Geotechnical site characterization challenges on energy transmission lines – a case study

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1 Introduction

Geotechnical site characterization studies are conducted either on polygon-based or alignment-based scale. In parcel-based investigations, the classification of potential geohazards might be determined as relatively straightforward. Accordingly, mitigation measures can be identified rapidly based on the site-specific conditions.

Alignment-based characterization is generally applied in transportation projects such as highways, railways, overhead transmission lines (OHTL). In alignment-based investigations, the variability of site conditions constitutes a significant factor that complicates the creation of an idealized soil scenario. While polygon-based characterizations can be carried out using a limited number of idealized soil profiles, alignment characterizations require consideration of numerous varying cases, including lithological heterogeneity, seismicity and groundwater presence. For this reason, alignment-based investigations are subdivided into distinct sections (lots) based on a principle that prioritizes geological conditions as the underlying framework [1]. In addition to the geological background, the locations of structures along the corridor are also taken into account in the determination of subzones. Location of structures such as culverts, viaducts, tunnels, ground investigations are scheduled, and reporting activities are conducted accordingly.

Site characterization of electrical transmission lines, the indicated cases are inherently more complex. Different from the polygon-based infrastructure projects, it is not feasible to plan site investigations or focus reporting efforts solely based on the locations of individual structures along the alignment. This is primarily because geotechnical and geophysical evaluations must be conducted at every investigation point beneath each tower installed along the corridor. Considering that transmission towers are typically spaced at intervals of approximately 350–500 m depending on the line capacity, and that transmission corridors may extend over hundreds of kilometres, this results in thousands of meters of boreholes and tens of thousands of laboratory test results. Idealized subsurface profiles derived using conventional investigation approaches, together with simplified lithological continuity assumptions and generalized engineering interpretations, may therefore fail to capture local subsurface anomalies and overlook critical geohazard risks along the investigation corridor. In this aspect, reliability-based design approaches may provide accurate and time-saving solutions for characterization works [2, 3].

Within the scope of this study, site characterization activities for a proposed overhead transmission line in Uzbekistan are presented, with a particular focus on integrated geotechnical and geophysical investigations. The procedures adopted for the geotechnical and geophysical evaluation of subsurface conditions, associated interpretation methodologies, and the development of a database to support engineering assessment are described in detail. Furthermore, the application of geospatial trend analysis techniques for the visualization and presentation of site characterization results is discussed. The study also addresses methodologies for identifying the presence of loose and soft soil deposits, together with mapping approaches aimed at supporting construction planning, illustrated through representative examples.

2 Project description

The project scope covers the geotechnical and geophysical characterization of a 500 kV capacity OHTL with 343 km approximate length. Site investigation scope includes drilling ≈ 900 proposed boreholes and 8700 m drilling depth with 870 Vertical Electrical Sounding (VES) surveys for each transmission tower. Additionally, sampling procedures are carried out for laboratory tests including mechanical, physical and chemical properties of subsurface deposits. Maximum individual drilling depth for each borehole is proposed as 10.0 m. Considering the length of the alignment, variable constraints per site conditions shall be considered. different geological settling, river crossings, hilly terrains, agricultural lands, thick alluvial deposits, high groundwater level, presence saturated loose & soft deposits, high seismicity are the main contradictions. Hence, inadequate bearing capacity due to soft soil deposits, liquefaction, slope instability, dewatering & sheeting needs, collapsibility, hard rock presence, chemically aggressive subsurface layers can be classified as main obstacles affecting different regions within the corridor [4]. The simplified layout for the project area is presented in Figure 1.

In order to perform accurate interpretation, OHTL alignment is divided into individual lots by considering;

- Geological settling,
- Geohazard potential,
- Geomorphological constraints,

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Figure 1. OHTL Alignment.

3 Creation of database

Heim et. al. [1] indicated that, a spreadsheet database documenting samples taken during the geotechnical investigation including the depth, material classification and corrected SPT blow count is an efficient way for determining zone boundaries and detect the anomalies regarding geohazard potential. Once the database is assembled, borings within geologically similar soil zones are grouped. Considering that OHTL towers will be supported by individual spread footings, geotechnical design can be carried out by acquisition of corrected SPT blow counts for each borehole. Additionally, laboratory test results will be combined with SPT ranges to identify geotechnical design parameters as location-based. In any case, average SPT values for boreholes are calculated and presented in histogram form with groundwater presence for same boreholes. For the evaluated investigation corridor covering Tower: 1 to 89 (Figure 2), following site conditions are observed:

- Geological Settling: Alluvial soft deposits in form of loose sandy silts and silty sands, regional presence of shallow groundwater after Tower: 29
- Potential geohazards: Insufficient bearing capacity, presence of saturated soft clays& silts, excessive settlements
- Groundwater regime: Shallow groundwater levels might lead to challenging submerged excavation for construction works.
- Chemical properties: Agricultural lands and saturated soft fine-grained soils might be a hint for aggressive soil conditions per corrosivity and presence of excessive organic content.

Regarding to site conditions described above, strength characteristics based on average SPT-N60 and GWL level is given in Figure 3. SPT-N60 values show significant decrease after GWL presence along investigation depth.

