Digital Modelling to Predict the Land Sliding Hazard in a Selected Area; Ponzano's (Italy) Test Case

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Abstract

Creating a digital model is one of the aims of the geotechnical engineers, to predict the land sliding hazard which occur in different regions in the world. In February 2017, an extensive landslide occurred in the hamlet of Ponzano as a sloped area in the Abruzzo region in Italy. In this regard, predicting the land sliding hazard is one of the important issues to prevent hazard to the civilizations. In this project we created a model in the 3D dimension through the Plaxis 3D numerical solution software from the data based of the region Abruzzo in 2007 to evaluate the land sliding hazard before happened and then compare the results with the data from the drone data surveyed recently in the 2022. In this regard, the data from the Abruzzo resources from 2007 imported into the QGIS as the open-source cross-platform software to analysis the geospatial data and then imported into the Recap software to work on the point cloud data and then imported into the Civil 3D software to create a solid surface from the TIN surface and finally since the solid surface contains a large number of irrelative details, they were imported into the Rhinoceros software to create a NURBS surface to be smoothed for better performance in the analysis. The NURBS surface imported into the Plaxis and all of the geometry and geotechnical engineering parameters by considering the investigated geotechnical survey that was conducted in parallel in the area, defined for the model. The "Hardening Soil" model considered for the 1st layer as the "clay and lime" and the "Hoek-Brown" model defined for the 2nd layer as the "marl-flysch". A fine mesh elements distribution assessed also for the model. The phases defined as the "gravity" to define the unit weight of the soil layers, the "plastic" phase to calculate the instant deformations and the "consolidation" to analyze the plastic deformations in the sloped area of the model. In parallel, the drone data achieved in 2022, were imported into the CloudCompare as the 3D point cloud processing software and different methods such as the "segment", "statistical outlier Filter", "CSF filter", "noise filter", "cross section" etc. were performed to clean the data and then imported into the Recap software to work on data and then imported into the Civil 3D software to create solid surface of the current data after the land sliding. In this regard, to evaluate the displacement occurred from the year 2007 toward the 2022, a TIN volume surface as the colored map created through the Civil 3D software to show the displacements in the z direction and all of the results were compared with the Plaxis 3D numerical solution software. The results showed that the colored map with the displacement in the positive and negative direction of the z is the same of the analyzed model and the values match each other's and we created a digital model of the selected area to predict the land sliding hazard in the region in the following.

Keywords: case study, digital modelling, land sliding hazard, Ponzano, Italy

Introduction

Land sliding is one of the main processes inducing changes on slopes in mountainous, hilly and coastal areas. Landslides are induced by different triggering factors (e.g., heavy rainfall [1,2] and snowfall events, snow melting, earthquakes [3,4], sea storms, etc.). The landslide is a complex movement in which two major components can be recognized: (1) rotational sliding affecting the upper and crown portion; (2) an earth flow-like geometry in the central and toe portion of the landslide, characterized by a rupture surface below the ground level [5].

On February 12, 2017, an extensive landslide occurred in the hamlet of Ponzano (Civitella del Tronto, Italy). In this regard, 32 houses seriously damaged and 100 evacuees in the area [5]. The landslide, was with an estimated volume of about 7000000 cubic meters [6]. Referring the NOAA website in 2017, it shows that during the period 2016-2017, the average precipitation was low, but it was short and highly intensive in several region considering the Apennines mountain in the Italy [7]. The land sliding in the Ponzano region happened by the two factors. 1st was the elevated snow melt which was accumulated in January 2017 and also the intensive rainfall in the area [8]. 2nd an earthquake happened in the area Abruzzo, Lazio, Marche and Umbria, in a region around 30 km away from the study area, in 2016 and caused 299 deaths in these regions [9].

Due to these situations, studying the area and supervising the region for predicting any possible land sliding hazard is vital and this necessitate creating the digital model from any area, also considering the Ponzano, to monitor the region and predicting the land sliding hazard to save the people of the habitation from any natural hazard.

