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Engineering Geological Conditions –Landslide Phenomena in the village of Ropoto Trikala, Greece

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ABSTRACT: A detailed investigation and analysis of both the engineering geological – geotechnical conditions and the instability phenomena occurring in the wider area where the village of Ropoto is situated, was carried out. The basic aim of the study was to evaluate the risk of certain zones and the possibility of intervention by the application of both simple and economically feasible measur es. The investigation clearly showed that the activation of slopes was caused by the co-ordinated effect of many factors, such as lithological composition, tectonics of pindos sediments covering the area, stratigraphy of both the different phases of flysch and the underlying transition zone, erosion processes, action of water and finally human intervention. Therefore, it was made clear that facing of any of the failures should be based on the detailed analysis of those factors which play a significant role in each case and refer to the wider area.

RÉSUMÉ: Un investigation detaillée des conditions géotechniques – géologiques et les phenomènes d' instabilité de la region du village de Ropoto a été effectuée. Le but de cette étude était d' évaluer le risque des certaines 20 nes et la possibilité d' intervention avec des mesures simples et économiques. L' investigation a prouvé que la coordination d' un grand nombre de facteurs (composition lithologique, tectonique de la serie de Pindos, la stratigraphie des faciés du flysch et la zone de transition, les processus d' érosion, l' action de l' eau et l' intervention humaine) est la cause de l' activation des pentes. Alors, c' est devenu évident que l' affrontement de ces problèmes doit être basé sur l' analyse detaillée des facteurs qui jouent un rôle important dans chaqun des cas de la région etudiée.

1 INTRODUCTION

The county of Trikala as well as the neighbouring county of Karditsa is severely affected by landslide phenomena. In these areas, the combination of engineering geological factors such as the physical condition (weathering, erosion, fracturing, etc.) of the various geological types, their physico - mechanical characteristics, with the intense relief, the heavy rainfalls and man's intervention favour the manifestation of landslides. In both counties such phenomena appear on a rather wide scale, thus causing serious problems (Lekkas 1996).

The village of Ropoto constitutes a representative sample of Pindos zone (Lekkas 1988a,b), and especially of the flysch formations, which are notable for the increased instability and the manifestation of significant landslide movements.

The investigation, which was carried out, showed that the area where the village is situated is facing today very serious problems. Although their creation is attributed to the co-ordinated effect of a number of factors, it is believed that the main reason must be searched to the abandonment of the village as far as facing of landslides is concerned. This abandonment, which can be dated back to the very early days of the manifestation of the phenomena, caused the unobstructed action of all factors and the therefore, the creation of very serious phenomena in two zones of the central part of the village. These zones coincide with areas where an uncontrolled and concentrated flow of surface water is observed.

2 PREVIOUS WORKS

Within the frame of the present study all previous reports concerning the area under investigation were examined and analysed.

The first of these reports dates back to 1963 (Dounas 1963), while the last one was carried out in 1994 (Apostolidis 1994), with six more studies in between (Angelidis 1984, 1991a, b, Angelidis & Bellas 1992, Eleftheriou 1967, Eleftheriou et al.

1976, Koukis 1979). Different directions and philosophy characterise these studies, obviously due to the fact that, during the course of time, they were carried out only in certain places, having as their main aim the examination of the erosion – weathering processes and the human interventions. Therefore, the inclusion of these failures in the wider engineering geological frame of the area is absent. The only case where a detailed analysis of the soil formations was made is the study by Angelidis & Bellas (1993). This study included the execution of sampling boreholes and laboratory testing and a try to relate the results to the physical condition and the behaviour of the formations was carried out. However, the rather limited extension of the study (one borehole in each area of concern) did not make possible the elaboration of the engineering geological environment and therefore, the complete understanding of the extend, the manifestation mechanism and the geometry of the failures.

The majority of the rest of the studies were simply reconnaissance investigations, usually within the frame of investigating larger areas of the county, and therefore they were not facing the seriousness of the problem. Only in a few cases the analysis was more elaborate and therefore the understanding of the phenomena much more complete. However, the proposed measures, although in such cases were much more substantial, were never applied.

