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ABSTRACT

The inhabitants of a village situated in the southern side of România have sued juridical action the local mining company considering that the coal quarry and the new sterile dump situated near up the locality, are the main cause of the civil buildings damages. In order to establish the true causes of damages occurred in the village area a number of 129 buildings has been monitorised and 19 geotechnical drillings were dug surveying the ground structure. Inclinometric tests have been performed for one year in 15 boreholes spread on several profiles. A global stability analysis was performed as well. Our study pointed out that, despite the appearances, the damages are due to local previous landslides and inadequate foundation solutions.

KEYWORDS

Ground movement, mining works, damaged buildings, inclinometric tests, stability analysis.

INTRODUCTION

During the last ten years the "Motru Mining Company" opened and developed a new coal exploitation in the zone of "Valea Mânăstirii" village. The mining works mainly consist in a coal quarry (named Steic Microquarry) having a maximum depth of 40 m and a sterile dump with an average relative high of 23 m. Since five years ago, the inhabitants of above mentioned village reported to the local council, damages appeared in their buildings. Local authorities and the mining company representatives inspections pointed out that the bulk of civil constructions was hardly fissured. Four buildings were completely destroyed and demolished.
In 1995 at the request of the local mining company, a team of researchers from Technical University of Civil Engineering Bucharest, started to study the causes of buildings injuries. The research programme was performed until the end of 1996 and it consisted of complex geotechnical surveys including geotechnical boreholes (total length of 172 m hydrogeological surveys, inclinometric systematic measurements), laboratory geotechnical tests on ground samples. A number of 129 houses was subsequently inspected registering the types of damages, the history of their development and the main features of buildings foundations and structures. The investigated area had a surface of about 216 hectares. We, obviously begun the research by studying the previous geological and geotechnical investigation on which the mining works opening based. The preliminary conclusion reached from the above mentioned document was that the initial project assured enlarged enough safety areas around the mining works so that the village zone to not be influenced. However we started to verify again the general ground stability using the new data arising from the complementary surveys in order to establish the real cause of the buildings damages. A detailed description of our field and laboratory tests and of the data interpretation is further presented.

