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## Salt of the Earth

Having a good knowledge of potential geotechnical hazards in a project area is of great value in the early design phases of a project, so that medium to high risks can be investigated and mitigation measures put in place or agreed upon early on. In this article, I discuss two common geotechnical hazards I encountered on project sites in Abu Dhabi –

- Highly saline superficial soil layer
- Gypsum Degeneration

The Emirate of Abu Dhabi has the largest landmass in the UAE and the underlying geology is the most complex. The general geology in the Abu Dhabi region is composed of superficial soils, which may range from reclaimed or natural sands to alluvial soils, overlying the mudstone rock formations. Within the mudstone, bands of gypsum are occasionally encountered.

Natural superficial soils along the coastline of the Emirate are known to contain high concentrations of saline minerals that have developed in areas where hard rock lies below the groundwater table, allowing water to remain close to the surface where it is susceptible to evaporation. Flooding from the highly saline Arabian Gulf during high tide and the intensive evaporation of these flood waters due to high temperatures result in the precipitation of soluble salts within the shallow soils. Concentrations of soluble salts as high as 15-20% have been observed.

When these superficial soils are subjected to an inundation of water from heavy rainfall, leaking pipelines, or continuous wetting from irrigation, the soluble salts dissolve. Depending on the concentration of salt, this may lead to subsidence being observed on the ground surface.

Another potential geotechnical hazard that has been identified in the Abu Dhabi region is the degeneration of the gypsum layers and the consequent formation of small to medium-sized cavities (known as vugs) and large cavities within the rock formation. Gypsum is a moderately soluble mineral, and the formation of new cavities may take many years. Due to the protracted period of formation, occurrences of cavities are rare but have been observed in some areas of Abu Dhabi, such as Zayed City, Khalifa City, Shakbout, Al Falah, and Al Shamkha.

The impact of the presence of cavities and vugs increases with size, however, deep-seated cavities are likely to have a lesser impact than those found at a shallower depth. Most cavities encountered are minor, and due to the bulking of collapsed material collecting in the small void, this results in low impact in situations where there is a migration of subsidence extending to the surface. However, large cavities have also been observed

in certain areas in Abu Dhabi which can result in a more significant impact.

In recent years, a significant number of incidents of structural damage have been observed on roads, infrastructure, and buildings in newly developed areas. These have been attributed to either the solution of soluble salts in the superficial soils or the presence of pre-existing cavities.

The Abu Dhabi Municipality (ADM) Infrastructure Section now reviews and approves the scope of work for all ground investigations for new developments. Some of the must-haves are:

1. The requirement for water soluble salt content tests to assess the concentration of soluble salts in the superficial soils above the water table, including the capillary zone, and;
2. Geophysical Survey to verify the presence of pre-existing cavities within the underlying Rock Formation.

Where investigations indicate concerning results, mitigation measures must be specified during the design approval stage of the project. These measures may significantly increase the cost of construction and may also lead to construction delays if not considered at an early stage in the design.

The ADM also recommends measures to be adopted for different ranges of concentrations of soluble salts. A summary of the recommended mitigation measures is presented in the table below.

Soluble Sal Concentration (%)	Mitigation
<2%	Do Nothing
3%-5%	Use Geogrid below the pavement layers above the subgrade layers
>5%	To be agreed with ADM.

Note: The above table is for Roads and Infrastructure projects only.

Occasionally, where the high-salt concentration soil layer is shallow, excavation and replacement of this material may be a more viable option. However, for deeper layers, due to the impracticality and/or elevated costs of this process, a long-term maintenance approach may be a more palatable option (subject to ADM agreement).

The Building Section of the ADM does not define remedial measures or construction solution requirements, but it is not unusual for consultants to recommend that where buildings are to be founded on soils with high soluble salt contents, they should be supported on piled foundations. This may appear to

be excessive for low to medium rise buildings, however, alternative approaches including pre-inundation of the site, may be explored to ensure that the building is not undermined during a flood event.

Where a cavity is detected during a ground investigation, further investigation (for example, verification boreholes) to assess its size and geometry is usually recommended. Grouting of large-sized cavities may be required, which can result in a significant increase in the construction cost and time. Whatever the development, it is recommended that funds be kept in the project “Risk” pot to alleviate the costs of remediation.

Where failures are observed on completed projects, a dispute often arises between parties as to the cause of the failure. In these circumstances, independent experts are appointed to opine on whether the failures are due to these natural phenomena, poor design, or poor construction work. Disputes may be easier to resolve under a Design and Build contract than under a construction-only contract. In a design and build contract, the risk remains with the contractor and its designer, and any ensuing issues must be remediated by the contractor. However, in a construction-only contract, it is usually difficult to separate subsidence from poor construction practices or from poor design if the design has not given due consideration to these phenomena.