# TECHNICAL NOTE

# FACTORS AFFECTING FOUNDATIONS IN RIYADH AREA

BY

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## INTRODUCTION

Building construction activity in the Riyadh area has increased enormously in recent years. More and more reinforced concrete structures with heavy foundation loads are planned and constructed on a scale unprecedented in the history of Riyadh. At the moment the subsoil information necessary for sound engineering treatment of foundations in the area, is scanty, if any. The authors discuss their experiences and some of the factors which affect the foundations in the area.

There is voluminous information of a general nature available in the literature for foundation treatments, but local factors should be studied individually and must be considered in any sound and economical foundation design. In this technical note, efforts are concentrated on discussing some of the important factors associated with this area. The information presented is not only valuable for sound engineering treatment of foundations but also it is hoped that this presentation will stimulate the thinking of local engineers to foresee the problems they are likely to encounter in the area and to solve them effectively.

This presentation is preliminary in nature and a prelude to a more comprehensive study of a wider scope.

## GENERALITIES

The area surrounding the city of Riyadh is generally rough with numerous mounds and shallow valleys. The whole plane rises gently towards North. Geologically the area is a sedimentary formation of shallow warm water deposits. There is very little rainfall and hence the area is devoid of natural vegetation. Low humidity and high temperatures with occasional sand storms are the prevailing phenomenon of the area. Most of the area is unchanged but is subjected to the intense weathering action of strong winds, high temperatures, and low humidity. The rainfall is mostly limited to a few storms of high intensity. The water flows with high velocity into the main valley eroding the silty aeolion deposits without seeping into the subsoil. Hence, there is not much of leaching action in the area. As a consequence, large concentrations of soluble salts having affinity to attack concrete are present in the subsoil.

## NATURE OF SUBSOIL

Due to its geology and the prevailing natural conditions, the subsoil can be broadly divided into four main zones of interest.

The top layer is mostly aeolian deposits, and mainly consists of silt and fine sand with a little gravel of calcareous origin. This layer is generally thin and only about half to one meter thick over most of areas.(1,2,4,5)However, in valleys these deposits can attain a thickness of several meters,(6)whereas they will be of negligible thickness over eroded areas.(1,4,5)These silt and fine sand deposits are loose and compressible and exhibit appreciable cohesion due to the presence of calcareous binder.(6)Vertical cuts of several meters can be made without shoring when these deposits are dry. But upon saturation they loose cohesion and collapse. Hence these deposits present difficult foundation problems wherever they exist to appreciable depths. Utmost caution must be exercised when designing foundations on this stratum. In the absence of any gravel and other solid constituents the bearing capacity for this stratum generally does not exceed one kg/cm$^2$. Even at such a low intensity of loading, settlements may be excessive(6)and detrimantal if these deposits are thick.

Below the aeolian deposits, zone two consists of a mixture of silt, sand, and gravel in varying proportions. With depth the stratum changes to highly weathered and disintegrated in situ limestone.(1,2,4,5) These two layers alternate to varying depths along-with thin layers of gypsum.(1,2)Depending on topography and other influencing factors this stratum may

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attain a thickness of two to four meters. Several field and laboratory tests were conducted on this stratum at different locations. Standard Penetration Tests carried out on this stratum gave consistently high blow counts indicating fairly high resistance to penetration and hence its compact characteristics. (2,4,5) Presently available data indicate that this stratum can be assigned an average bearing capacity of 3 kg/cm$^2$. These results were also substantiated by several field load tests carried out on this stratum. (4,5) The natural moisture content of the stratum during all field tests was within a range of 4% to 6%. The stratum is liable to soften when saturated with water. Hence, precautions are advisable against assigning a bearing capacity of 3 kg/cm$^2$ for this stratum if submerged conditions are anticipated. Morever high concentration of soluble sulphates having affinity to attack foundations are present within this stratum. (1, 2,3). Therefore, local site information must be obtained before planning any major foundations to rest on this stratum and necessary precautions must be taken against any alkali attacks.

Below zone two the underlaying zone three extends to several meters in thickness (2,3,6). This stratum mainly consists of fractured, weathered, and partially disintegrated limestone in a firm matrix. Due to intense weathering and chemical disintegration, it is not uniform in its constituents and composition. Within this stratum there are occasional thin layers of softer matrix of highly disintegrated limestone and sandstone. This soft matrix completely disintegrates and forms into a soft silty clay when immersed in water. Often the bedding planes are uneven and disrupted and there are pockets filled with calcite crystals and other impurities. The whole stratum though solid when dry, softens and loses appreciable strength when immersed in water (1,2,3).