GEOLOGICAL AND GEOTECHNICAL ASPECTS

The "Valea Mânăstirii" village is situated in the southern part

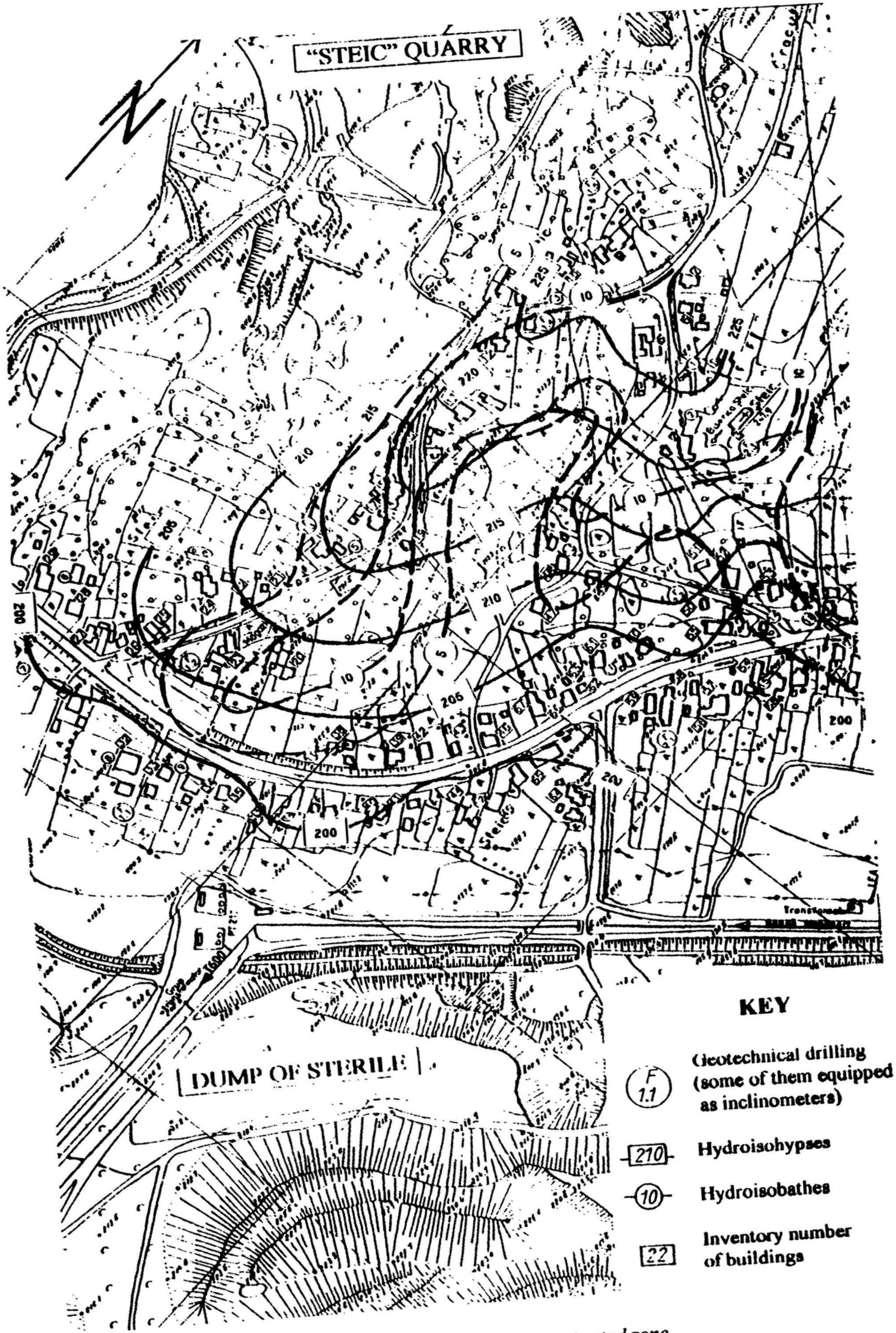

Fig. 1 Partial top view of investigated zone

of Romania, at about 300 km West from the capital city Bucharest. The village is located on northern bank of river Motru valley. The natural ground elevation varies among +200 m (above black Sea level), in the river Motru alluvial plane where the dump is erected, and about + 230 m at the hill top. Due to the space reasons Fig. 1 presents only a part of investigated area.

However we considered that the presented map is conclusive enough, being representative for the entire studied zone. The quarry (Photo 1.) is placed on a plateau situated at the hill top.

Photo 1 Steic quarry. General view

From it several coal layers are exploited, a part of the sterile ground has being deposited in the above mentioned dump body.

Within the village area the bank is characterised by an average slope of 1:5, greater to the superior side and in torrential valleys zones.

Our field investigation performed within the village area pointed out several local zones characterised by typical landslide morphology (waved ground surface, step free faces, depressed places with hydrophyle vegetation, inclined trees). By geological point of view, the cross sections based on the performed geotechnical drillings, emphases the bedrock (superior Pliocene as age), represented by successions of clayey and sandy layers, with coal intercalated strata, and Quaternary shallow deposits. Quaternary deposits are represented in the bank area through clayey and silty colluvial deposits. The drillings also pointed out alluvial deposits, mainly coarse in the alluvial plain and in the two buried terraces situated at the superior slope side. The main geotechnical parameters of the above mentioned deposits are presented in the table No 1.

HYDROGEOLOGICAL DATA

On September 10, 1996 we measured the piezometrical level of ground water in 29 domestic wells spread out on the village area. A part of this "water points" is presented in Fig. 1. Considering this investigation we were able to mark the lines of equal elevations of ground water level (hydroisohipses) and the lines of equal depths of ground water surface (hydroisobathes). Ground water surface is situated at depth, varying between less than 5 m (usually 2m) at the slope foot (southern side of build area) and more than 10 m to the hill top (northern side of the village). The general flow direction of ground water is from North to South being characterised by an average hydraulic gradient of 0.08. We

