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Analysis of the Technical Feasibility of Future Civil Works Focused On the Geological and Geotechnical State in the Area of Punzara, Canton Loja

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Abstract **-** The main objective of this study is to assess the technical feasibility of undertaking future civil construction projects in an area with complex geological conditions. Specific objectives include determining the dynamics of slope movements in the area, developing a geological-geotechnical guide to guide the design of future works, and assessing the suitability of the soil to support construction. The methodology applied combined high-precision topographic survey techniques, extensive field observations, and the analysis of satellite images of the area. This allowed detailed measurements of horizontal and vertical displacements, as well as the execution of in-situ geotechnical tests such as SPT and triaxial compression tests in the laboratory. The results obtained highlight the varied geology of the site, with soils showing notable differences in their cohesion and internal friction properties. Analysis of the ground movement patterns reveals a combination of upward and downward trends, with most of the monitored points experiencing slow but steady displacements. The geotechnical studies conclude that, despite the complexity of the subsoil conditions, the area is technically feasible to accommodate future construction works, provided that adequate foundations, such as spread footings, are implemented, the design of which takes into account the bearing capacities of the soil and the geological particularities of each sector. This work provides practical recommendations based on the findings, to guide the development of future infrastructure projects in this area of high geological complexity, thus contributing to minimizing the risks and optimizing the results of construction interventions.

Keywords**:** Technical feasibility - Slope movements - Geological-geotechnical guidance - Soil suitability - Geotechnical testing.

1. Introduction

The planning and execution of civil works require a thorough analysis of the geological and geotechnical conditions of the terrain where the projects will be located. This is essential to ensure the technical feasibility and long-term stability of the constructions. In the particular case of the area of Punzara, canton Loja, the general objective of this work is to analyze the technical feasibility of future constructions, focusing specifically on the geological and geotechnical state of the terrain. To this end, it is proposed to determine the dynamics of slope movements, develop a geological-geotechnical guide for future works, and define whether the study area is suitable for the implementation of projects, based on the diagnosis of the soil. The analysis of technical feasibility is essential to ensure the stability and safety of constructions, as well as to adequately guide urban development and infrastructure planning in this region. [1]

2. Methodology

The analysis of the geological and geotechnical conditions of the terrain is fundamental for the planning and execution of civil works, as it makes it possible to determine the technical feasibility and evaluate the long-term stability of the constructions. The main objective of this research is to analyze the technical feasibility of the implementation of civil works in the area of Punzara, canton Loja, focusing on the diagnosis of the geological and geotechnical state of the terrain. To this end, a comprehensive methodology was implemented that included geological-structural mapping, geodetic monitoring, geotechnical investigation, and laboratory analysis. The results obtained allowed the elaboration of a geotechnical map and the evaluation of the suitability of the terrain to support future works, as well as the generation of a geological-geotechnical guide with recommendations and design criteria for the study area. [2]

2.1. Geological-geotechnical survey and characterization of the study área

The reconnaissance of the area began with the analysis of Google Earth satellite images to observe the different accesses to the area. Subsequently, a field visit was made to observe the current state of the urbanization, the outcropping lithologies, the number of houses built, the areas at greatest risk, the state of the pavement, and the predominant lithologies in the study polygon, which belongs to the Quillollaco geological formation. [3]

2.2. Exploratory field phase

2.2.1 Lithological Map

A topographic map was generated at a scale of 1:2500 using ArcGIS software and the digital terrain model of the city of Loja. Then, a lithological and structural survey was carried out in the field, recording the information on cards for each outcrop. These data were placed on the topographic map and the lithologies were differentiated with colored pencils. Finally, this field information was digitized in ArcGIS to generate the lithological map at a scale of 1:2500. [4]

2.2.1 Differential GPS monitoring

Eighteen strategic points were located within the development and on the side road, considering the geological characteristics, for differential GPS monitoring. These points were selected in areas prone to hazards such as fractures, pavement uplifts, and small landslides.

