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# Damage of a Broadcasting Station Due to Shrinkage of Soil

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SYNOPSIS This paper discusses the causes of damage of a broadcasting transmission station suffered from settlement cracks. The station buildings were low-rise reinforced concrete structures with isolated footings founded on alluvial deposit. Investigations revealed that the main causes of the observed nonuniform settlement were the existance of silt pockets below some footings, and the shrinkage of clayey soils due to dryness of the subsoil after ceasing the cultivation of land and using it as construction site. Rehabilitation scheme included structural repair of the cracked columns, beams and walls, and injection grouting of the foundation soil beneath the settled columns.

## INTRODUCTION

The authors were assigned to investigate the buildings of a broadcasting transmission station suffered from settlement damage. The station was located in a small town at the middle of the Nile delta, about 100 km north of Cairo. It consisted of two low-rise buildings founded on spread footings. The main building was two-storey, reinforced concrete skeleton type structure with brick walls. Its length was 40 m and its breadth was 20 m in two thirds of the building and 30 m in the rest of it. The second building was a warehouse with dimensions of 33 m x 21 m . The foundation level was at 1.50 m below the ground surface the station buidings were constructed at the center of a large site, 600 m by 270 m, surrounded by cultivated land. This site was also a green field before the construction of the station. However, it has not been cultivated since the erection of the buildings. A navigation canal existed at about 100 m west of the site. A longitudinal depression, 20 m to 50 m wide and 3 m deep, was crossing the site and passing east of the buildings. It was used in the past as a drain. A general layout of the site is shown in Fig. 1.

The work started at the site of the station in 1979. It was completed and opened in 1981. Cracks started started to take place in 1987. They appeared firstly in the brick walls, then extended recently to the columns. Window and door frames were destorted, and floor settled remarkably. Shrinkage cracks were noticed on the ground surface around the builings ( see Figures 2,3,4, and 5 ).

## SUBSURFACE INVESTIGATION

Investigation were conducted to study the subsurface conditions. Seven borings with depth of 20 m were executed. Six of them were adjacent to the buildings as shown in Figure 6 and the seventh was located on the boundary of the site close to the main gate to reflect the normal conditions in the area outside the construction site. The ground water table appeared firstly at – 11.30 m , then rose up to about – 3.70 m in all borings, except in the far boring where it was encountered at – 3.50 m and stabilized at –3.00 m.

The soil profile consisted mainly of top soil, 1.3 m to 2.5 m thick, followed by layers of brown stiff silty clay, 8.0 m to 9.7 m thick, underlain by medium sand. The number

