Seismic Stability Analysis and Stabilization of an Unstable Urbanized Slope

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Keywords
Slope • Seism • Stability • Reinforcement • Factor of safety

1 Introduction

Tizi-N'Bechar city (Province of Setif, Algeria) is located within the geographical coordinates of Latitude 36° 25′ 52″ N and Longitude 5° 21′ 36″ E. It covers an area of around 71.65 km^2. Due to its booming population, this city expands and extends towards virgin zones often less favorable than those already urbanized. Instabilities of inclined soil massifs are to be feared in these zones due to its geological and geomorphological context in addition to the unfavorable climatic and geophysical conditions. This paper aimed to analyze the stability of a potentially unstable natural slope intended to construction of supermarkets and proposed a solution for its reinforcement. The data of our topic were gathered and the obtained stability calculations results were first detailed. The slope reinforcement solutions against any possible instability related to geotechnical properties, hydrogeological conditions and probable seismic effects of the site are then discussed.

2 Problem Data and Slope Stability Calculations

Tizi-N'Bechar city is characterized by a rugged relief consisting mainly of mountains and hills. The studied site is characterized by a declivity steep upstream (30%) and moderatly stiff downstream (10%) near a thalweg. According to geological map of the corresponding area, ground geological formations of this site consist of quaternary alluvia and Tellian formations represented by hard black schists. The massif comprises three layers of soil consisting of silt, clay and marl going from the top to the bottom (Table 1). The water table fluctuates from the a low level in summer (completely dry slope) to a high level in winter (fully saturated slope). Tizi-N'Bechar city is classified as a zone of average seismicity (RPA 99 2003). However, this city geographic position is feared because of its seismic activity comparable to that of bordering cities experiencing an intense seismic activity (AFPS 2003). The slope stability calculations were performed by the pseudo-static approach using TALREN 4 (version 2.0.3) and PLAXIS-2D (version 8.2) softwares. The corresponding results were expressed in terms of minimum factor of safety F_s (i.e. position of the critical failure surface). Stability calculations of the slope, carried out under its own weight using the limit equilibrium method, show that it is potentially unstable (F_s = 1.02) (Fig. 1a). The calculation results obtained under similar conditions using the φ-c reduction method are agree with the assumption of a circulair failure surface and confirm the calculation results carried out by the previous approach (F_s = 1.01) (Fig. 1b).

3 Research of a Reinforcement Solution of the Slope

Among the possible solutions considered for the reinforcement of this natural slope, only those which appear to be sustainable, technically feasible and economically acceptable were suggested below. Stability calculations of the slope after an upstream pickling and downstream filling show that it is

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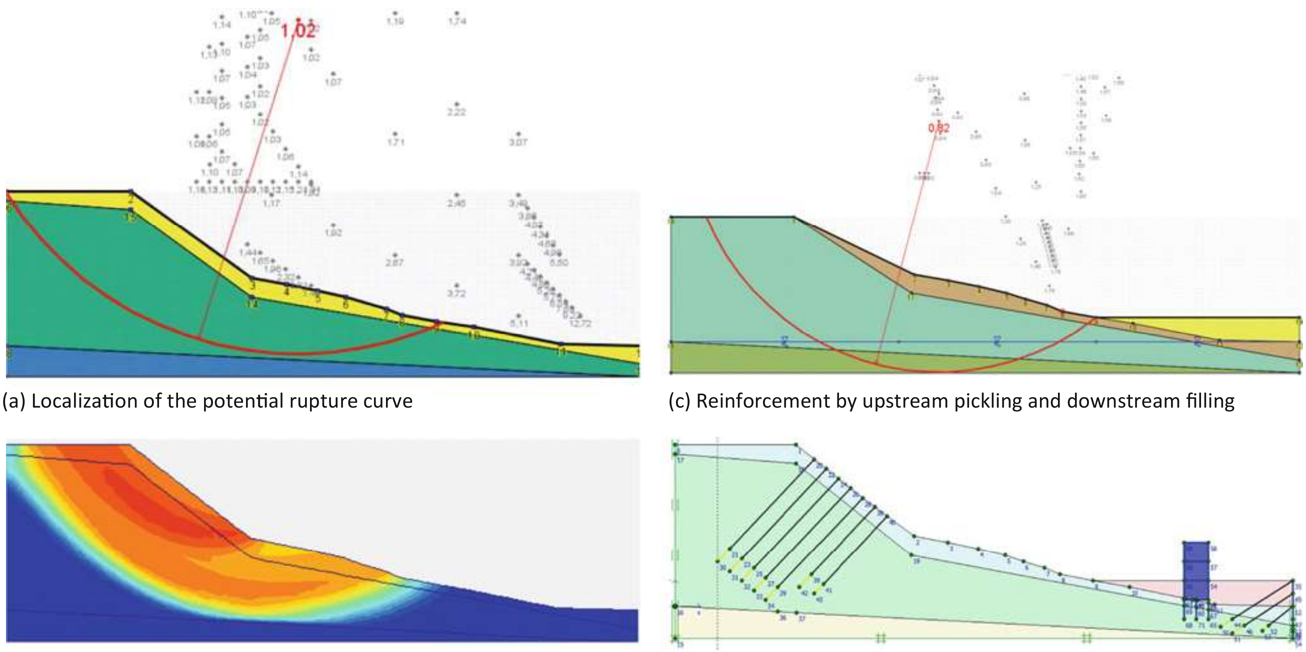
Table 1 Geomechanical characteristics values considered for calculations

Soil layers	Silt	Silty clay	Marl
Dry unit weight, γ_d (kN/m^3)	16	17	18
Humid unit weight, γ_h (kN/m^3)	18	19	20
Effective cohesion, c' (kPa)	10	13	30
Effective internal friction angle, φ' (°)	15	20	07



(a) Localization of the potential rupture curve
(c) Reinforcement by upstream pickling and downstream filling
(b) Localization of the plasticized area
(d) Reinforcement by nailing, piling and anchored wall

Fig. 1 Graphical results of the stability and stabilization calculations of the slope

stable under its own weight (Fs = 1.29). It becomes unstable in the presence of a water table located at half-height of it (Fs = 1.03). It collapses under the effect of an additional slight seism (Fs = 0.82) (Fig. 1c). From these observations, the resort to an alternative reinforcement solution of the slope by means of upstream nailing and downstream piling combined with an anchored wall at toe (Fig. 1d), seems to be convenient. The slope stability calculations thus reinforced show that it is stable under its own weight (F_s = 1.24). It will probably be unstable under the combined effect of its own weight, water table located at half-height and a seism corresponding to the current structures (F_s = 1.03).

4 Conclusion

The purpose of this paper was to discuss the stability calculation results of an unstable slope located in Tizi-N'Bechar city (Province of Setif, Algeria) and to propose a technically and economically adequate solution for its reinforcement. The geological and geomorphological context of the constitutive soils spurs the fear of a possible instability of this natural slope, particularly during probable climatic and/or seismic events. The stability calculations of the slope under its own weight justify this fear since they show that it is potentially unstable. However, the calculations of the slope reinforced by means of an upstream pickling and downstream filling indicated that it would be stable. Although this solution is the most advantageous, it is inadequate when the slope is subjected to a slight seism combined with a water table located at its half-height. A reinforcement solution of this unstable urbanized slope by means of an upstream nailing and downstream piling combined with an anchored wall at toe is thus necessary.

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