Table 1 Geotechnical characteristics of shallow deposits

Shallow deposits		I_P	I_C	w	n	γ	γ_S	ϕ'	C'
		(%)	-	(%)	(%)	KN/m^3	KN/m^3	(°)	kPa
Colluvial deposits	Clayey silt	20÷23	0.60÷0.70	19÷22	39÷47	16.5÷18.2	26.6÷26.8	17÷23	10÷30
	Silty clay	28÷32	0.50÷0.65	20÷28	38÷42	17.2÷19	26.7÷27	14÷17	25÷36
Alluvial deposits	Terrace deposits	-	-	16÷18	29.5÷30.5	18.1÷18.6	26.5	32÷36	0.0
	Alluvial plan deposits	-	-	22÷25	31÷36	17.8÷18.2	26.5	28÷33	0.0

The southern margin of the quarry is situated at more than 200 m from the nearest house, but in general, excavation begin to develop at an average distance of over 400m from the village limit. As we noted before, the dump is situated in the southern part of studied zone, on the alluvial plain of the river Motru. The minimal distance between the northern dump slope foot and the southern constructed area limit is about 120 m. (200 m in Fig. 1).

noted that within the village zone does not exist a continuous aquifer, the ground water being collected by the pervious horizons of bedrock and shallow deposits many times cut off by the colluvial clayey formations. This fact determines a low discharge of ground water from the slope area to the pervious deposits of river Motru alluvial plain, and consequently, the tendency of colluvial deposits to be saturated until the levels pointed out by the hydrogeological survey. It is very important to mention that due to the lack of a true drainage to the slope base the ground water levels are strongly influenced by the precipitation regime. Asking the inhabitants about the variations of ground water levels they observed in their domestic wells during the times, we established great amplitudes of piezometrical level (seasonal variations of 2 ÷ 4 m). The seasonal variations of ground water levels induce changes in the soil physical state and its mechanical behaviour. More sensitive in the repeating changes of the saturation degree are the colluvial soils on which the bulk of constructions is funded so that we concluded that this can be one of the causes of registered structure damages.

INCLINOMETRIC MEASUREMENTS

After performing 15 drilled -- holes, those were equipped as inclinometric well. A set of 5 inclinometric measurements was performed during the interval of May 22 ÷ October 15, 1996. The deformation registrations were made by SINCO digital device having an accuracy of 0.25 mm /m. A number of 6 inclinometric wells locations are pointed out in Fig. 1.
A special highlighting refers to the inclinometric F 1.1 and F 2.1 located in the relative plate zone, on the alluvial plain. The representatives of company that made the inclinometers were amazed when we designed the above mentioned locations, because they had used the methodology only in order to point out the ground movement in the slope area. We did not abandon the idea explaining them that is necessary to place a row of inclinometers parallel with the dump slope foot in order to verify if any eventual influence of the fill in ground movement exists. The lack of deformation registered in the above mentioned devices strongly confirmed that no influences of dump exist in constructed area. Even the case there was no influence of a mining work highlighted by inclinometric measurements. Only two inclinometers (F 1.2 and F 1.4) pointed out some displacements of the shallow part of colluvial deposits (Fig.2 and Fig.3). However, in the zones were inclinometers F 1.2 and F 1.4 were placed, our field investigations localised shallow landslides pointed out by specific morphological features as described in chapter 2.

SLOPE STABILITY ANALYSIS

Studying the general stability of the slope on which the village is located four calculus profiles were considered. In Fig.1 the positions of the first two sections are presented while in Fig. 4 and 5 respectively, the corresponding calculus profiles are shown. (Chirică et al. , 1996).
The possible slide surfaces were divided into three categories:

- long length sliding surfaces as 1.1, 1.3, 1.4, 2.1, 2.3 etc;
- medium length sliding surfaces as 2.2, 2.4 etc;
- short length sliding surfaces as 1.2, 2.5.

The stability analysis was performed in two steps as follows:
- back calculus for all considered sliding surfaces (19) in order to determine the most probable limit values of shear strength parameters in conditions of safety factor having the value 1.00 (Fig. 6 and Fig. 7);
- stability calculus for all considered sliding surfaces using the values of shear strength parameters obtained from back calculus on one hand and the values determined by laboratory tests on the other. Two assumptions regarding the piezometrical level were made;
Finally 240 calculus variants were took into account, corresponding to the 19 sliding surfaces analysed in the above mentioned conditions.

