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Engineering geological evaluation and zoning of bearing capacity of Gypsum soils in the Gachsaran formation using SPT test results on Masjed Soleyman Petrochemical site

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Abstract

Gypsum soils are among the most complex and problematic soil types due to their high solubility and the limited understanding of their engineering behavior. This study addresses these limitations by developing detailed bearing capacity zoning maps at 1.5-meter depth intervals down to the groundwater table, using SPT test results from over 80 boreholes drilled at the Masjed Soleyman Petrochemical site. The maps were compared to the level and direction of underground water flow obtained from EDP tests, as well as to the regional gypsum karst map, which was created using a combination of geophysical (GPR) and geotechnical (boreholes) methods. This comparison helps identify potential project locations and provides insight into the region's suitability for project implementation. In the second step, the study area was divided into two distinct regions by conducting laboratory and in-situ (including 6 PLT tests under both dry and saturated conditions) soil mechanics tests, and integration results with geological data and the locations of sensitive facilities to determine the allowable bearing capacity of single and mat foundations (regarding shear strength of the soil), calculated for each region. The combination of SPT data, the uniformity of subsurface layers, and correlations between bearing capacity and karst development maps indicate that variations in bearing capacity are mainly controlled by weak interlayers and by the dissolution and leaching of gypsum. Over time, these processes lead to the formation of gypsum karsts, representing a major geotechnical hazard and the most critical factor affecting the stability and suitability of the region for construction.

Keywords: *Bearing capacity, gypsum soils, Masjed Soleyman petrochemical, SPT test, Gachsaran Formation*

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Extended Abstract:

1. Introduction

Gypsum can negatively impact engineering structures if soil deformation is not properly assessed, potentially leading to failure (Al-Sauodi et al., 2013). Although gypsum soils have good dry strength, wet conditions caused by rainfall or groundwater changes dissolve salts and gypsum, creating pores and weakening soil bonds (Fauziah et al., 2012; Al-Sauodi et al., 2013). Therefore, evaluating the engineering behavior of gypsum soils is challenging, as they must support structural loads without shear failure and keep settlements within acceptable limits. This study used data including 80 with in-situ SPT, plate load test (6 test in dry and saturated condition), and laboratory tests, evaluating and zonation the allowabale bearing capacity of the Masjed Soleyman Petrochemical Plant in the Gachsaran Formation and its relation to gypsum karsts and groundwater flow.

2. Materials and methods

In this study, A total of 113 boreholes, 20–40 m deep, were drilled across the 510,000 m² Masjed Soleyman petrochemical site to study subsurface geology and materials. Boreholes data were analyzed using RockWorks and ArcGIS to generate geological profiles and identify the subsurface geology strata where in situ SPT testing was conducted. Standard Penetration Tests were then performed in 80 boreholes at 1.5 m intervals following ASTM D-1586 to evaluate the bearing capacity of gypsum layers in the Gachsaran Formation. SPT sections and bearing capacity zoning maps were created at 1.5 m intervals using Bowels (2001) relations in ArcGIS. The results were analysed using geological data, including groundwater levels, flow directions, and gypsum karst maps. In the second step, the bearing capacity was evaluated, and zonation was performed using Hansen's (1970) equation for various footings. This evaluation was based on three components: (1) laboratory soil tests (including gradation, Atterberg limits, specific gravity, and direct shear tests conducted according to ASTM standards), (2) in-situ plate load tests (ASTM D1195), and (3) in-well geophysical tests (ASTM D7400). Additionally, subsurface geology and the locations of sensitive petrochemical infrastructure were taken into account.

3. Tests results

Geological profiles and subsurface maps at 1.5 m SPT intervals show that gypsum deposits in the Gachsaran Formation have a complex spatial distribution. The site's main materials are silt and clay with gypsum, gradually transitioning to gypsum rock with depth. Bedrock depth ranges from <10 m in the southwest to >20 m in the northwest and 10–20 m in the center. Electric depth probe (EDP) tests indicate a complex groundwater flow, with the water table at 9–10 m below the surface.

Drilling and GPR studies was identified 32 gypsum karsts, with over 23 located below the groundwater level and aligned with its flow, highlighting the strong influence of groundwater. Most karsts around 15 m depth in gypsum rock. SPT tests show the site's soils is predominantly hard to very hard when dry (Murthy, 2007; Rogers, 2006). Bearing capacity zoning maps were generated at 1.5 m intervals down to 10.5 m using RockWorks and ArcGIS (Fig1-A, B, and C) , and relation between depth and capacity bearing were compared in ArcScene (Fig 1-D). Integrating gypsum karst and groundwater maps showed that bearing capacity is influenced by groundwater fluctuations, karst presence, and the complex layering of the Gachsaran Formation. Because SPT calculations account for pore water pressure, the bearing capacity is adjusted accordingly. Results indicate that capacity generally increases with depth (Fig-1, D, E), although gypsum karsts create localized zones of low capacity (Fig 1, B, C and F).