Figure 2. Layout for project area (Tower: 1-89).

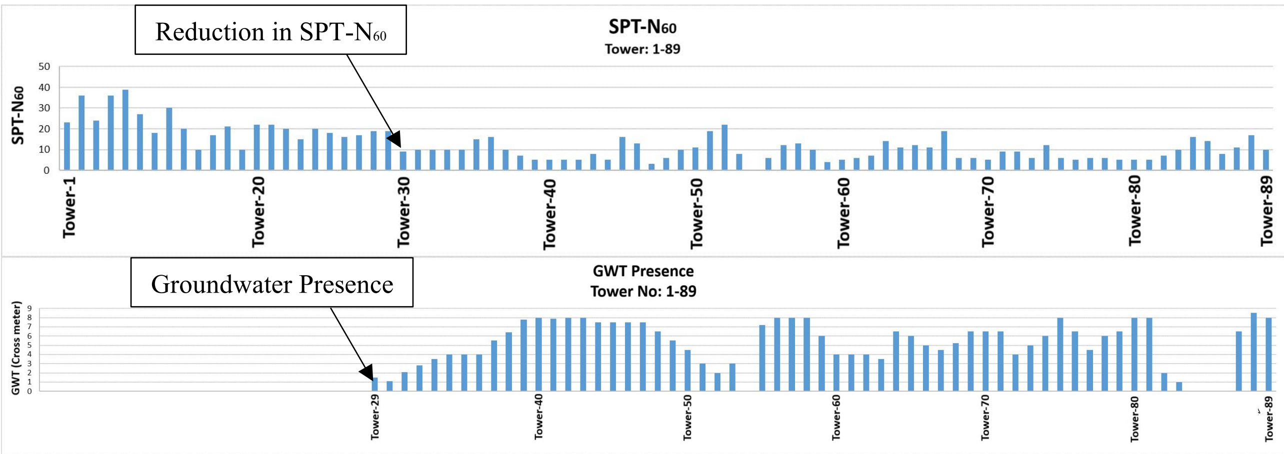

Figure 3. SPT-N_{60} – GWT histograms.

4 Interpretation and mapping studies

As described in the previous sections, the OHTL towers will be constructed on spread footings. Hence, maximum bearing pressures below the footings are calculated by considering both ultimate bearing capacity and maximum allowable settlement (s= 25 mm) cases. The minimum of these values is considered as maximum bearing capacity for individual tower footings. For the spread footings having width higher than 1.0 m, settlement controls the maximum bearing pressure on coarse-grained deposits [5]. Hence, immediate settlement analysis are performed to determine bearing pressures. For fine-grained deposits, SPT-N based ultimate bearing capacity formula for undrained conditions are checked. Additionally, maximum bearing pressure value creating allowable settlement is calculated. Different from the coarse-grained deposits, immediate (elastic) and consolidation settlement components are considered by using numerical analysis software. The minimum of these values is used.

By using tower-based bearing pressure values, results are processed by geospatial trend analysis in Surfer software. As a result, maximum bearing pressure heatmap is produced for each lot. The heatmap shows the local anomalies and location of the loose deposits along the investigation corridor represented by low bearing capacity values (See Figure 4).

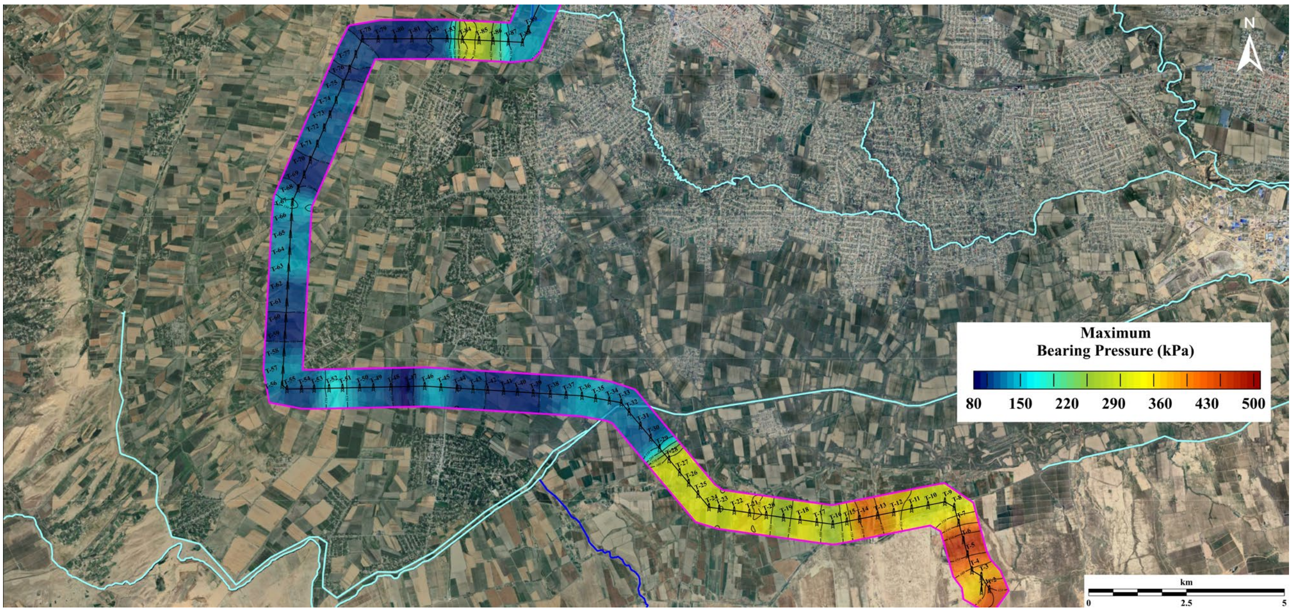

Figure 4. Bearing capacity heatmap (Tower:1-89).