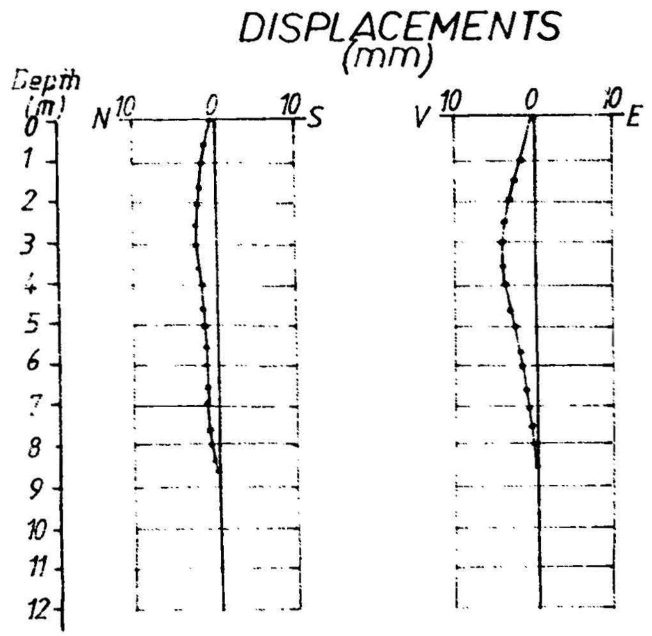

Fig. 2 Inclinometric measurements in the drilling F 1.2

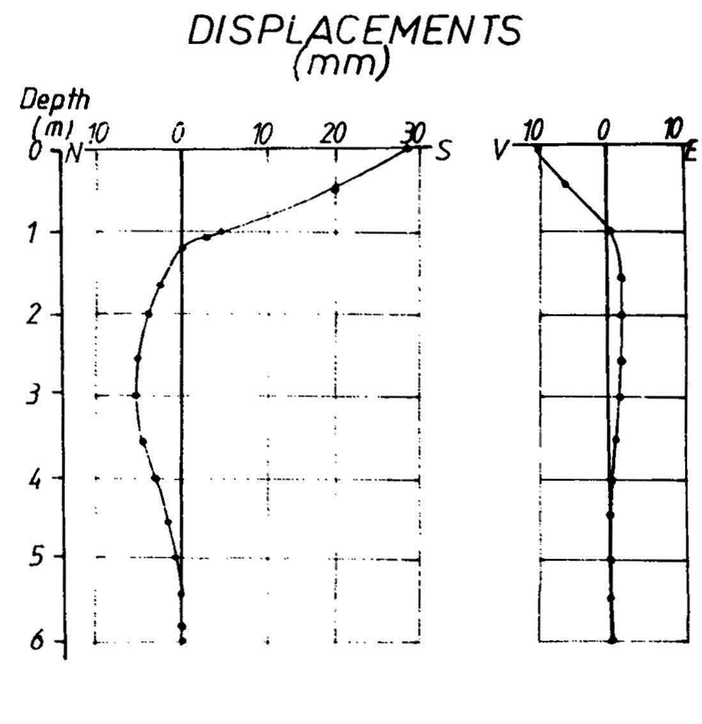

Fig. 3 Inclinometric measurements in the drilling F 1.4

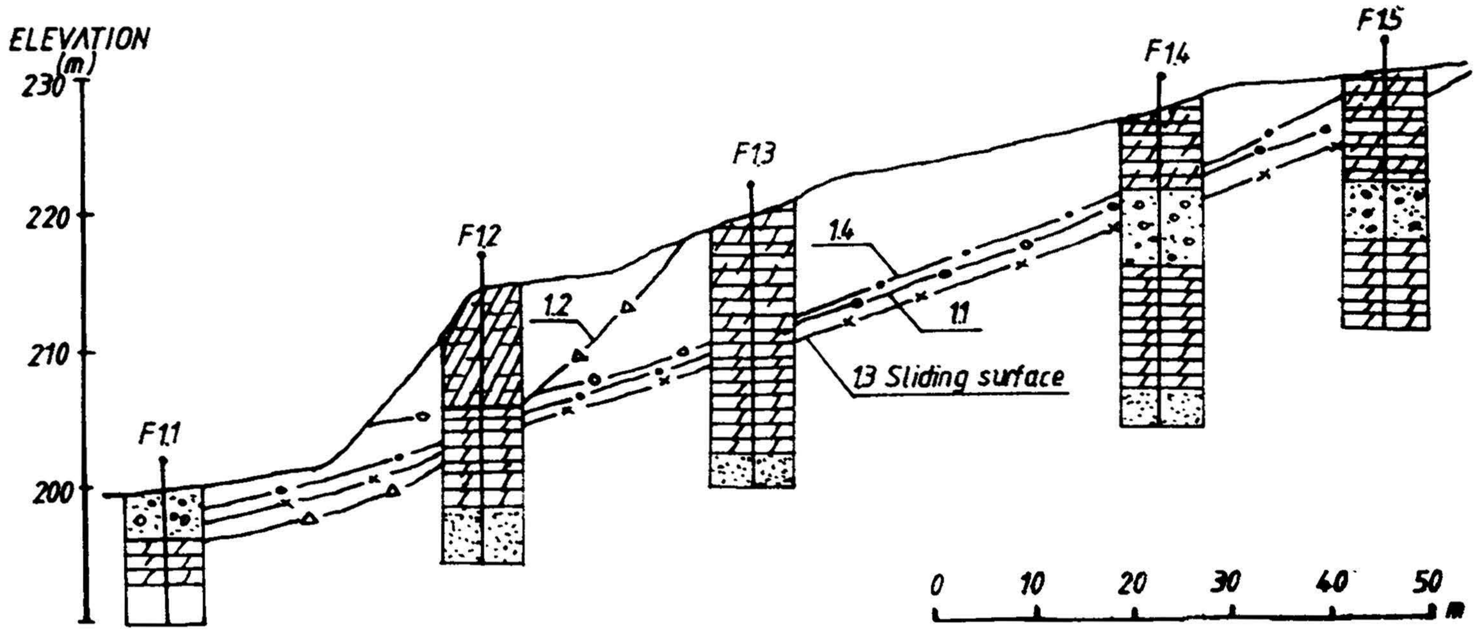

Fig. 4 Stability calculus profile 1 -1

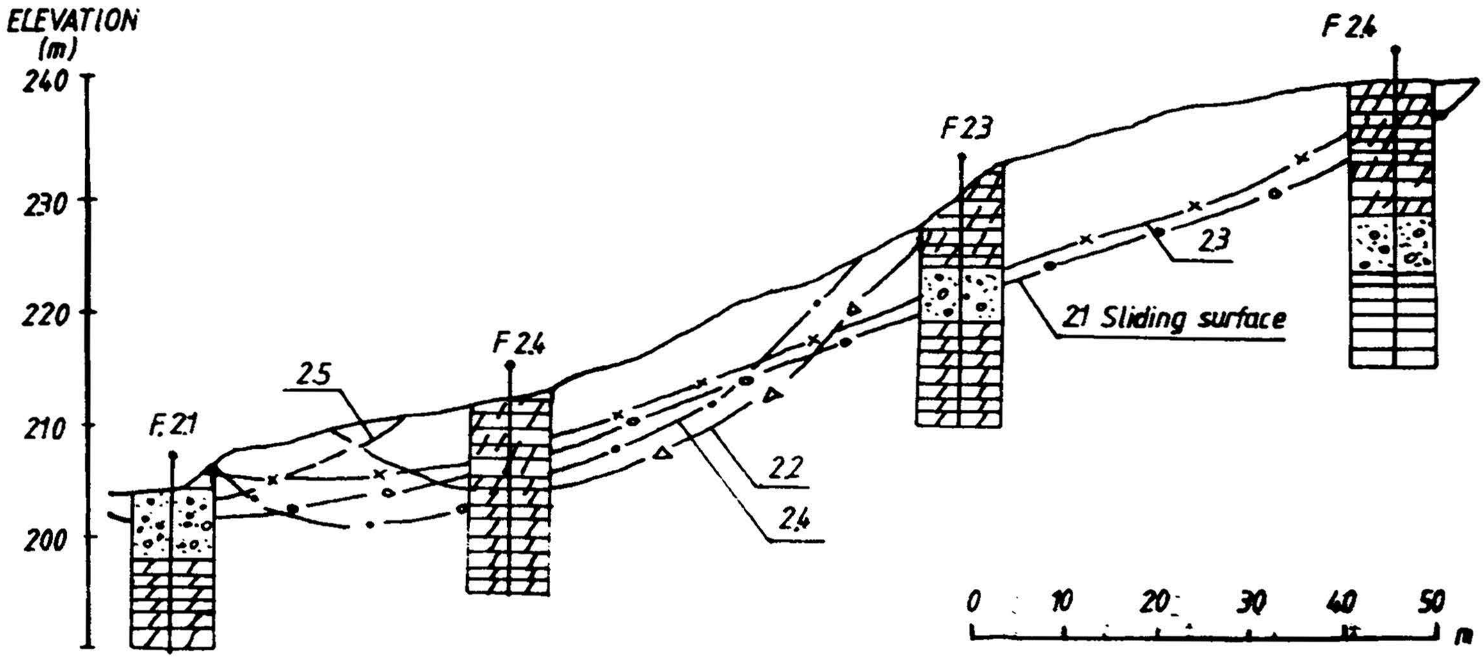

Fig. 5 Stability calculus profile 2 -2

The most probable values of shear strength parameters are confined in the interval 10° ÷ 17° for the friction angle and 0 ÷ 10 kPa for the cohesion. We also