Core samples from different locations within this stratum were subjected to unconfined compression tests in the laboratory. The results indicate fairly good compressive strength ranging from 86 kg/cm$^2$ to 550 kg/cm$^2$ for the specimens tested under dry conditions. (1,2,3) However, when the test specimens were submerged in water for 48 hours and then tested, the results show a marked decrease in compressive strength; sometimes more than 50% (1,3) Specimens from softer matrix layers completely disintegrated on submergence in water. (1,2,3) Due to nonhomogeneity and other influencing factors described earlier, it is difficult to assign an exact value for its bearing capacity. However, depending on the type of matrix, its constituents and texture, orientation of bedding planes, and extent of disintegration, the bearing capacity (1,2,3,4,5) for this stratum may range from 3 to 15 kg/cm$^2$. Detailed investigations are advisable before a definite value is assigned for its safe bearing capacity for the resting of heavy foundations. For minor structures this stratum offers a good and economical foundation solution with an allowable bearing capacity of 3 to 5 kg/cm$^2$, barring any unusual circumstances. Moreover, soluble sulphates do not exist in such a high concentrations as in zone three (1,2,3).

Lastly, at deeper depths below zone three and sometimes as an outcrop at shallow depths (1) there exists a thick layer of solid limestone. This stratum possesses excellent strength characteristics and is best suited for resting of all foundations. Several core samples from this strata, tested in the laboratory consistently gave very high values for compressive strength. The compressive strength for this stratum ranges between 700 kg/cm$^2$ to 1450 kg/cm$^2$ with negligible effects due to submergence in water. (1,2,3) This stratum possesses remarkably high strength and is unaffected both by water and soluble sulphates. In this zone, heavy foundations with loading upto 25 kg/cm$^2$ can be constructed with negligible elastic settlements, barring any unforeseen and unusual local circumstances. Whenever loads of such magnitude are planned, it is essential that a through and detailed investigation be conducted within the planned area and the results carefully analysed.

## CHEMICAL CORROSION OF FOUNDATIONS

Soluble salts and in particular soluble sulphates exist in high concentration in the overburden in most of the areas around Riyadh. (1,2,3,4) The soluble sulphates have great affinity to attack foundation concrete. (7, 11,13) Hence precautions to counteract the effect of their attack are necessary for the safety and durability of foundations. The high concentration of soluble sulphates in the area can be attributed to the twofold action of the natural phenomenon. Neither there has been any leaching out of these salts from the soil by rain and flooding, nor have these areas been subjected to plant activity which slowly assimilate sulphates from soils. (16,17) Sulphates in soils are formed by the process of oxidation due to the activity of numerous micro-organisms on more reduced form of sulphur present in the soil. (16,17).

Due to the recycling process in nature, animals in turn utilize plants and the wastes are returned to earth. In particular, water from pits will produce and release hydrogen sulphide under high temperatures which in turn attacks foundation concrete and steel.9,10,12,16,19

The attack on foundation concrete in Riyadh area is two pronged; by soluble sulphates present in the overburden and by hydrogen sulphide released by soak pit water. Salts in solid form do not generally attack concrete,9 but in solution, being dissolved in water, will react aggressively on concrete.8,9 The chemical reactions between sulphates and concrete can be represented as follows:

$Ca(OH)_2+Na_2SO_4.10H_2O \ldots \rightarrow CaSO_4.2H_2O+2NaOH+8H_2O$

$2(3CaO.Al_2O_3.12H_2O)+3(Na_2SO_4.10H_2O) \ldots$
$3CaO.Al_2O_3.3CaSO_4.31H_2O+2Al(OH)_3+6NaOH+17H_2O$

$3CaO.2SiO_2.aq+MgSO_4.7H_2O \ldots \rightarrow CaSO_4.2H_2O+Mh(OH)_2+2SiO_2aq$

The end products of these reactions have considerably greater volume than the original compounds they replace.(9,10) The result is expansion and disruption of concrete and corrosion of steel. The magnitude and relative degree of attack by sulphates from soils and water on foundation concrete and steel have been extensively studied and recommendations are available in the literature. (7 to 19)

Subsoil investigations carried at various places around Riyadh, indicate high concentration of soluble sulphates upto 0.88% by weight in soil samples(1,2,3) from zone two and upto 2600 ppm in water samples(6) from subsoil in certain localities. Although the values quoted are the highest among the several values for the areas, 20% of the mean of the highest values is generally considered as a guide for sulphate concentration in the area.(14) The average concentration of sulphates in many areas investigated so far indicate that severe attack of foundation concrete is a high probability. Moreover, due to lack of central sewage system individual soak pits are common in Riyadh. The water from soak pits and leaking mains form a temporary water table of a false nature in zone two as it cannot seep through the harder limestone of low permeability underneath. 2,4 This water is toxic in nature mainly from soak pits and it not only helps to dissolve the soluble sulphate present in the soil but also releases hydrogen sulphide under high temperatures. In presence of moisture, hydrogen sulphide dissolves in water forming weak sulphuric acid which is highly corrosive both on foundation concrete and steel.(12,17) Climatic, geological, and environmental conditions in the Riyadh area favour the attack of soluble sulphates on foundation concrete and steel, and hence precautions to counteract their effects are necessary for safety, stability, and durability of all foundations in the area.

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