2.2.1 Geotechnical characterization

Four 5 to 6-meter-deep percussion borings were distributed within the development, where Standard Penetration Tests (SPT) were performed every 1 meter, following ASTM D-1586. Disturbed samples were obtained from each meter of drilling and were identified and described according to ASTM D-2488. [5]

2.3. Laboratory phase

2.3.1 USCS

With the samples recovered from the boreholes, the necessary tests were carried out for soil classification according to the Unified Soil Classification System (SUCS), following the corresponding ASTM standards for granulometric analysis, moisture content, and Atterberg limits.

2.3.2 Shear strength

To obtain the shear strength values of the soil, the UU triaxial compression test was carried out following ASTM D-2850. Due to the natural conditions of the samples, a pre-treatment was necessary to remold and compact it adequately before the test. [6]

2.4 Cabinet Phase

2.4.1 Geotechnical Map

For the elaboration of the geotechnical map, the cohesion and friction data obtained from the tests of the 4 boreholes carried out were used. With this information, effective zones were delimited around each borehole point, covering the entire project area. Then, the bearing capacity of the soil at the boreholes was calculated using the formula proposed by Meyerhof, considering the number of SPT blows. These data on capacity, friction angle, and soil cohesion were used to analyze the dimensions and type of foundation suitable for supporting the loads. A standard three-story house was designed and the total area, dead and live loads, column size, and foundation design were calculated, verifying that the pressures do not exceed the bearing capacity of the soil. [7]

3. Results and Discussions

The lithological map prepared at a scale of 1:2500 shows that the study area belongs to the Quillollaco geological formation, predominantly characterized by thick clastic-supported conglomerates in a sandy matrix, intercalated with metric lenses of sandstones. Five main lithological units were identified within the area: alluvial deposits, clay-loam deposits, sandy siltstone, conglomerate with sandy siltstone matrix, and conglomerate with sand and clay lenses. Differential GPS monitoring A network of 18 monitoring points strategically distributed in the study area was established, recording their three-dimensional coordinates every 15 days for 4 months. The monitoring results show millimetric displacements in some points, mainly in those located in areas with greater geological instability. [8]

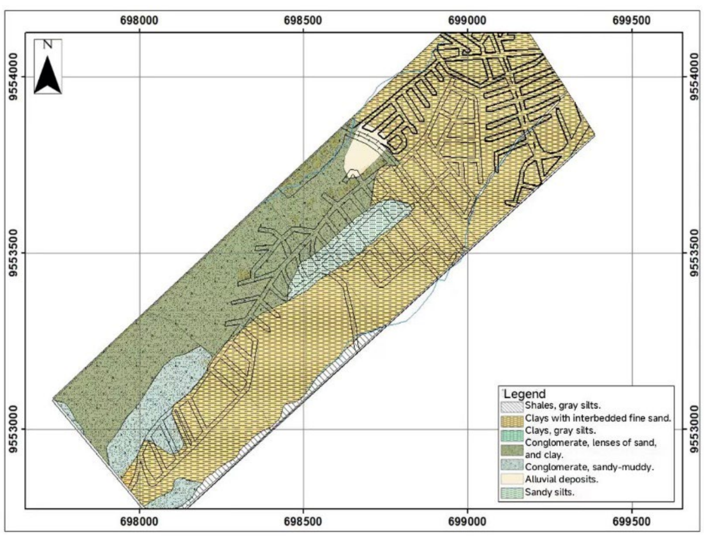

Fig 1. Lithological map

The analysis of the displacements showed positive and negative values. The majority of the points do not exceed 1 meter in horizontal displacement (E-N), except points 1 and 5, which show values of 1.16 m and 1.09 m respectively. As for vertical displacement (Z), 10 points show values below 1 meter, while points 1, 5, and 7 have higher values, reaching 3.83 m, 3.80 m, and 2.35 m respectively. The 18 monitored points show vertical and horizontal deformation, with points 5 and 7 standing out with the highest values in horizontal deformation of 3.79 m and 2.34 m respectively. After SPT tests and laboratory analysis, the bearing capacities of the soils in each of the four boreholes were determined. These results served as the basis for the design of the recommended foundation for a future 3-story house. [9]