observed, from the diagrams presented in Fig. 6 and Fig. 7 that the long length sliding surfaces, characterised by the smallest values of shear strength parameters, are the most dangerous.

In the two calculus steps a STAB 1 numerical programme was used (Chirica, 1982) based on Fellenius method. The results of stability analysis are presented in table 2.

The analysis clearly emphasis that the studied slope are characterised by a natural instability potential.

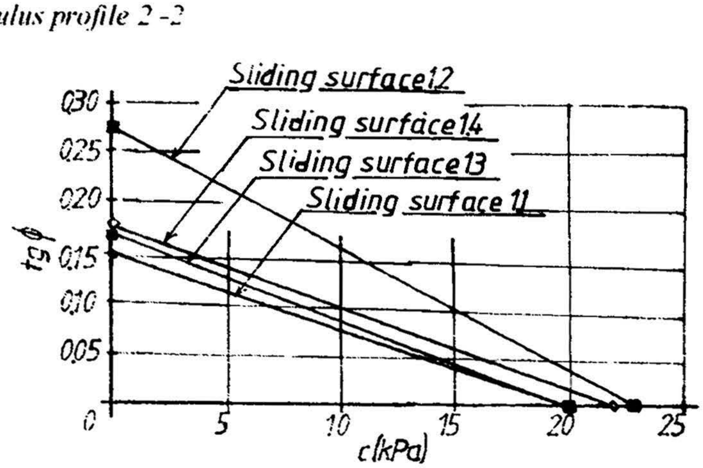

