# Technical Aspects on a Landslide Affected Construction

Andreea-Terezia Mircea

*Abstract*—One main geological phenomenon a civil engineer has to deal with is related to landslides which include a wide range of ground movement. A change in the stability of a slope can be caused by a number of factors (geomorphological, physical, seismic, volcanic or human activity-related), acting together or alone. Every construction has to be founded on soil, transmitting all the loads to the foundation stratum. The research was aimed to reviel technical aspects on a landslide affected construction - a box feeder, built in order to improve the technological flows of a brick systems company, having a reinforced concrete rigid box-type main structure, and a lightweight steel roof support. A platform for storing the necessary raw material was arranged behind this construction. Short time after the feeder was put into operation the surrounding land filling structure showed signs of swelling and fractures. The paper presents aspects of the technical investigation carried out in order to establish the geotechnical situation regarding the foundation soil, the technical condition of the feeder's structure, as well as to set up the main solutions and operation needed to be taken in terms of strength and stability, in accordance with the legislation on quality in construction and construction safety.

***Keywords***—construction quality and safety, geotechnology, landslide, slope stability, technical investigation.

## I. Introduction

EVERY construction has to be founded on soil, transmitting all the loads to the foundation stratum. The soil is in direct contact with the structure, and acts as a medium of load transfer, so the aspect of stress distribution through the soil is being essential [1]. Unexpected changes occur in soils when certain environmental changes take place.

One main geological phenomenon a civil engineer has to deal with is related to landslides which occur when the stability of a slope changes from a stable to an unstable condition. This may be caused by a number of factors that make the slope vulnerable to failure, and which may act together or alone, like the following [2]:

- Geomorphological factors (e.g. jointed or fissured materials, nonuniformity of the slope lithology, adversely orientated discontinuities, and high slope gradients);
- Physical factors (e.g. slope loadings, rapid snow melt, freeze-thaw, prolonged rainfall, groundwater changes, seismic activity, and volcanic eruption);
- Human activity factors (e.g. deforestation, construction, heavy traffic, excavation, land use changes, vibration etc.).

The research was aimed to reviel technical aspects on a landslide affected construction: a box feeder designed to meet the customers need in terms of storage capacity and production rate, built in order to improve the technological flows of a brick systems company (see Photo from Fig. 1).

Fig. 1 Structure of the box feeder

Fig. 2 The storing platform behind the feeder

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The box feeder is a universal machine used for raw materials in the clay preparation process, being built and supported by solid steel frames. It has a reinforced concrete rigid box-type main structure, and a lightweight steel roof support.

The feeder is built-in with a moving steel slat plate bottom of which the speed is adjustable, and a sliding shuttle door controls the amount of material leaving the feeder.

Behind this new construction, a platform for storing the necessary raw material for bricks fabrication was arranged (Photo from Fig. 2).

Only few months after the feeder was put into operation the surrounding land filling structure showed signs of deformations, swelling and fractures, as an obvious evolutionary process (Photo from Fig. 3).

Consequently the terrain deformation and movement produced translations and rotations of the structure (Photos from Fig. 4 and 5).

Fig. 3 Deformations, swelling and fractures of the surrounding land filling structure

## II. Purpose of the Technical Investigation

Causes of the terrain deformation and movement may be considered to be factors that made the slope vulnerable to failure, that predispose the slope to becoming unstable.

Although the action of gravity is fundamental for a landslide to occur, it is well known that there are other contributing factors which affect the natural slope stability, being aggravated by human activities, including deforestation and construction activities, which destabilize the already fragile slopes.

The above described situation required a technical investigation to be carried out, in order to establish the geotechnical circumstances regarding the foundation soil, the technical condition of the box feeder's structure, as well as to set up the main solutions and technical operation that are need to be taken into account in terms of strength and stability, in accordance with the existing legislation on quality in construction and construction safety.

The technical investigation has been developed at the request of the general contractor for upgrading and refurbishment of the bricks systems company.