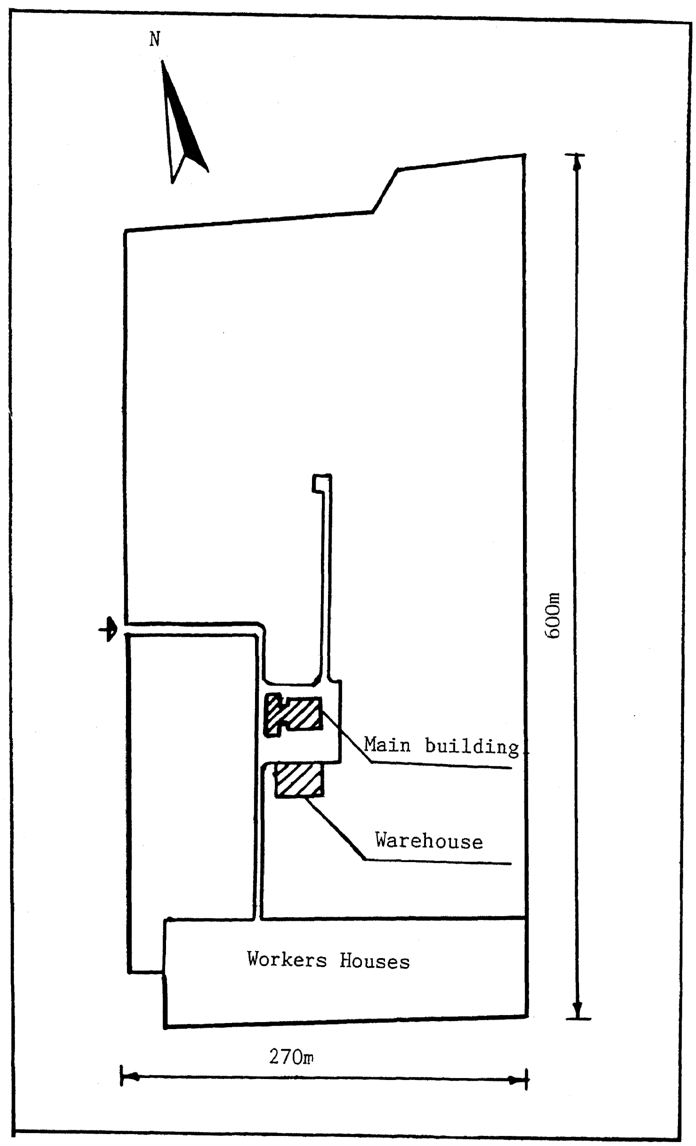


Fig. 1. General Layout of the Site

of blows per 30 cm recorded in the Standard Penetration test ranged from 10 to 27 in the clayey layers, and was between 10 and 75 in the sand strata. A layer of silt, about 1.0 m thick, appeared right below the foundation level in borings 1,2, and 3.

The previous soil exploration carried out before construction came up with almost the same soil profile, but it indicated that the initial level of water table in borings was at - 3.0 m, and the final was at - 1.5 m. However, the number of borings was not enough to detect the presence of the silt pockets.

