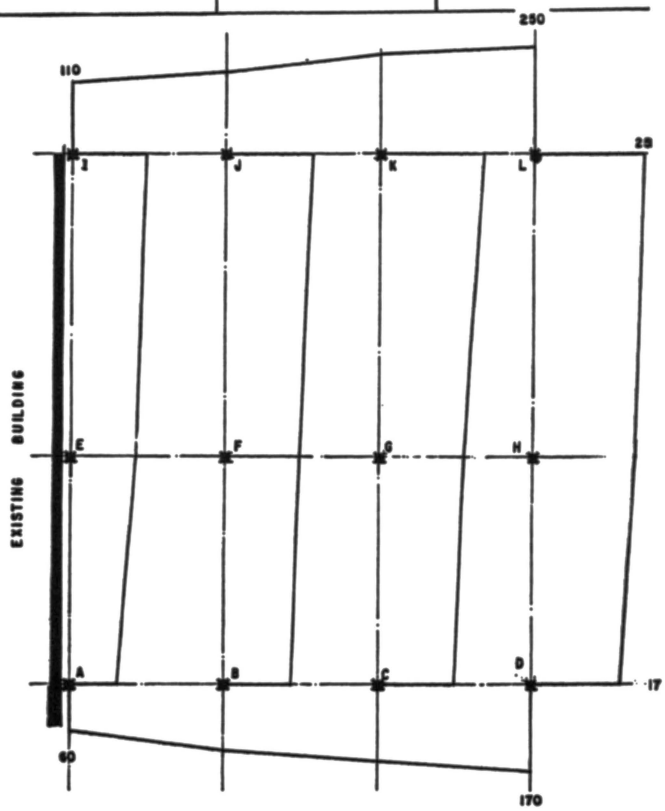


Fig. 6. Distribution of Settlement Below Foundation (in mm.).

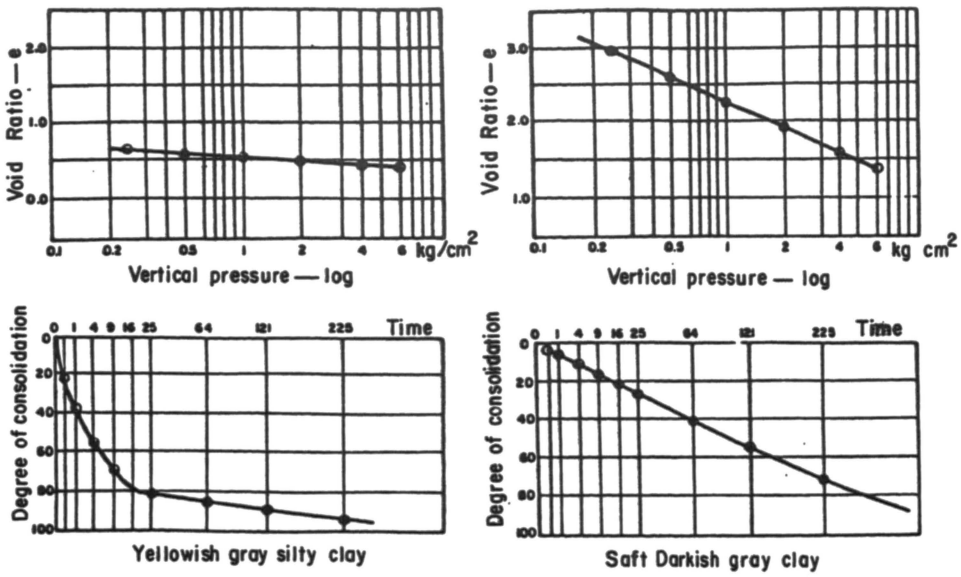


Fig. 7 Results From Consolidation Tests

the maximum and minimum pressures and settlements occur below corners L and A respectively. This indicates that the variations in pressure distribution below foundations caused the observed variations in settlements.

Furthermore the confinement of clay layer adjacent to the piled foundation of the existing building caused, in addition, a differential settlement between the restricted side A-I and the free side D - L. This is indicated by the ratio between observed and calculated settlements (So/Sc) given in Table 2. The ratio So/Sc is (0.33 and 0.35) at the restricted side A-I and (0.64 and 0.65) at the free side D-L. The smaller value of So/Sc occured at the side of less freedom for changing in volume and accordingly less settlement. Also, as Skempton and Bijerrum (1957) pointed out, an element of soil underneath a foundation undergoes lateral deformation as a result of applied foundation loading. Therefore if lateral deformation is restricted, due to the confinement by piled foundation, the subsequent consolidation is also restricted.

As a result, the differential settlements of the Annexe could be attributed to the combined effect of pressure distribution variation below foundation and confinement of clay layer on one side due to the piled foundation of the adjacent building.

The high values of settlement for the given small values of pressure are due to the high compressibility of the clay layer. Also, the values of settlement obtained by calculation are higher than the observed values because 100% consolidation had not yet taken place.

CONCLUDING REMARKS

1. In the case presented, settlement proved to be very sensitive to minor changes in stress distribution and boundary conditions.
2. The pattern of settlement followed the pattern of pressure distribution.
3. The side adjacent to existing building settled less than the free side.
4. There is a very reasonable correlation between observed and calculated settlements.
5. The main causes of differential settlements are are likely to be due to the combined effect of non-uniform distribution of pressures below foundation and non-uniform boundary conditions (confinement of clay layer only on one side).

ACKNOWLEDGEMENT

The authors would like to thank engineer Mohamed Abd El Fattah Sayyed who had greatly incormorated in settlement observations, soil study and reporting the case.

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