Fig. 4 The soil deformations produced translations and rotations of the structure

Fig. 5 Soil deformations in front of the structure

## III. Information Related to the Construction

According to the classification criteria [3], this type of construction is categorized as class IV of importance - construction of secondary importance/ construction of minor importance.

The structure is situated in the centre part of the country, (see the Physical Map from Fig. 6), being positioned in the seismic zone D [4], with a coefficient Ks = 0.16, and a corner period Tc = 0.7 s.

In terms of climate actions, the construction is placed in an area with the characteristic snow load of 1.50 $kN/m^2$, and with a characteristic reference value of the wind pressure of 0.50 $kN/m^2$, according to the design code assessments under the action of snow and wind, correlated to the fundamentals of construction design.

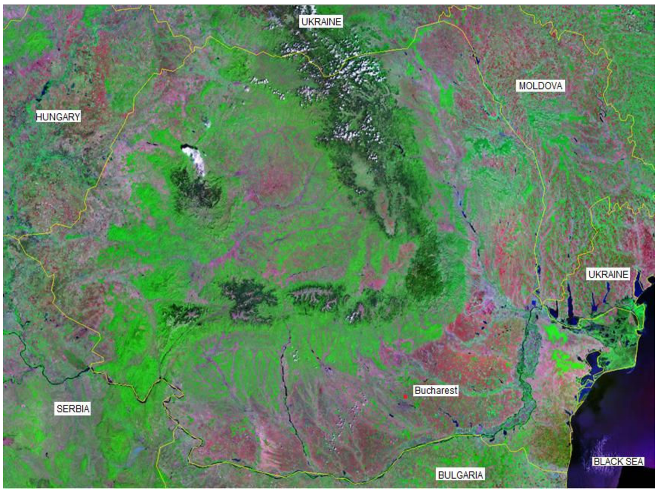


Fig. 6 Physical Map of Romania - Source: http://geology.com/world/romania-satellite-image.shtml [5]

The box feeder receives the raw material and delivers it at a constant and controlled rated to the next stage of manufacture (see Photo from Fig. 7). The technological process starts from the excavated clay that is laid in layers in a stockpile to achieve consistency of the mix and in order to ensure that the maximum amount of extracted mineral is beneficially used in manufacture. During the manufacturing process clay is collected from the stockpile and loaded into the box feeder. Then water, sand and other additives are added to the clay and mixed in accordance with the recipe for a particular product type.

The investigated construction object was built on reinforced concrete elastic foundation base with monolith reinforced concrete walls [6]. The box structure consists of monolithic diaphragms with a thickness of 30 cm (on the exterior transversal axes 1 and 5, respectively on the axis A) located on the open perimeter, and with a thickness of 25 cm on the inside (on the horizontal axis 2 – 4, and on the longitudinal axis B, above the level +3.20). The slabs are made also from monolith concrete, having a thickness of 30 cm. The inside of the concrete box is filled with earth filling.

This very rigid assembly sustains the supply bunkers where the raw materials are taken over through a conveyor belt supported by a metal scaffold, to the production hall.

Fig. 7 The box feeder built on reinforced concrete foundation

## IV. Geotechnical Conditions

The site studied is located in the peripheral part of the industrial district, placed in the northeast region of an urban settlement, at the contact area of a river terrace and the hills to be found northeast of the city.

Investigations carried out on site (an 8.0 m deep drilling and a survey performed at the foundation of the construction object - see Photo from Fig. 8) lead to the following findings:

- The foundation type of the investigated construction object is of reinforced concrete having a width of 1.50 m;
- The foundation depth is about 2.10 m from the surface of the ground in the surveyed area;
- The ground stratification intercepted as a result of drilling is shown on the stratigraphic column from Fig. 11;
- At the depth of 3.0 m from the ground surface a layer of soft plastic clay, which has low strength characteristics and deformation properties was found, so that the loads generated by the earth filling and the raw materials stored in the adjacent platform provoked deformations on the surrounding land filling structure.

Following the geological studies the characteristics of the ground stratification intercepted as a result of drilling were taken into account during the entire technical investigation.