Additionally, heatmaps of resistivity ranges are produced based on the Vertical Electrical Sounding (VES) survey results. Average resistivity values for the top 5.0 m below the natural ground surface are calculated. Considering that low resistivity values in near-surface layers, particularly in agricultural soils, may reflect chemically aggressive conditions associated with soil texture, moisture, salinity, and organic matter content [6] The VES results are used for the selection of the appropriate cement class for construction activities (see Figure 5).

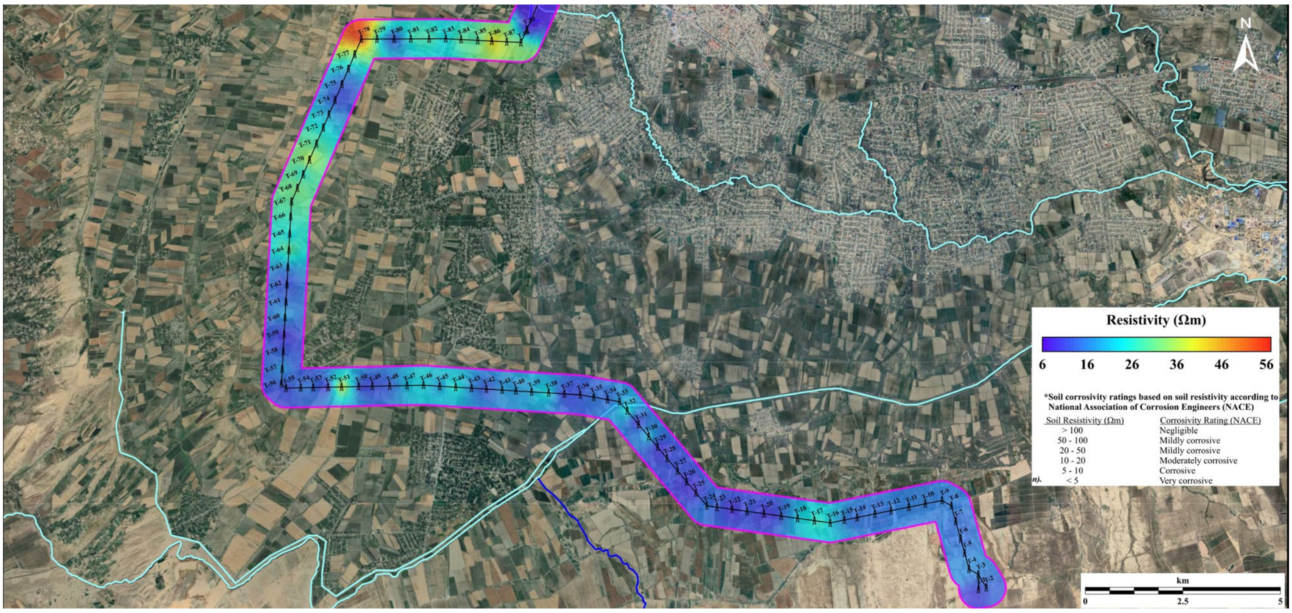

Figure 5. Resistivity heatmap (Tower:1-89).

5 Results and conclusions

Within the scope of this study, geotechnical and geophysical site characterization studies for OHTL constructions are evaluated based on a case study held in Uzbekistan. Different from polygon-based characterizations, alignment characterizations require consideration of numerous varying cases, including lithological heterogeneity, seismicity and groundwater presence. Hence, alignments are divided into individual lots for accurate characterization by considering different types of geohazard cases such as inadequate bearing capacity, groundwater presence, topographical constraints etc.

For proper interpretation, creation of investigation database is mandatory for such projects including huge amounts of site& laboratory data. Examples from issued case history are presented including average SPT-N_{60} ranges and groundwater table levels in histogram form. Eventually, geotechnical and geophysical interpretation examples including bearing capacity calculation for towers and resistivity ranges acquisition are presented. Geospatial trend analysis processed by Surfer software is used to produce heatmaps showing resistivity and bearing capacity ranges. Even if the heatmaps offer user-friendly outputs, the reliability of the maps is strictly based on the proper interpolation method and convenient database per aim of the study [7]. Eventually, geotechnical and geophysical characterization of problematic soils are critical for alignment-type projects such as highways, railways and OHTLs. Integration of GIS-based data visualization tools and interpretation methods are crucial to detect anomalies for further construction activities.

References

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