Fig 2. Location of the monitoring points

Table 1. Displacements, vectors, effective deformation, and motion analysis

Displacement			Displacement vector		Effective deformation		Analysis	
E (m)	N (m)	Z (m)	E-n (m)	Z (m)	E-n (m)	Z (m)	Vertical Deformation	Horizontal Deformation
0.530	1.042	3.839	1.169	3.839	1.164	3.832	Movement	Movement
0.125	0.010	0.155	0.125	0.155	0.120	0.148	Movement	Movement
0.095	0.015	0.124	0.096	0.124	0.091	0.117	Movement	Movement
0.049	-0.047	-0.016	0.068	-0.016	0.063	-0.023	Movement	Movement
0.635	0.889	3.800	1.092	3.8	1.087	3.793	Movement	Movement
-0.114	0.106	-1.515	0.156	-1.515	0.151	-1.522	Movement	Movement
-0.009	0.297	2.354	0.297	2.354	0.292	2.347	Movement	Movement
0.128	-0.050	-0.473	0.137	-0.473	0.132	-0.48	Movement	Movement
0.045	0.088	0.232	0.099	0.232	0.094	0.225	Movement	Movement
-0.282	0.306	1.589	0.416	1.589	0.411	1.582	Movement	Movement
0.120	0.007	-0.047	0.120	-0.047	0.115	-0.054	Movement	Movement
0.119	0.051	0.012	0.129	0.012	0.124	0.005	Movement	Movement

0.122	0.000	-0.035	0.122	-0.035	0.117	-0.042	Movement	Movement
-0.664	0.528	1.675	0.848	1.675	0.843	1.668	Movement	Movement
0.060	0.011	-0.081	0.061	-0.081	0.056	-0.088	Movement	Movement
0.072	0.012	0.043	0.073	0.043	0.068	0.036	Movement	Movement
0.126	0.026	0.060	0.129	0.06	0.124	0.053	Movement	Movement
0.436	0.789	4.114	0.901	4.114	0.896	4.107	Movement	Movement

For borehole 1, a square spread footing of 1.3 m wide and 1.5 m depth is proposed, which would support a bearing capacity of 712.60 t, an ultimate load of 421.66 t/m² and an allowable load of 14.06 t/m². For borehole 2, a square spread footing of 1.5 m wide and 1.5 m depth is recommended, with a bearing capacity of 115.46 t, an ultimate load of 80.18 t/m² and a permissible load of 2.67 t/m². For borehole 3, a square spread footing of 1.0 m wide and 1.5 m depth is suggested, which would support a bearing capacity of 409.15 t, an ultimate load of 409.15 t/m², and a permissible load of 13.64 t/m².

Finally, in borehole 4, a square spread footing of 1.10 m wide and 1.5 m depth is proposed, with a bearing capacity of 84.96 t, an ultimate load of 70.21 t/m² and an allowable load of 2.34 t/m². These foundation design recommendations are based on the geotechnical parameters obtained in the field and laboratory studies and will serve as a guide for the structural design of the house, ensuring the stability and safety of the construction.[10]

Analysis of the information gathered shows that the area studied has predominantly clay and sand deposits, with variations in humidity, compactness, and consistency. At certain points, a shallow water table and supersaturated soils can be observed, which has generated stability problems in the sector, evidenced by openings, subsidence, and displacements in the pavement. Based on these findings, the area has been zoned into four specific sectors: the green area, designated as a non-buildable zone due to its high water table and low admissible soil capacity (2.67 t/m²); a prohibited zone for construction near streams, where current regulations do not allow building; a low-risk construction area, suitable for single-family dwellings of up to three floors with an admissible capacity of 13. 64 t/m² which requires soil improvement; and, finally, a medium risk area, suitable for buildings of similar characteristics but which requires greater soil improvement (50 cm) and robust foundations, as it presents subsidence and elevations in the pavement, with an admissible capacity of 14.64 t/m². [11]