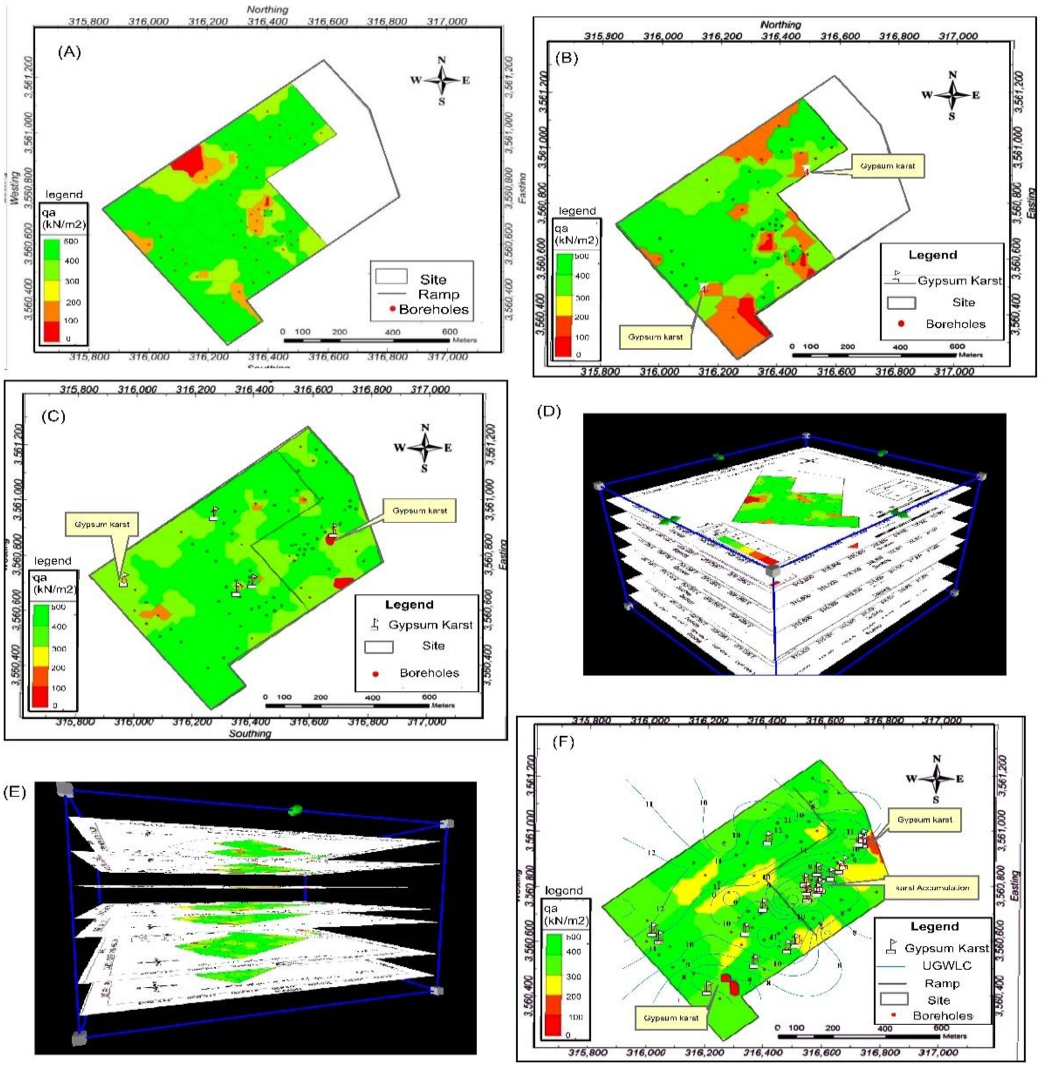

Fig 1. (A) Zoning map showing bearing capacity at a depth of 1.5 m below ground level, (B) Implementation of a digital map of gypsum karsts identified at a depth of 4 meters on a zoning map that shows the bearing capacity at a depth of 4.5 meters below the ground surface, (C) Implementation of a digital map of gypsum karsts identified at a depth of 7-8 meters on a zoning map that shows the bearing capacity at a depth of 7.5 meters below the ground surface, (D) Process of importing bearing capacity maps into Arc Scene 10.5 software, (E) Analysis of changes in bearing capacity with depth in the study area, and (F) Zoning map of bearing capacity changes at the groundwater level, showing the location of gypsum karsts and their depth below the groundwater level.

To improve bearing capacity estimation, data from laboratory tests, field soil mechanics tests, geophysical surveys, and the locations of sensitive petrochemical facilities were integrated. The study area was divided into two zones (Figure 2), and the allowable bearing capacity of each was evaluated to support structural design and placement.

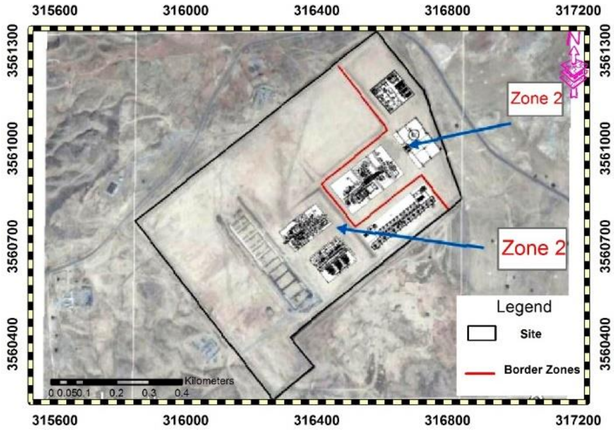

Fig 2. Petrochemical site zoning by geotechnical factors and location of sensitive structures

4. Conclusion

Drilling results show highly variable subsurface layering of clay, silt, gypsum, and gypsum rock at the Masjed Soleyman site. Plate load tests under saturated conditions revealed high settlements in silty pits (PL3 and PLT4) due to sliding of grains, collapse of voids, and increased porosity from gypsum dissolution, which can lead to significant deformation or failure beneath foundations and foots. Bearing capacity analysis for square, strip, and mat foundations shows that Zone 2 has higher capacity than Zone 1, mainly due to deeper gypsum karsts and layers of crushed gypsum and anhydrite, with groundwater at 9–10 m depth. Numerical modeling is still required to evaluate how the characteristics of subsurface gypsum karsts affect bearing capacity.

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