3 ENGINEERING GEOLOGICAL SETTING

Ropoto village is geographically located in the North Western part of Trikala, and formations from the Pindos zone take part in its geological structure (Fig. 1).

The engineering geological units which are covering the area and form the corresponding conditions, are the following:

(a) River deposits consisting of mainly coarse grained units (some sands, pebbles, gravels and boulders).

(b) Flysch weathering mantle of a yellowish – brown to greyish – brown colour consisting of silty sand to clayey sand with grits, gravels and rarely pebbles. It is a loose formation with low geomechanical characteristics and a poor bearing capacity, which covers with a varying thickness (usually 2-8m) the underlying flysch formations.

(c) Screes: Cornered fragments of a mainly limestone origin and various sizes, grits and soil materials of a silty sand composition. Loose formation and possibly semi-coherent with depth.

(d) Flysch formations: sandstone and siltstone alterations, with predominance of the sandstone phases, which reach a thickness of up to 1m. Strongly folded formation, which under the effect of the usually poor geomechanical behaviour, the strong rainfall and human intervention could manifest serious landslide phenomena. These special conditions can be additionally reinforced by the application of dynamic loading (seismic activity).

(e) Alternations of whitish – grey thin platted marly limestones with clayey marls and scattered cherty intercalations, which in the upper horizons change into alternations of sandstones, clayey schists and scattered intercalations of marly limestones. It consists a strongly folded and tectonically affected formation, with a varying geomechanical behaviour.

(f) Carbonate rocks: Upper Cretaceous limestones, thin plated with nodules or thin intercalations of chert lumps. They are characterised by a satisfactory geomechanical behaviour and they present only minor problems as far as slope stability is concerned (creation of screes).

(g) Formations of first flysch, consisting of intercalations of purple coloured marly limestones, marls and sandstones. It constitutes a multi-folder, strongly fragmented formation, which, in places of strong relief, may produce landslide phenomena.

4 TECTONICS

Regarding tectonic conditions, it is noted that in the whole area Pindos tectonics predominates (Lekkas 1988a, b). Therefore, large flexuous folds in the main part of the village, where flysch formations are developed, are present. These folds are formed with an axis of a south – south-east to north – north-west direction and bed dips 30-35° towards either the WSW or the ENE. Furthermore, two main fault systems are observed. The first, of a NW-SE direction, formed along the fold axes, and the second, of a SE-NW direction, which contributes to the formation of the basic hydrographic axes and the main tectonic depressions of the area.

5 HYDROGEOLOGICAL CONDITIONS

Among the main parameters of the natural environment, hydrogeological conditions play a significant role.

Both the tectonic structure of the area and the presence of permeable (carbonate rocks) within practically impermeable formations (deposits of first flysch and flysch), result to the formation of contact springs, usually of significant discharge.

In addition, the presence of a weathering mantle and fragmentation zone of significant thickness results to the manifestation of either springs of significant discharge or seasonal springs, throughout the village.

Water from the springs directly permeates the

materials of the weathering mantle and the fragmentation zone, keeping them in a saturated condition and impairing their geomechanical behaviour.

6 SLOPE MOVEMENTS

The above mentioned conditions formulate an engineering – geological frame in which the manifestation of slope movements becomes quite probable. It must be noted that in most of the cases these movements are serious to very serious and refer to wide spread zones, locally extending to significant depths and affecting the upper fragmented layers of the basement formations.

In the central part (Fig. 2) of the village (main housing area) landslide phenomena are observed in both depressions (positions 2 and 3). Position 2 constitutes the northern and smaller depression and can be distinguished into two sections. The western section presents smaller dips and includes cultivated areas and a small number of houses. The eastern one presents strongly dipping slopes and is densely build. Basement formations (flysch and transition zone), covered by a thick weathering mantle structure the depression. Water from a number of springs flows into the area. Two landslides of minor importance are observed in the west side of the depression. However, landslides reported in older reports, in the elevation of 780-800m, do not seem to get activated. Today's landslides are observed in the elevation of 740m, acquiring a width of 50-60m and a leap of 10cm. This slide has destroyed a road and the yards of two newly build houses. Downward (elevation of 700-710m) these failures extend to cover all the depression. Successive fractures and slides, causing damages to houses, roads, etc. are observed in this area. Regarding the geometry of this slide, its confinement downwards and the formation of its toe in the area of the county road seems to be caused by the presence, in a small depth from the surface, of the formations of the transition zone. These formations, which form the previously mentioned anticline, prevent the sliding surface from reaching deeper horizons and act in a confined manner thus prohibiting the quick development of the phenomena. In addition, the tectonic structure of the area supports the manifestation of springs of significant discharge.