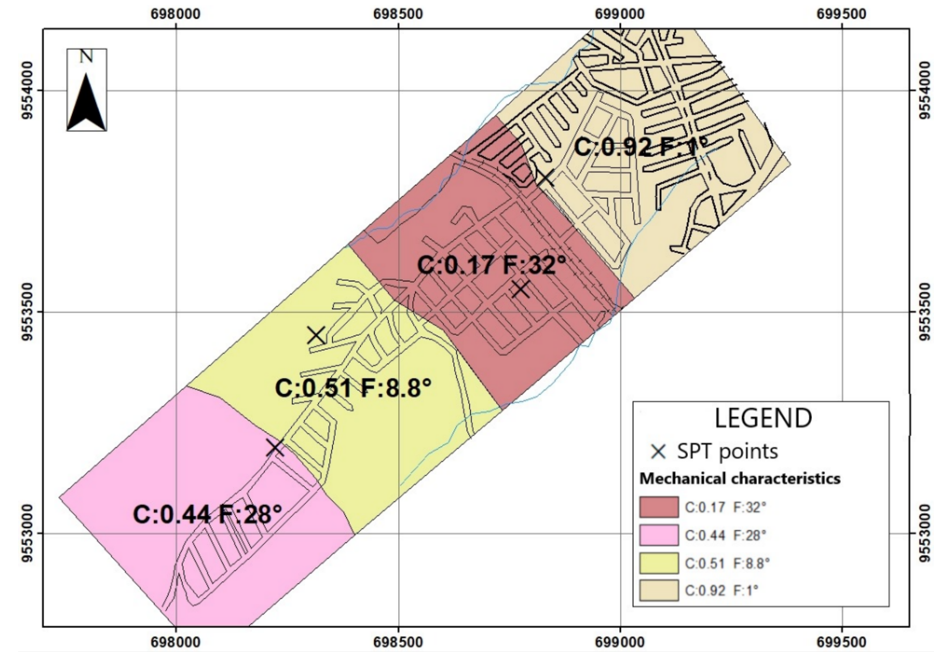

Fig 3. Geotechnical map

Table 2. Carrying capacities of the different boreholes

Soil bearing capacities					
Survey	Depth (m)	N spt	B (2m)	B (3m)	Average (t/m^2)
S-1	4.45	19	25.24	21.78	23.51
	5.00	26	34.53	29.80	32.17
	5.45	21	27.89	24.07	25.98
S-2	4.45	18	23.91	20.63	22.27
	5.45	18	23.91	20.63	22.27
S-3	4.00	14	33.21	28.66	30.93
	4.45	13	30.55	26.36	28.46
S-4	4.00	10	29.22	25.22	27.22

4. Conclusions

The study area, belonging to the Quillollaco geological formation, has a complex lithological composition, characterized by thick clastic-supported conglomerates in a sandy matrix, with intercalations of metric lenses of sandstones. Five main lithological units were identified, revealing the geological diversity of the area.

Differential GPS monitoring revealed significant millimeter displacements, with critical points showing horizontal movements of up to 1.16 m and vertical movements of up to 3.83 m. These results indicate a marked instability in the area. These results indicate a marked geological instability that potentially compromises the viability of civil works without preventive interventions.

The geotechnical zoning allowed the identification of four sectors with differentiated characteristics: a non-buildable green area, a prohibited zone near streams, a low-risk construction area for single-family homes, and a medium-risk zone requiring soil improvement. This classification shows the heterogeneity of the terrain and the need for specific interventions.

The borehole surveys revealed significant variability in the bearing capacity of the soil, ranging from 2.34 t/m^2 to 14.06 t/m^2. This geotechnical heterogeneity requires customized foundation designs and detailed analysis before any construction intervention.

The area presents considerable geotechnical challenges, including shallow water tables, supersaturated soils, and evidence of instability such as openings, subsidence, and displacements. These conditions demand a precautionary and technically rigorous approach to any construction project.

The Punzara area presents a geological and geotechnical complexity that significantly limits the feasibility of civil works. The viability of any project will depend on thorough technical interventions, specialized designs, and a preventive approach that mitigates the risks inherent to the instability of the terrain, guaranteeing the structural safety of future constructions.

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