In this regard, we created a model by the Finite Element Analyzes (FEA) method using the Plaxis 3D software ([10]) to create the digital model of the area considering the condition of the region before the land sliding happened and then compare the final results with the current condition of the region after the land sliding happened by using the drone data surveyed recently in 2022 in the Ponzano region, which could also helpful to calibrate the model for the future and next generation of the land sliding happening in the region and orient to creating a digital model of the region as a prediction digital model. To create the digital model, also the geotechnical engineering parameters, determined from the geotechnical study report which was investigated some months ago in 2022 in the Ponzano region.

Project Area

Ponzano is one of the hamlets of the Civitella del Tronto municipality in the northern sector of the Teramo Province, close to the border with the Marche Region 'Fig. 1' and 'Fig. 2'. It is located in a hilly area at an average elevation of 360 m. The slope angle ranges from 4 to 12° [5]. The area is extensively covered by crops and pastures with scattered woods and small groups of houses. One of the regions that was also considerably effected by the land sliding was the Carosi village near the Ponzano village 'Fig. 2'.

Fig. 1. Ponzano in Italy

Fig. 2. Ponzano and Carosi village

Analysing Land Sliding In The Ponzano Region

In this project we modeled the Ponzano area in the Plaxis 3D software as the FEM software from the data in 2007 and then compare the results with last updated data which was surveyed in 2022 to calibrate the model and create a digital model for analyzing the region.

First Step: Analysing Region from Data 2007 Using Plaxis 3D

In the 1st step of the model, the data which was used for analyzing in the QGIS software [11,12], received from the 'opendata resources' of the Abruzzo region [13]. These data were in the format of the SHP and scaled of 1:5000 with the edition of the 2007. By receiving these data, they were imported into the QGIS software for the analyses. In the QGIS the vertices extracted, and the related study area selected with the selected topography and then exported to be used in the ReCap software [14], as the Autodesk software; ReCap is a software designed for the transposition of laser scans of objects, landscapes or structures, in a point cloud, or in a 2D mesh to carry out further interventions. Afterward, the file imported into the Civil 3D software [15] as the Autodesk software which is a surveyor professional software to create the solid surface from the data to be able to be imported into Rhinoceros software [16] to create the NURBS surface for the Plaxis. This procedure is done because the solid surface is a triangulated mesh and contains a lot of faces and irrelative details for the intended analyzes in the Plaxis 3D and for better performance and faster meshes, the surface needs to be simplified and smoothed with less triangles, which is named Non Uniform Rational Basis-Splines (NURBS) surface. By creating the NURBS surface, it is imported into the Plaxis 3D software as the structure to be used in the model.

In this regard, 5 different boreholes also were drilled in the region and the laboratory tests were investigated on the specimens, to determine the geotechnical engineering parameters for the model, which was done on 2022. The boreholes were mostly investigated near the village Ponzano. The laboratory tests showed that mostly the first 40 m below the ground surface is the clay and lime layers and the second layer below that is the marl and flysch layers. In that case, the 1st layer was modeled as the "Hardening Soil" behavior and the 2nd layer was modeled as the "Hoek-Brown" behavior 'Fig. 3'. The underground water level was mostly determined around 1-3 m below the ground surface. In the following the geotechnical laboratory test results that were investigated on the specimens are shown.

Tab. 1. Geotechnical laboratory test results

Specimen	Depth m	Moisture %	γ_n kN/m3	γ_s kN/m3	Grain Size Distribution Test				Direct Shear Test		Triaxial Test (UU)
					Gravel %	Sand %	Silt %	Clay %	C' kPa	φ	C_u kPa
1	8.9 – 9.45	15 - 19	20.69	27	-	24.1	44.1	31.8	15.4	0	448.07

Subsequently, the mesh created in the model by using the element distribution as the fine mesh. In the last stage, the phases defined for the Plaxis 3D software to be ready for the analyses. In this stage, the 'gravity' phase defined for the model to implement the unit weight of the soil layers to the model. The Plastic and the Consolidation analyses also defined to implement the elastic (instant) and plastic (consolidation) settlement to the model. In the following, the results of the displacements in the x, y and z direction as well as the plastic points are shown on Fig. 4, Fig. 5, Fig. 6 and Fig. 7.