Fig. 8 The survey performed at the foundation of the investigated construction object

## V. ASSESSMENTS AND OBSERVATIONS

When implementing the investigation following main criteria have been considered:

- The seismic zone (Zone D), and the climate actions (wind and snow) of the place where the construction is situated;
- The structural system (rigid box with walls and slabs made of reinforced concrete, and foundation system of continuous elastic foundation type);
- The construction's class of importance (class IV);
- The operating system, and the date of the construction's entry into service (spring 2006);
- The geotechnical characteristics of the foundation soil;
- The nature of the observed depreciations that occurred.

Based on these criteria, the construction was investigated by the qualitative assessment method [7], which emphasizes the following:

Fig. 9 Construction of the storing platform behind the box feeder

- A landslide phenomenon started in the earth filling area, caused by the storing platform arranged behind the box feeder's structure (see Photos from Fig. 9 and 10).
- Below the structure's foundation level a gray-yellow layer of soft plastic clay has been detected, having a thickness of about 50 cm, with reduced strength and rigidity properties (layer no 3 of the stratigraphic column shown on Fig. 11).
- The structural system of the feeder is very a rigid box, so that the registered landslide into a plan of soil created in the layer no 3 (gray-yellow soft plastic clay) produced a rigid body rotation and translation of the structure (Fig.12);
- The rotation took place with predilection on transverse direction, and the translation mainly on the longitudinal direction (Fig. 13 and 14), some of the deformations reaching about 50 cm from the initial position, as well as visible fractures of the superficial layer.
- The characteristic of soft plastic clay, of being susceptible to earth flow, as well as the rotation of the structural system that took place, explain the fact that the access road is swelled in front of the box feeder on a length of about 15 m (see Photo from Fig. 15).

At the time of performing the investigation the phenomenon was not yet stabilized and furthermore it could be amplified by the soil-infiltrated water from the proximity slopes (see Photo from Fig. 16), and its leakage through the earth fill structure.