However, the most serious of the landslide phenomena are located in the southern, larger depression, where the largest part of both housing and agricultural activity also takes place.

Two extensive failure zones are encountered in this depression. The first, which starts from the forested area and reaches the cultivated area and the second, which immediately follows, and affects constructions, destroys houses and roads as it is developed in successive ruptures and slides.

From a geological point of view, flysch and formations of the transition zone structure the area of the depression. An anticlinal structure of the basement formations, certified in this area, results to a reduction of the thickness of flysch and to an approachement of the transition zone formations to the surface. This structure, which plays a significant role to the arrangement of the failure zones, is combined with synclinal ones both upwards and downwards. It is noted that a weathering mantle covers all the basement formations, with a thickness locally exceeding that of 15m, which constitutes the village's foundation material. The absence of any protective measure resulted to an evolution of the phenomena almost to the limit, with the formation of a unified sliding surface, which is manifested with a vertical main scarp of 7m and a horizontal shifting of 3m locally. This zone, with a mean lateral extension of 200m and a length of 500m, results to the development of a foot, and a subsequent accumulation area of 100x150m. The toe of the slide is formed in the cultivated area, while the sides are observed in the boundaries of the depression. Since the soil formations are continusly in a saturated condition the stability conditions are just on the limit. Any absense of the preventive factors, such as the anticlinal structure, which is formed immediately below the toe of the slide, the geological composition of the formations, etc., would have lead to the development of the failure into a form of soil liquefaction. However, such a danger is not absent, since any burdening of the area (e.g. dynamic loading) could neutralise the action of the preventive factors.

The other large landsliding zone includes all the individual fractures located just underneath the toe of the previous slide. These fractures create serious damages to a number of houses and/or shops, the main church of the village, as well as to a number of auxiliary buildings. This zone seems to be formed in the downward side of the anticlinal structure and acquires a greater mobility, since, in addition to the permeating water, also accepts the loading of the toe materials of the previous slide.

The seriousness of this zone is similar to the previous one, since the largest part of the village is located in this area. In addition, since its development is closely connected to that of the previous slide, the preventive measures should be unified for both slides.

Regarding the manifestation causes, these refer to the combination of the morphological conditions, as they are formed by the by the tectonic action in the area, the geological structure of the area, the non controlled runoff and finally the reduced geomechanical characteristics of the weathering mantle and the fragmentation zone.

The last slide, as far as the village area is concerned, is located in the eastern part of the housing

Figure 1. Map showing the geotechnical units of the area.