Fig. 2. Horizontal Crack in the Facade

Fig. 3. Inclined Cracks in Walls

Fig. 4. Cracks in Columns and Walls

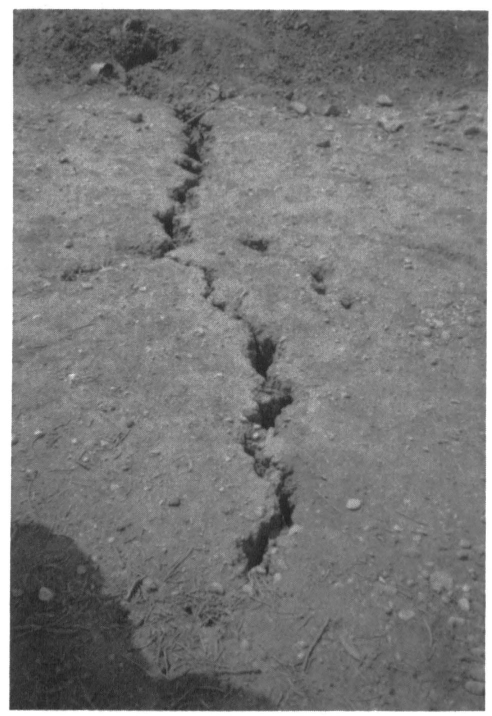

Fig. 5. Shrinkage Cracks on the Ground Surface

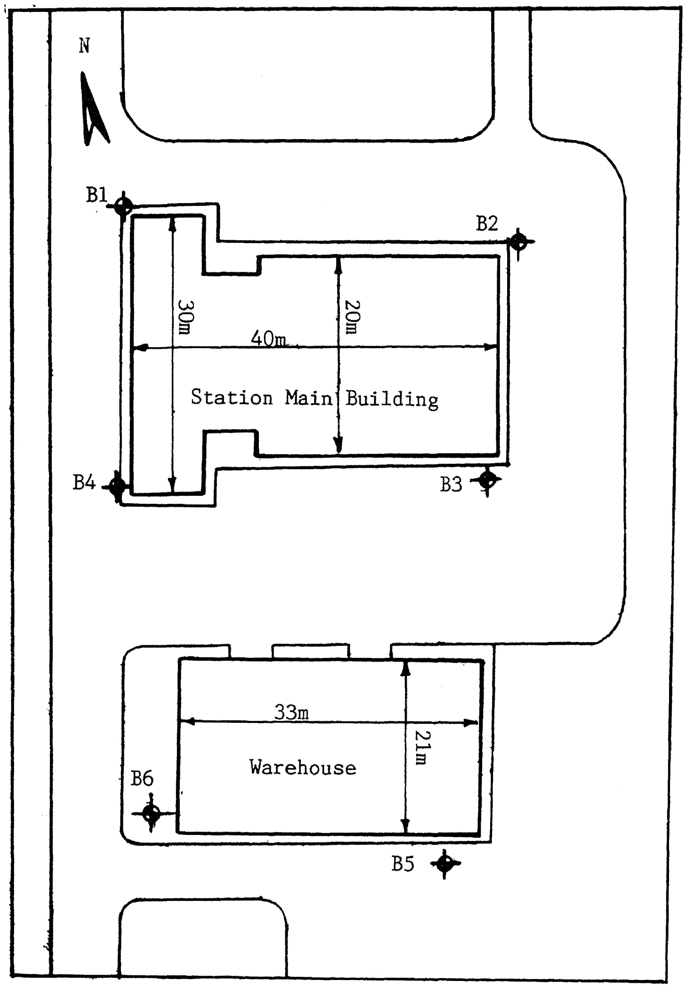


Fig. 6. Location of Borings

LABORATORY TESTINGS

Laboratory investigation included the determination of the physical properties of soil layers, such as natural moisture content, bulk density, gradation, and Atterberg limits and strength tests. The undrained shear strength of the cohesive soils was determined by the Unconfined Compression test. The laboratory test results indicated that the clayey layers consisted mainly of very stiff silty clay with high plasticity, the water content ranged from 24 % to 40 % and the dry density ranged from 1.25 to 1.64 $t/m^3$. The liquid limit was between 51 and 72, and the plastic limit was between 20 and 28. The percent of sand in the silty clay layer increased with depth.

SITE INSPECTION

During inspection of the buildings, it was noticed that there were numerous wide cracks in the brick walls as shown in Figures 2 and 3. There were also vertical and inclined cracks in two corner columns. Noticeable cracks were found in some grade beams. Floors were deformed and settled inside the station.

Many wide shrinkage cracks were clearly observed on the ground surface in the area surrounding the station buildings. The depression passing through the site in the vicinity of the building was completely dry.

When the foundation design was reiewed, it was found that the foundation pressure was about 0.9 $kg/cm^2$. The footing design was sound and on the safe side regarding the stiffness of the foundation clayey soil, but it did not take into consideration the bearing resistance of the weak silt pockets located under some of the footings.

CAUSES OF DAMAGE

It was obvious that the station buildings were subjected to differential settlement which caused these damaging cracks. The laboratory investigation disclosed that the settlement was not due to compressibility of clayey soils, but it was a result of the desiccation of the top clay layer located above the water table and the unequal settlement due to the compression of the weak silt pocket below some footings.

The authors surveyed all the available information about the environmental changes which might have caused the desiccation of clay. Investigations revealed that this land was green fields before the construction of the station, and was usually irrigated by inundation. The longitudinal depression passing through the site used to be partially filled with water drained from the surrounding fields. It was stated in the geotechnical investigation carried out before construction ( in 1979 ) that the ground water table was encountered at depth of 1.50 m. This information means that the clayey layers below the level of - 1.50 m were permenantly submerged in water.