Fig. 6 Results of back analysis for the profile 1 - 1

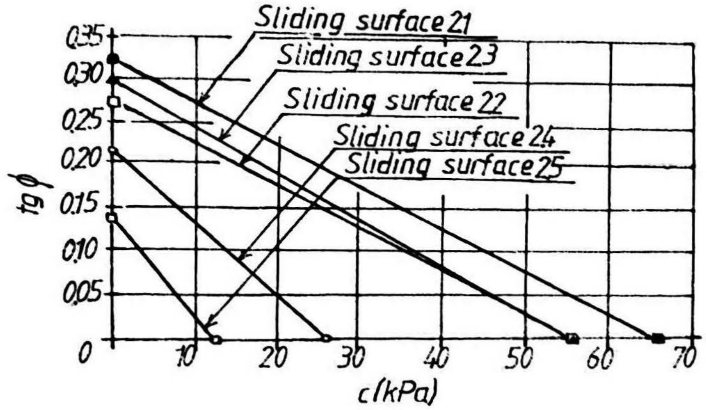

Fig. 7 Results of back analysis for the profile 2 - 2

The entire zone is affected by temporary stabilised landslides that can be reactivated when the ground water level rises or when the slope is overloaded by new built constructions. Although we did not performed stability calculus in dinamic conditions is also clear that the vibrations induced by the heavy trucks caring coal has a negative influence on the safety stability factor.