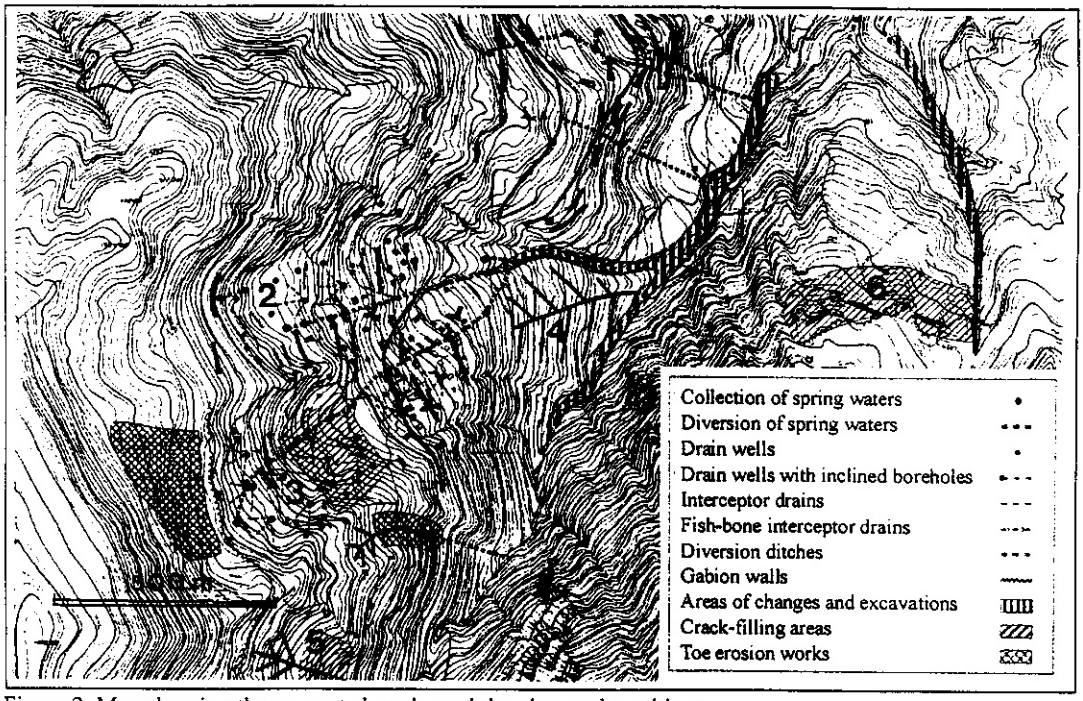

Figure 2. Map showing the suggested works and the observed postitions.

area, in a slope which is characterised by medium to strong dips and is formed as a continuation of the two depressions. Landslide phenomena in this area are old (Koukis 1979). Today, the are developed upwards and appear as successive fractures, with their upward boundary almost reaching the fringes of the housing area. They acquire a visible vertical main scarp of 1-1.5m, in the flysch weathering mantle of a thickness of some meters. This slide is mainly caused by the permeating water as well as by the action of water of the main and secondary water ravines of the area.

Landslide phenomena of a smaller importance (as far as safety of the village inhabitants is concerned) also occur in other places, around the main housing area (Fig. 2) and they affect agricultural roads (position 5), smaller housing areas (position 6) and finally the main county road (position 1).

7 PROTECTIVE MEASURES

Taking into account the above description of the slides and the general geotechnical setting, it is realized that, even in this stage, facing of the phenomena is possible. In most cases taking relatively simple and non-expensive measures can carry out such facing.

However, in the case of the main village, and especially that of the larger depression, the extensive, both in depth and area, failure zones have lead to a critical condition as far as stability is concerned. Therefore, the application of either usually very expensive measures or a decision to move the village to a safer place becomes absolutely necessary. The difficulty of applying measures which might lead to a change in land use, arises from both the presence of the relatively densely build area in the downward side of the depression and the presence of agricultural land.

Summarizing, the measures proposed in all cases refer to:

- retention of slopes by the construction of gabion walls,
- drainage networks and arrangement of surface waters in order to lead them out of the slopes,
- unloading the displaced deformed material, line and grade control for the formation of gentler slopes,
- development of drains in disturbed areas,
- local arrangement of the bed of both the main and secondary currents,
- dense plantation of both the unstable masses and the formed technical slopes,
- an extensive network of large diameter wells in both depressions, combined with inclined boreholes for the decrease of the water horizon and
- extensive water collection of any type of springs and outlets in both depressions.

8 CONCLUSIONS

Intense manifestations of landslides occur in the village of Ropoto (county of Trikala), which require either the immediate application of measures or movement of the village to a safe area.

It is believed that the above views concerning the stability conditions and the application of measures would greatly help towards the processes inhibition and the removal of the landslide manifestation causes, and therefore towards the reservation of the village. A right planning and a good application of the measures is necessary to this direction. Such an application must take place during a period of the year with favorable weather conditions.

It is noted that the economic and social consequences, as they arise from the application of all the measures, should be compensated with the consequences that would arise from the solution of moving the whole of the main village of Ropoto to a new, safer place. This last solution should be very carefully examined and applied in a case where construction of all the proposed measures for the prevention and facing of the phenomena would not be possible. The latter are very serious and present real and immediate danger for the lives of the inhabitants, in addition to material damages, serious or not, which are continuously caused.

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