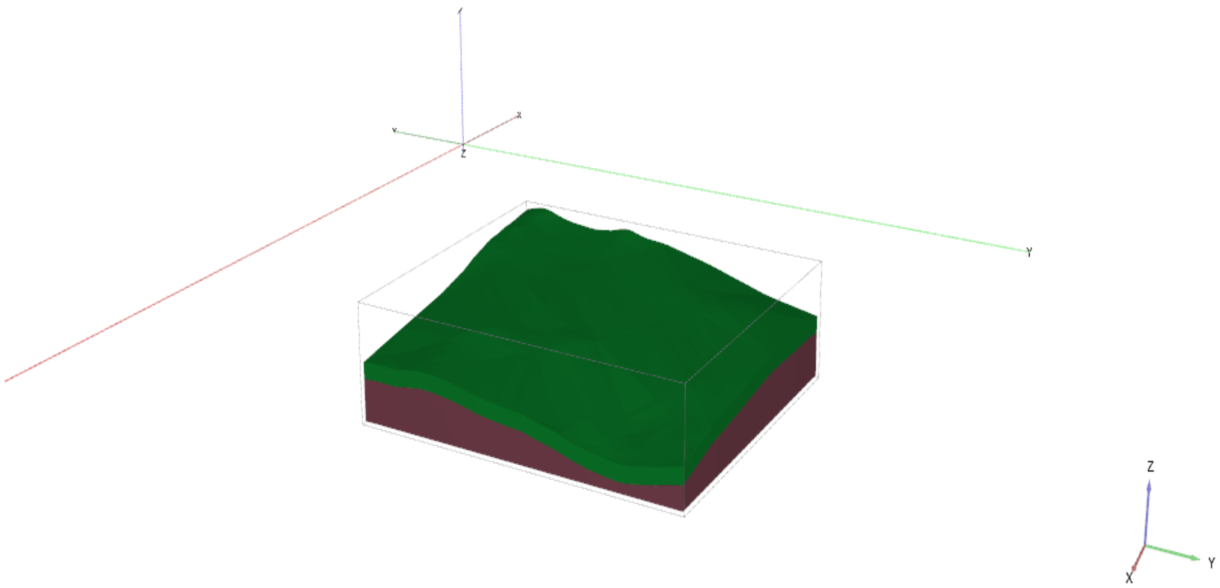

Fig. 3. Plaxis model of the Ponzano region

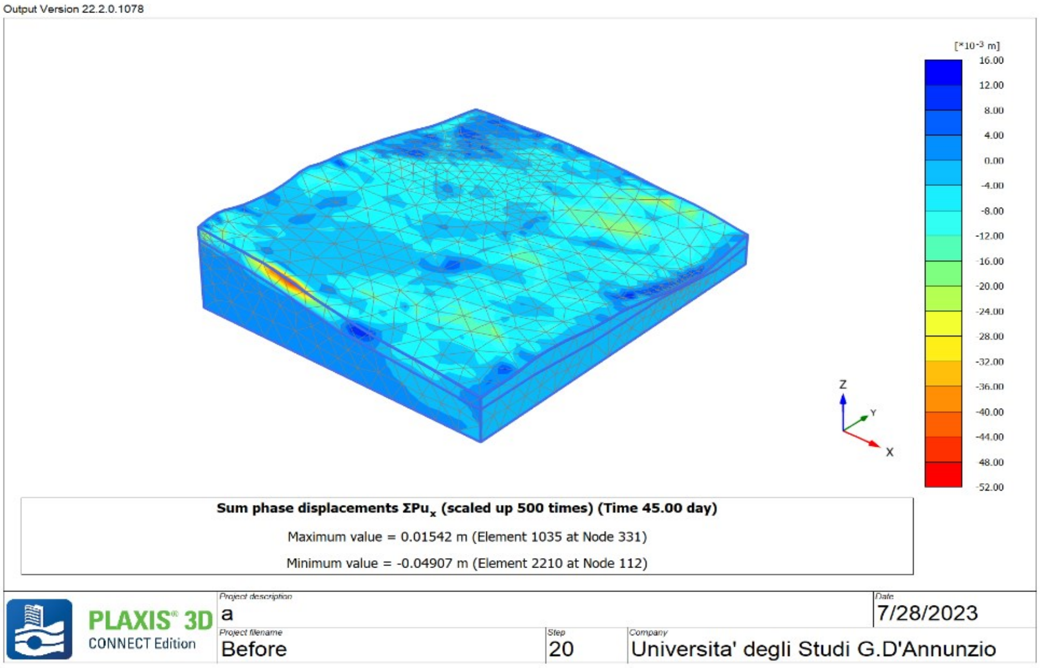

Fig. 4. X displacement after Plaxis analyses

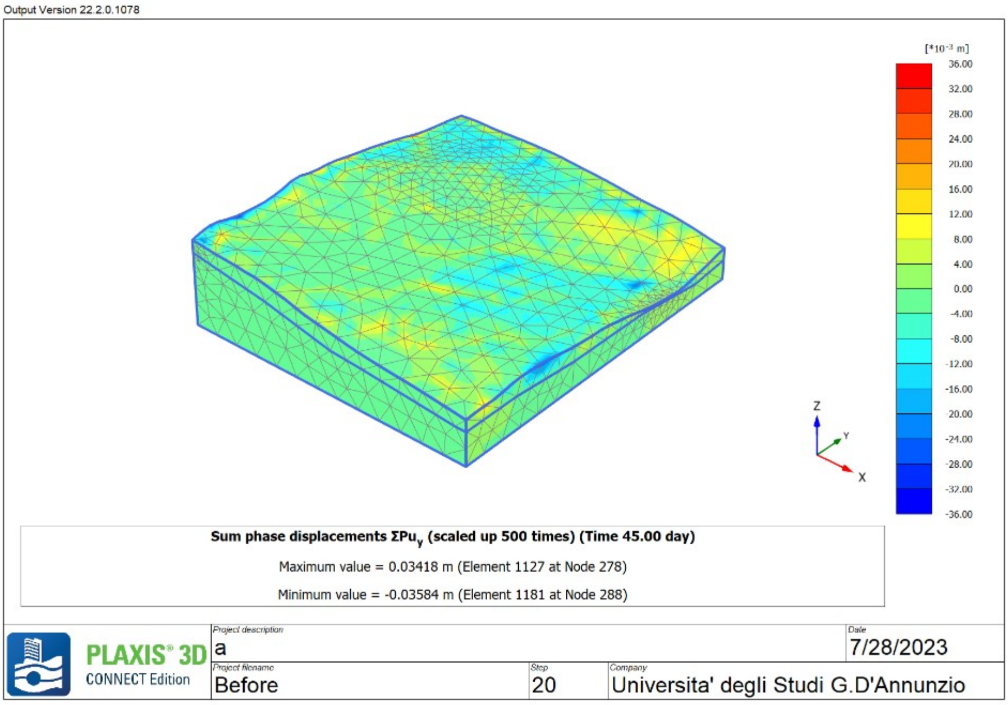

Fig. 5. Y displacement after Plaxis analyses

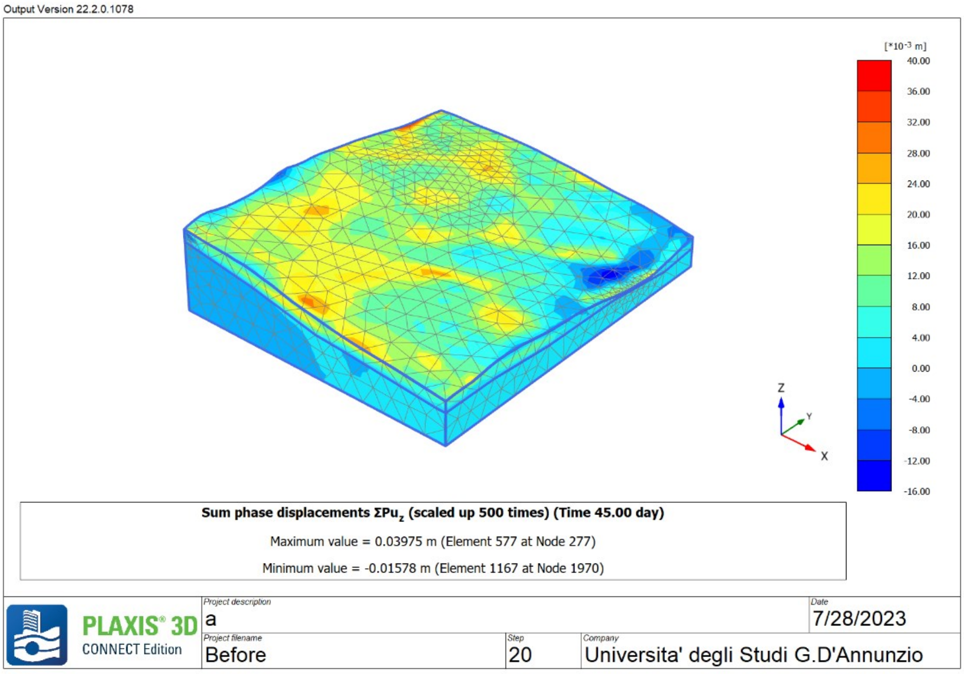

Fig. 6. Z displacement after Plaxis analyses

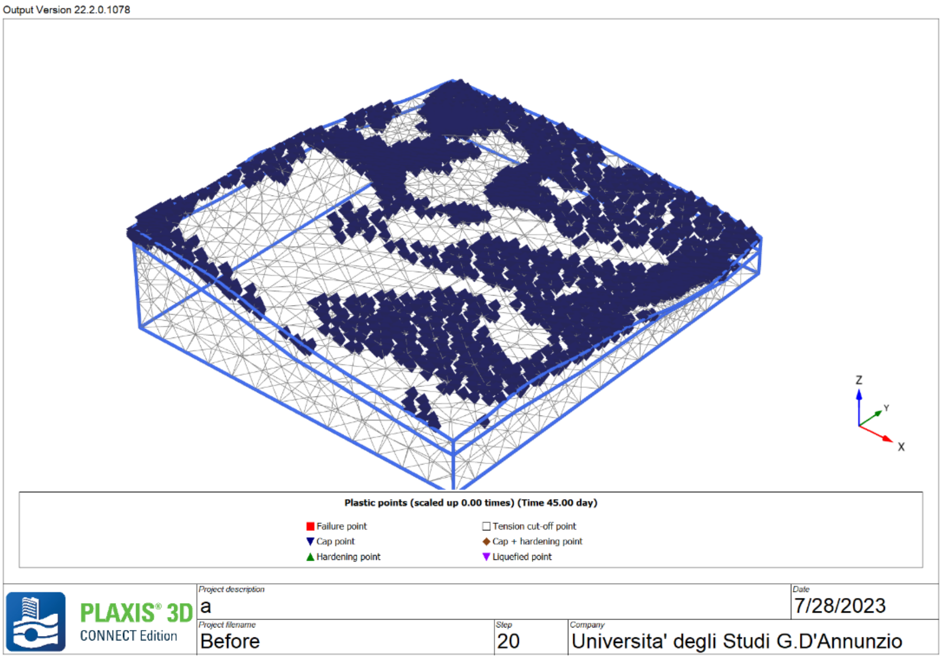

Fig. 7. Plastic points after Plaxis analyses

Second Step: Analysing Region from Data 2022 Using Drone Data

In this step to compare the results of the Plaxis 3D software that used the data of 2007 (before the land sliding happened) to evaluated the land sliding hazard in the Ponzano region, we used the data of the surveyed analyses by the drone data which was conducted recently in 2022 (after the land sliding happened) to calibrate the model and create a digital model for predicting the land sliding. In this regard, a surveyed analyses by using the drone data conducted in the region after the land sliding happened ‘Fig. 8’ and the data imported into the CloudCompare software [17] and different methods such as the “segment”, “statistical outlier Filter”, “CSF filter”, “noise filter”, “cross section” etc. were used to clean a clean data of the surveyed region (after the land sliding happened) and then imported into the ReCap software for more works on the data and then into the Civil 3D software to create solid surface and then into the Rhinoceros to create the NURBS surface; CloudCompare software is a point cloud processing software which handle the triangular meshes and calibrated images in the regions.