BUILDING DAMAGES INVENTORY

A number of 129 constructions were investigated in order to establish the constructive features, the damages types and their history. The inventory was completed with photos (Photos 2 and 3) and videotape registration.

Our investigations pointed out the following observations:

- A large number of houses are hardly damaged due to the phenomena specific to foundation on unstable ground. The structures injuries were amplified by several design and construction deficiencies and by the low quality of used construction materials;
- the buildings have, in general, a single floor and have structural walls made of brick masonry with lime mortar, wood or concrete blocks; the slabs are wood made;
- the utilised bricks are characterised by low quality being hand made and insufficiently burnt; moreover, the masonry is poorly executed, presenting regions with non interlaced joints partially filled with mortar (Photo 4);
- even the wood made buildings are the oldest they behaved best, presenting less damages than the others;
- the cracks are due, mostly, to the displacements recorded at foundation level, being in continuous evolution; the displacement triggering event is represented by the rainfalls.

Several types of damages were identified as following:

- cracks in walls, having inclined directions at the corners of the buildings, produced by local settlements of the foundation ground; the cracks are spreading becoming even wider and deeper in the foundations;
- breaks of walls and foundations due to global bending of the building, as a consequence of differential settlements,

Table 2. Safety factor values for analysed sliding surfaces

Failure surfaces	SAFETY FACTOR F_S VALUES FOR			
	ϕ=10°; c=0kPa	ϕ=10°; c=5kPa	ϕ=14°; c=0kPa	ϕ=17°; c=0kPa
1.1	0.40	1.40	-	-
1.2	0.70	0.84	0.90	1.06
1.3	0.65	1.30	-	-
1.4	0.60	1.20	-	-
2.1	0.30	0.60	0.75	0.90
2.2	0.40	0.70	0.83	1.00
2.3	0.40	0.70	0.85	1.00
2.4	0.55	1.05	1.11	-
2.5	0.76	-	-	-
3.1	0.40	0.80	0.84	1.01
3.2	0.33	0.67	0.75	0.90
3.3	0.30	0.62	0.70	0.83
3.4	0.30	0.65	0.70	0.83
4.1	0.30	0.54	0.72	0.80
4.2	0.30	0.50	0.60	0.75
4.3	0.40	0.72	0.82	0.99
4.4	0.40	0.72	0.82	1.00

Photo 2. Damages registered at building No. 14

- vertical shearing of structural and partition walls favoured by the non-existence of required differential settlements joints between parts of building erected at different times.

CONCLUSIONS

The complexe research performed in "Valea Mânăstirii" village zone, relived that the closely situated mining works (a coal quarry and a dump of sterile) do not influence the constructed perimeter.

A strong argument supporting the above conclusion is given by the lack of any deformation registered in the inclinometers placed around the village. The houses damages, sometimes very severe, are due, on a hand, to the foundation ground geotechnical features, and to the imperfections appeared during the buildings design and construction, on the other.

- the lack of differential settlements joints between the buildings parts erected in different stages;
- the low quality of construction materials and the superficiality of local builders that have not an adequate professional training.

Photo 3. Damages registered at building No. 53

Photo 4. Construction defects at the building No.49

The natural causes leading to the ground displacements are the followings:
- the slope where is the village location is affected by temporarily stabilised and shallow active landslides; seasonal variation of saturation degree determine at their turn, the local ground displacements characterised by reduced sliding velocities.

Inspecting 129 buildings the following main design and construction faults were pointed out:
- too shallow foundation works at depths smaller than 1 m, improper to the ground geotechnical conditions;
- actual tendency to construct brick and concrete blocks made buildings that through their greater weight overload the ground, leading to appreciable settlements and local reactivation of temporary stabilised landslides;

Our researches emphasised the fact that despite the appearances, the major economical and social problems appeared in the studied zone are not due to the mining works placed in village vicinity. The damages affecting the majority of buildings situated in "Valea Mânăstirii" village area emerge from constructive solutions improper to specific features of the foundations ground. So that, every case has to be separately treated after a detailed geotechnical survey in order to chose adequate remedial works and constructive solutions for the new buildings. Popular experience determined, in the past, the construction of wood made houses, lighter and more flexible, more suitable for the local geotechnical conditions. The nowadays tendency of replacing the traditional construction materials with heavier materials was proved this time rather improper.

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