Fig. 10 Side view of the box feeder's structure

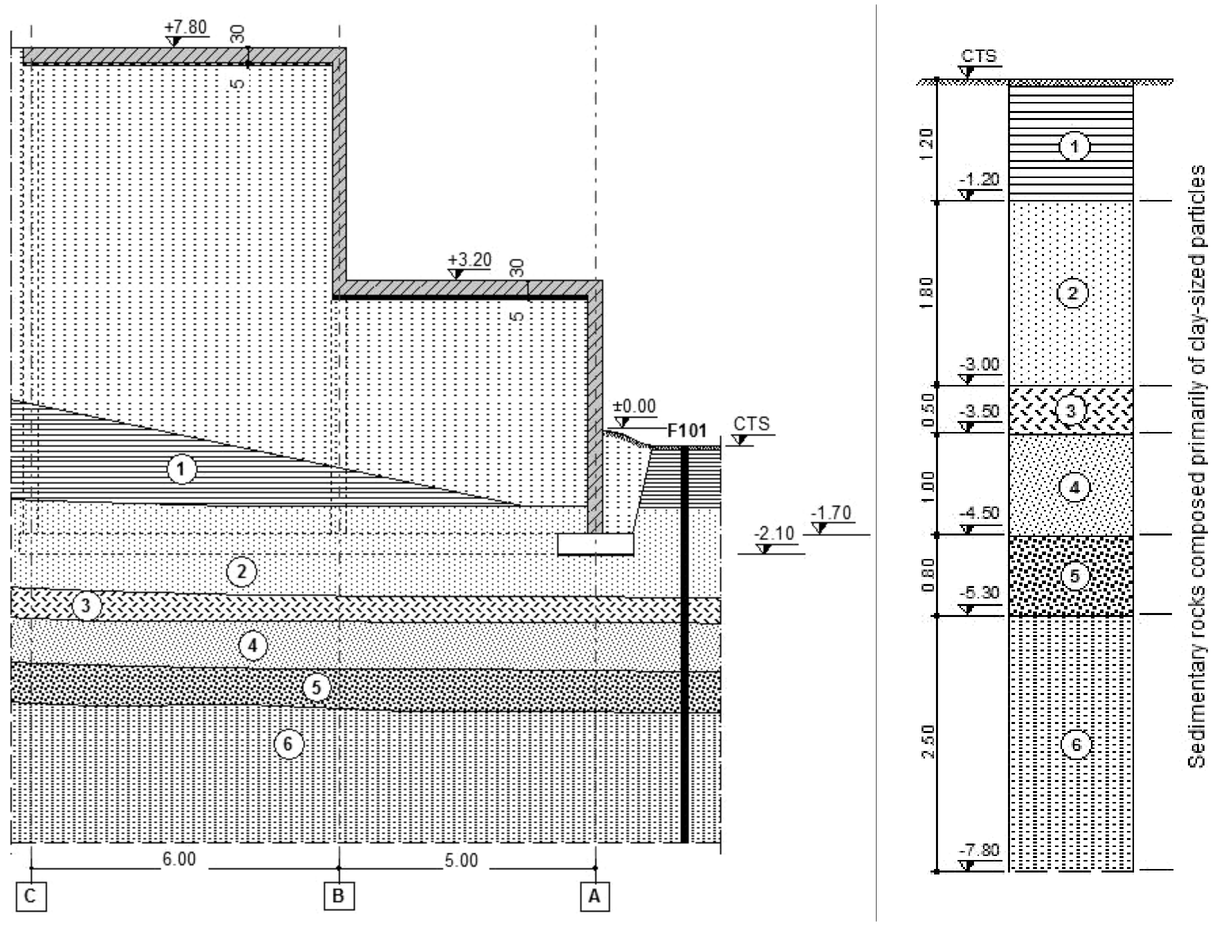


Fig. 11 Ground stratification and the stratigraphic column

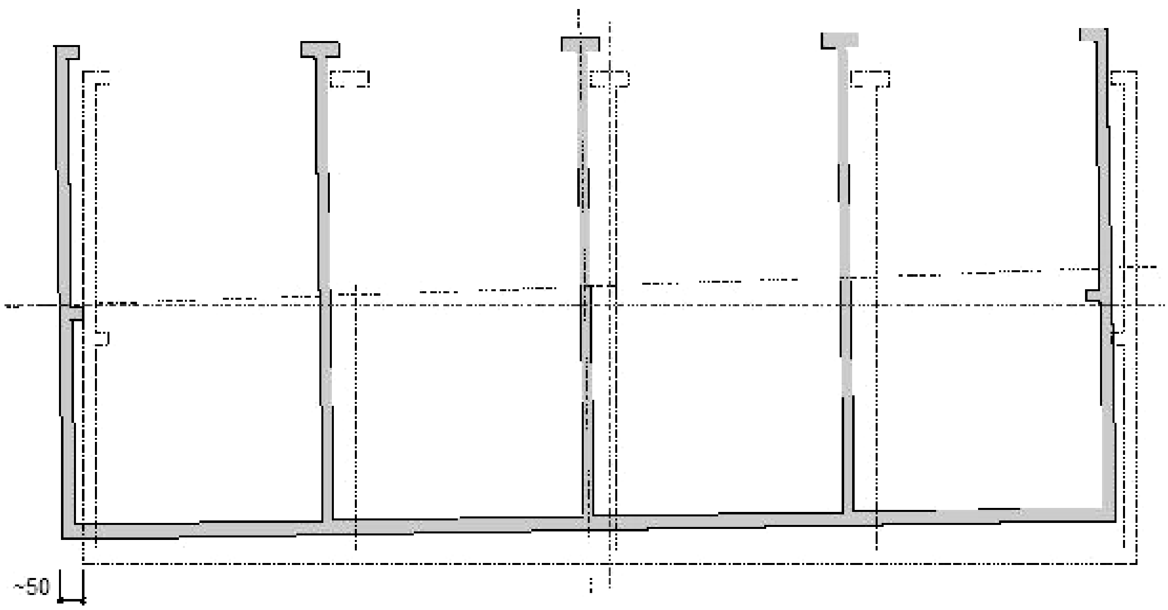


Fig. 12 Rotation and translation of the structure

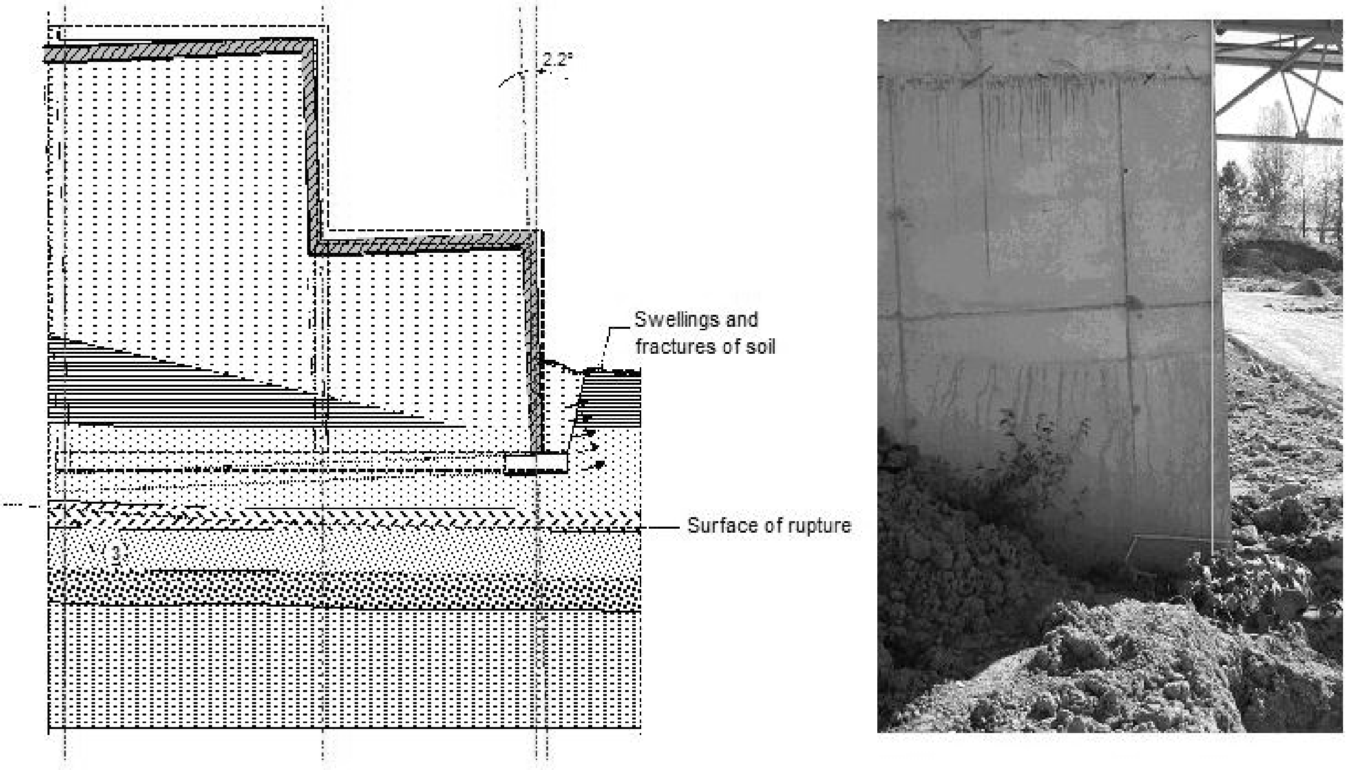


Fig. 13 Transversal rotation of axis 1, and soil deformation

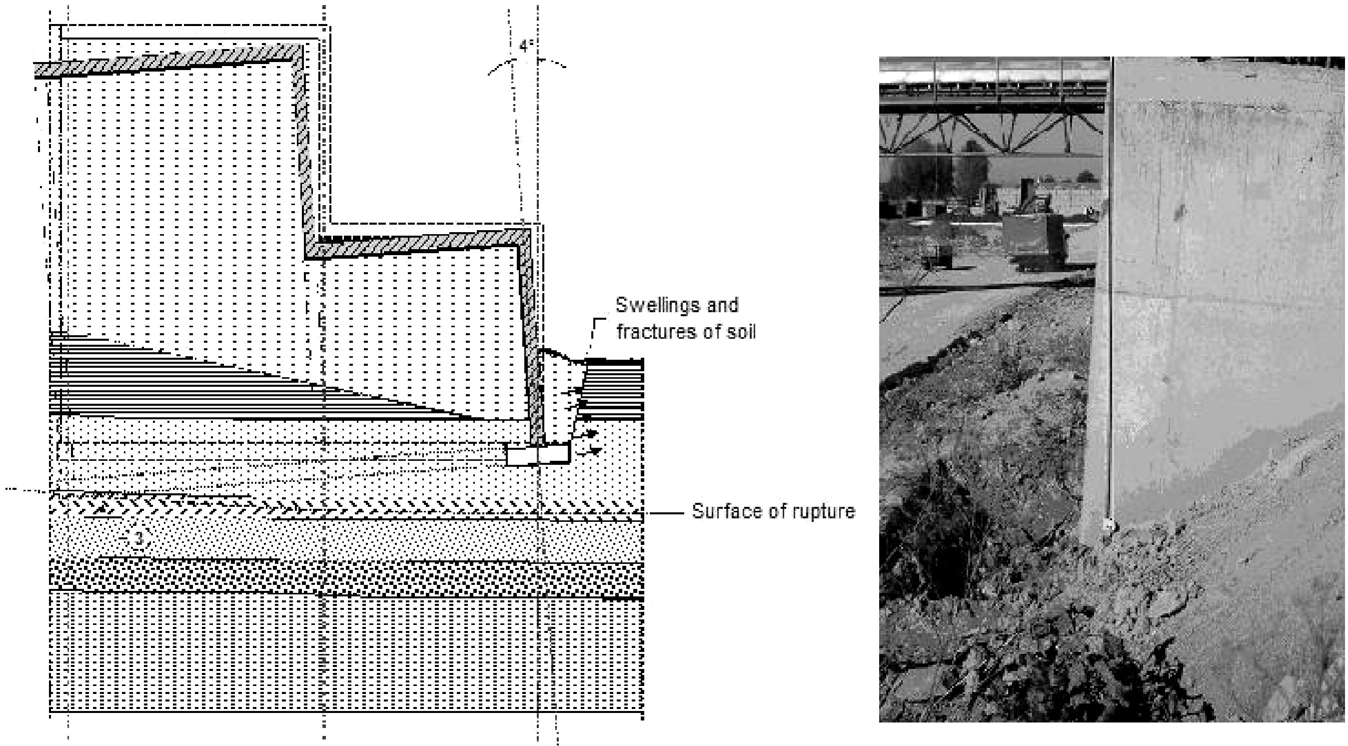


Fig. 14 Transversal rotation of axis 5, and soil deformation

## VI. Conclusions and Recommendations

It is difficult to establish a classification for landslides [8], because almost every slope movement has to take into consideration regional geological conditions. This enables a sliding phenomenon to be classed within a group on the basis of simple characteristics, easily determinable in the field [9].

Five kinematically distinct types of landslide were identified by Varnes (1978) [10]:

1. Fall: starts with the detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place. The material then descends largely by falling, bouncing or rolling.
2. Topple: is the forward rotation, out of the slope, of a mass of soil and rock about a point or axis below the centre of gravity of the displaced mass.
3. Slide: is the downslope movement of a soil or rock mass occurring dominantly on the surface of rupture or relatively thin zones of intense shear strain.
4. Flow: is a spatially continuous movement in which shear surfaces are short lived, closely spaced and usually not preserved after the event. The distribution of velocities in the displacing mass resembles that in a viscous fluid.
5. Spread: is an extension of a cohesive soil or rock mass combined with a general subsidence of the fractured mass of cohesive material into softer underlying material. The rupture surface is not a surface of intense shear. Spreads may result from liquefaction or flow (and extrusion) of the softer material.