The recent soil investigation showed that the ground water started to appear at depths ranged from 10.40 m to 11.30 m from the ground surface in borings No. 1,2,3, and 4, when the sand strata were reached in the boring process. It rose up to - 3.50 m after 24 hours. That mean the ground water was lowered at least 2 m below the foundation level. The decrease in the level of the ground water table increased the effective stresses over the foundation soils located below -3.50 m and caused considerable shrinkage in the top bearing highly plastic clayey soil. Comparing the moisture contents and the dry densities of the silty clay layer right below the recent ground water table and of the layers at greater depth above the sand strata, it was found that the moisture content of the top silty clay layer ranged between 23 % and 28 %, and the dry density was between 1.20 and 1.64 $t/m^3$, while the moisture content of the lower clayey layers ranged from 33 % to 41 %, and the dry density was between 1.06 and 1.39 $t/m^3$.

In general, changing the function of this area from a cultivated land to a construction site stopped the irrigation process for many years and resulted in lowering of water table and desiccation of the top clayey soil. This desiccation was not in equal rate or distribution below the covered area of the building. The behaviour of the silt pocket upon drying and its weak bearing characteristics have worsen the problem and magnified the unequal settlement.

The problems caused by shrinkage of clay under shallow foundations were reported in many litrature. Hammer and Thompson (1966), demostrated that large trees, with their deep root systems and huge amount of water demands, are capable of causing the shrinkage of subsurface clay soils, and consequently cause unexpected settlement to structures. Elleboudy (1990) demostrated two cases of soil desiccation that caused unequal settlement of structures. Says (1984) also described the influence of soil desiccation on structure and the effect of shrinkage of alluvial soils on the settlement of three grain tanks. Blight (1966) studied the engineering behavior of the unsaturated surface soils above the water table, which constitute important load bearing layers in civil engineering works, due to environmental changes such as change in atmospheric relative humidity. He stated that the effects of intense desiccation on the volume change and shear strength properties of clays appear to be equivalent to those produced by heavy overconsolidation. Fled (1964) emphasized that the structure must be treated as a living thing being affected by outside causes and tending to compensate internally to localized overstress, more readily when the action is slowly applied. The actual behavior of a structure and its tolerance to settlements are affected by the combination of type of structure, soil and foundation type, and environmental changes.

## REHABILITATION SCHEME

The recommended rehabilitation program included the following steps:

1. Stabilizing the conditions at the site in particular the level of the ground water table by stopping any irrigation of gardens around the buildings, and preventing any seepage from water or sewage pipes which might complicate the problem. Installing piezometers for periodical measurements to assure its stability at the recent level.
2. Establishing several measurememt poits at crack location on walls and columns to detect furthur movement or settlement as shown in Figure 7.
3. After ceasing of differential movement, the silt pockets beneath the cracked columns could be injected by cement grout to increase the bearing capacity at these spots.
4. Increasing the size and the reinforcement of footings located on the silt pockets to reduce the foundation pressure to less than 0.5 $kg/cm^2$. jacketing the cracked columns. Retieing the repaired columns and footings with new rigid grade beams at the foundation level. Refilling of the soil surrounding the footings with well-graded, well- compacted sand up to the level of the ground floor.
5. It was also recommended to build a wide, water-tight, side-walk, surrounding the buildings, and sloped outward to direct any surface water away from the soil beneath them.

Fig. 7. Measurement Points on Cracked Walls

## CONCLUSIONS

The change in the environmental conditions during the life time of structures is one of the most important factors affecting their safety and stability. Hence, the designer should suspect the environmental changes, especially when dealing with clayey soils, and take them into consideration in the foundation design. Desiccation of clays due to lowering of water table and decrease of moisture has become a repeatable phenomenon and occurred in many construction sites. Therefore, engineers must not overlook these changes and do not skimp on foundations, in particular spread footings in light buildings which should be tied properly to withstand unexpected differential displacements. Extra expenditure over the foundations during construction may save a lot of money and effort required for repair in the future. Observations and expectations of soil moisture changes and fluctuation in the ground water table are extremely significant for predicting any future problems, particularly when highly plastic clay soils are encountered and when the function and environment of the area are subjected to changes after construction.

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