Study of A Case of Unsuitable Structural System on Heterogeneous Soil

M.M. REYAD
Ph.D.
Associate Professor of Soil Mech. and Found. Eng., Building Research Center, Cairo, Egypt

SUMMARY This paper presents a case story about group of residential buildings constructed in new desert area. Some Egyptian deserts have uncommon soil formation which is still not well known for many engineers. Due to insufficient investigations, the geotechnical properties of the bearing stratum were not adequately recognised specially the behaviour of the supporting soil under different stresses when it is provided with water. The result was unsuitable structural system led to severe cracks and unexpected damage in most bearing walls directly after use. The paper presents all the carried out investigations and studies to identify the problem in order to prevent any more deterioration and adopt the most convenient remedy.

1. INTRODUCTION

It is well known that Cairo, the capital of Egypt, suffers from high population intensity and lack in housing specially for low-income people. It was recommended by specialists to occupy the surrounding deserts which represent 94% of Egypt area. An industrial company decided to construct a permanent residential neighbourhood for the labourers. The chosen location lies at about 50 Km to the south west of Cairo center. The company had afforded comfortable transportation means to and from its factories.

The project was planned so that the neighbourhood consists of fifteen groups of buildings. The group consists of twelve small adjacent low-cost houses. Houses were built of a ground floor able to carry one additional floor in future. At the center there is a market, clinic, recreation area and small workshops. All buildings are surrounded by new cultivated green areas.

On January 1988, about 80% of the houses were completed and began to be occupied by the dwellers. After about six months, unexpected hair cracks began to appear in most walls. The cracks have gone wider and wider and the deterioration was very clear to human eye. The author was responsible for studying the case and solving the problem.

2. INVESTIGATIONS AND STUDIES

The study was divided into three parallel stages, i.e the state of the superstructure itself, inspection of the existing foundations and soil investigations allover the site. In the first stage all drawings and calculation sheets were revised, different in situ and laboratory tests were carried out on most concrete elements. Brick used in construction of the bearing walls as well as the joining mortar were also examined. Gypsum monitors and electronic indicators were used to measure and follow up the cracks width. Foundation inspection was done by manual excavation on both sides and around the corners of the continuous strip footings and the concrete dimensions were measured. Samples from both the concrete and the soil just under foundations level were also carefully examined.

For soil investigation purposes, 25 open test pits were dug with sufficient width to see and distinguish between the different soil formations along the sides of the excavation. The open pits stopped at depth ranging between 2.00 & 3.50 m below natural ground surface due to the appearance of hard limestone. Additional 10 mechanical borings went deeper down to depth about 10 m. The ground water table was not encountered down to the end of all borings. The samples were carefully examined and tested according to the ASTM in trusty laboratories in Cairo.

3. RESULTS AND DISCUSSIONS

3.1 The Superstructure

Houses are built according to the wall bearing system. The building consists of continuous strip footings under the brick walls which carry the reinforced concrete roof slab through reinforced beams. The test results indicated that the used bricks conform to the standard specifications but the joining mortar suffers from lack in cement content, moreover, some bricks were placed besides each other without any mortar. Concrete elements were in good condition and their strength was acceptable. The different crack indicators showed that the movement was still going on and most cracks were still going wider so that they reached 12 mm in some walls. Some cracks had a broken path around the bricks while some others had cracked the bricks themselves. Figures 1 & 2 show sketches for some cracks as examples and figure 3 shows the structural system of the houses.

3.2 The Foundations

Houses are founded on shallow foundations consist of continuous strip reinforced concrete footings on the shape of inverted T-section resting on 10 cm thick plain concrete strips under the whole length of the bearing walls as shown in figure 3. Foundations rest directly on the natural soil at depth ranging between 0.90 & 1.10 m below ground surface. They were well designed, well constructed and they were in good condition without cracks, no rust and the concrete strength was acceptable.