Fig. 8. Surveyed drone data analyses

Comparing The Displacement Happened Before And After The Land Sliding

To compare the results and showing the displacement happened in the z direction between the data analyzed before the land sliding happened (on 2007) through the QGIS software analyzer and the drone data which was surveyed on 2022 (after the land sliding happened), we used the Civil 3D software to compare the results 'Fig. 9'. The differences show that in the Ponzano and Carosi villages and also in the NE direction of the region, there is uplift displacements in the z direction and in the NW and West direction we have settlement and negative displacement.

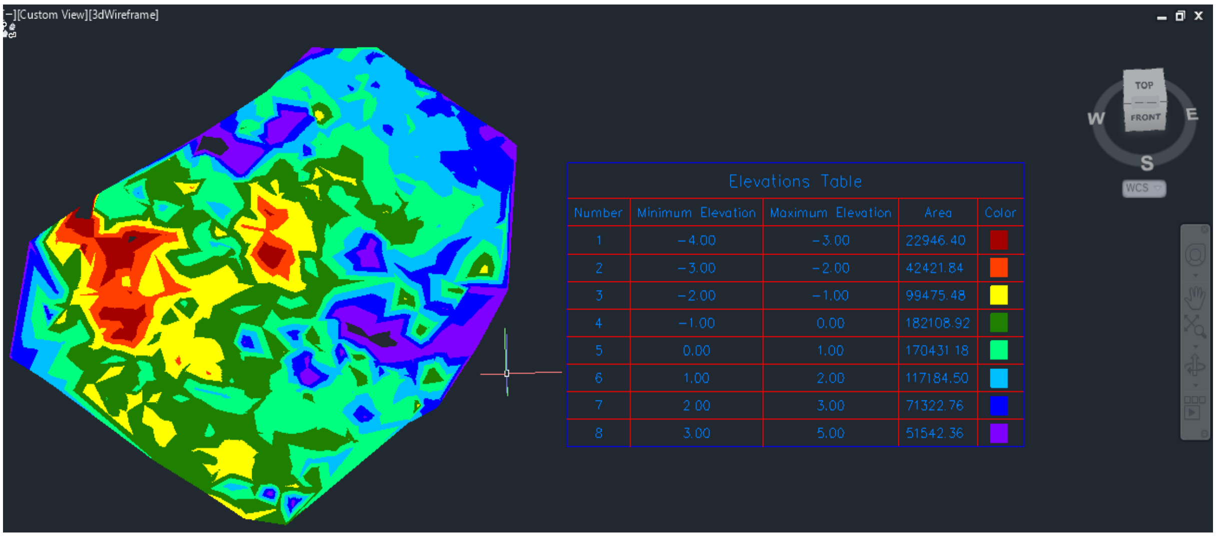

Fig. 9. Compared Z displacement between the data before the land sliding happened on 2007 (using Plaxis 3D analyses) and the data after the land sliding happened on 2022 (using the drone data analyses)

Discussion

The results showed in this paper are resourced from the drone data and a primary analysis of the Plaxis 3D software without considering the loads of buildings, infiltration of the snow and rainfall, pore pressure of the underground water surface flow and also the seismic loads and at this step we create a digital model of the effected area by considering the data, but in the following we are working on the data to create a comprehensive model of the Ponzano region using the FEA Plaxis 3D software to analyze the region by considering all of the effective parameters and then compare the results with the colored map, resourced from the drone and QGIS data, to calibrate the model and create a complete model of the Ponzano region.

Conclusion

The results show that by the land sliding happened in the Ponzano region in 2017, the deformations in the z direction are different. In the Ponzano and Carosi villages and mostly in the NE direction of the Ponzano region, the deformation is in the positive direction of z (uplift) and mostly in the NW and West direction and also in the center, the deformation is in the negative direction of z (settlement). This could be by the results of the seismic that was happened in 2006 near the region and also by considering the effects of precipitation of the rainfall and the load of the melted snow on the area and also the pore pressure of the underground surface and the loads of the buildings in the villages.

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