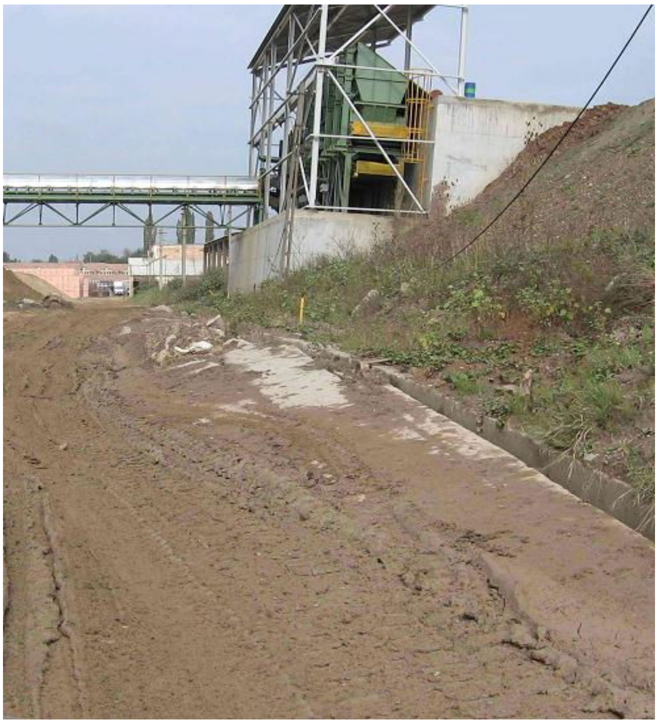

Fig. 15 The access road is deteriorated on a length of about 15 m

Fig. 16 Amplification of the deformation process due to the possibility of water infiltrations from the proximity slopes

However, a sixth mode of movement was named Complex Failure, in which one of the five distinct types of movement is followed by another type (or even by more types) [11].

Landsliding is a process that occurred in this investigated case as a combined result of human activities (e.g. poor forest management and construction activities) associated with natural causes (snow and heavy rainfalls) which have disturbed the slope stability. Following the investigation, the soft plastic clay layer flowed mainly in the transverse direction of the filling structure. But blocking this flow in the transverse direction may have led to the increase of the phenomenon in the longitudinal direction.

The research concluded as shown above:

- The filling structure did not show any signs of depreciations and degradation of structural nature;
- The threat may have arisen only if the phenomenon continued, because under the examined conditions the construction may have lost its functionality.

In order to maintain towards the construction's functionality it was essential to stop the landslide phenomenon. In this regard, the recommendation was to adopt one of the next two solutions:

a) Stopping the landslide in transverse direction by blocking it with a tangent pile screen stiffened by a superior foundation, positioned next to the construction's object longitudinal axis A, in order to prevent slide movements in the longitudinal direction, as well as providing reinforced concrete beams supported each on two piles under the foundation base of the transverse axis C;

b) Stopping the landslide in transverse direction by blocking it with a tangent pile screen stiffened by a superior foundation, identical to the previous solution, and in addition by blocking the slide in longitudinal direction using a tangent pile screen adjacent to the transverse axis 1, similar as for the transverse direction.

Recommendations for completing the construction work:

- All construction activities have to be carried out in respect of the certified project approved by a technical expert, member of the investigation's developing team;
- If during the construction works defects of the structural elements or hidden defects of the construction are found, or if problems arise that require modification of the design data, the investigation's developing team has to be consulted;
- Continuous monitoring of groundwater movements [12] enables judgements to be made concerning the nature and intensity of the landslide activity.

The risk of landslides can be reduced by avoiding construction on steep slopes and existing landslides, or by stabilizing the slopes with different methods. Stability additionally increases when ground water is prevented from rising in the landslide mass.

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