3.3 The Supporting Soil

Now, we are face to face with the main source of the happened troubles. The comprehensive soil investigations indicated that the upper layer, which

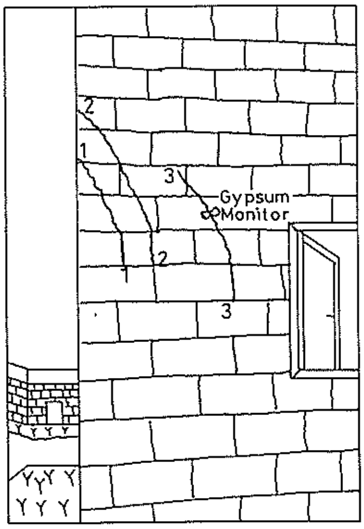

Figure 1 Cracks in an exterior wall

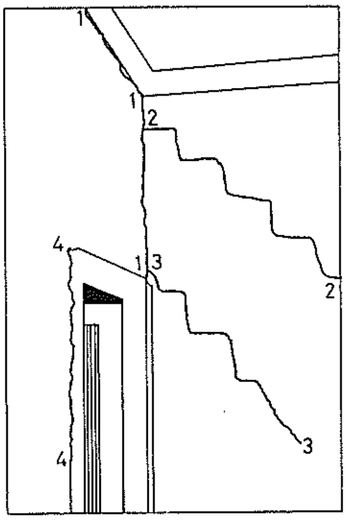

Figure 2 Cracks in an interior wall

extends at some locations down to depth 3.5 m, consists of random formation of heterogeneous soils. It contains fill, collapsible slightly cemented silty sand, expansive hard laminated silty clay, claystone and siltstone. All these kinds are found in different thicknesses, at different depths, in random succession and may lie within the area of the same building. Figure 4 shows the erratic formation of the soil in the upper layers.

As it is well known that the effect of water on such soils is so dangerous, any source of water will cause very complicated soil behaviour and the definite result will be differential movement along the continuous footings. Buildings could not tolerate or withstand the occured movement because their structural system does not afford sufficient rigidity and cracks began to appear.

The main sources of surface water were the continu-

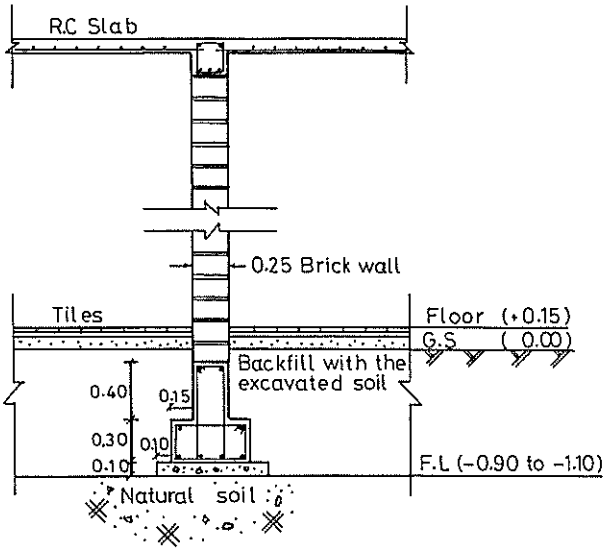

Figure 3 Typical section in interior walls and existing foundations

ous flooding of the green areas surrounding the walls, the continuous leakage of wastewater from the inspection chambers and from the separation lines between tiles in the bathrooms. As the water was still invading the soil, more and more deterioration was still taking place.

4. THE DECISION

The previous study shows that the mistake has two major parts. The first is that the bearing stratum consists of random combination of dangerous types of soils unsuitable to carry any type of shallow foundations directly without pretreatment and strict precautions. The second is that the adopted structural system cannot afford sufficient rigidity so that the buildings can withstand the occured differential movements without any distress.

5. PROPOSED REMEDY

The proposed remedy is divided into three stages:

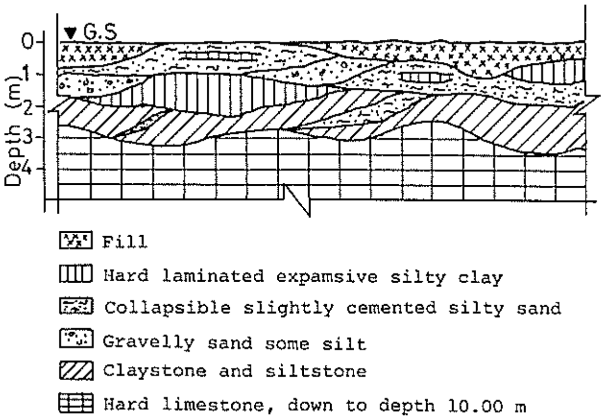

Figure 4 Typical geotechnical section in the bearing stratum

5.1 Soil Replacement

Buildings must be strongly shored up to avoid any movement. Soil is removed out at the points of intersection of the existing foundations to make excavated pits with minimum dimensions 1.50 x 1.50 m down to depth 0.95 m below the present foundation level as shown in figure 5. The bottom of excavation is regularly soaked for 72 continuous hours and the accumulated slurry is removed, then it is strongly compacted. The replacement material is gravelly sandy soil with traces of fines. It is compacted on three equiheight layers of 0.25 m each. Compaction is done at the optimum moisture content to gain minimum 95% of the maximum dry density as predetermined experimentally from the Modified Proctor Test with minimum value 1850 kg/cu.m for each layer.

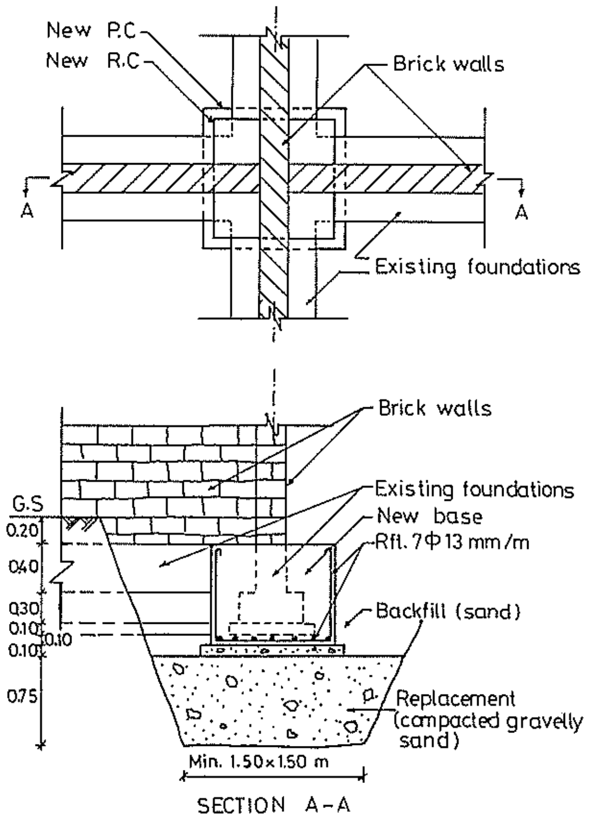

Figure 5 The proposed soil replacement and the new foundation support

5.2 Foundation Support

The new foundation support is shown in figure 5. It consists of reinforced concrete base resting on 0.10 m thick plain concrete. The reinforced concrete base has minimum dimensions 1 x 1 m and with sufficient height to surround and envelop the existing foundations at their intersections. Clean sand must be used for backfilling around foundations.

It is very important not to carry out the previously mentioned works allover the same house at the same time. The following repair works have to be done after the foundations are completely supported.

5.3 Repair Works

Thin and moderate cracks are filled with new effective filling material. Damaged walls must be removed and rebuilt again after considering the necessary safety precautions. All inspection chambers must be replaced by new chambers constructed of reinforced concrete base and walls acting as one unit and must be properly insolated. Compacted clean sand is placed under their bases and behind the side walls. Water and sewage lines must be inspected, repaired or replaced and coated by granular soil. Compacted clean sand layer with reasonable thickness must be placed under floor tiles. All buildings have to be surrounded by wide footpath with suitable outwards slope to avoid water accumulations. Grean areas must be irrigated by mechanical sprayers to avoid flooding. Maintenance works must be done regularly.

6. CONCLUSIONS AND RECOMMENDATIONS

This case reveals clearly that any shortage or lack in soil investigations leads to many troubles which waste time, effort and money to overcome. It is strongly recommended that for any new building, whatever its value or its size, soil must be thoroughly investigated allover the site. Field and laboratory tests have to be carried out carefully and the effect of water on soil behaviour under different stresses must be well recognized. The choice of suitable type of foundation and convenient structural system is very essential. Engineers must strictly apply the specifications and the code of practice during construction to avoid any future troubles.

7. REFERENCES

Hamza Associates, Consultants And Engineers, Dokky Street, Giza, Egypt.