Rudarsko-geološko-naftni zbornik | Vol. 4 | str. 51–58 | Zagreb, 1992.

UDC 624.131.38:526.918

Izvorni znanstveni članak

REPEATED PHOTOGRAMMETRIC MEASUREMENTS AT SHAPING GEOTECHNICAL MODELS OF MULTI-LAYER LANDSLIDES

Želimir ORTOLAN[1] and Jonatan PLEŠKO[2]

[1] Civil Engineering Institute of Croatia, Janka Rakuše 1, 41000 Zagreb, Croatia; [2] Faculty of Geodesy, Kačićeva 26, 41000 Zagreb, Croatia

Key-words: Repeated photogrammetric measurements, Displacement vector, Geotechnical models, Multi-layer landslides.

Repeated photogrammetric measurements are a valuable source of »conserved« information during final shaping of geotechnical models of complex multi-layer landslides. Photogrammetric measurements of a sequence of detailed unchanged points enable establishing the clear limit between the moved and stable parts of the terrain. The paper provides a number of practical and theoretical findings resulting from an adequate interpretation of photogrammetric measurements made on a thoroughly analyzed landslide where a three-level slide was observed. The results obtained indicate that the method used in this paper should be adopted as a standard procedure.

Ključne riječi: Opetovana fotogrammetrijska mjerenja, Vektor pomaka, Geotehnički model, Višeslojno klizište.

Opetovana aviosnimanja dragocjeni su izvor »konzerviranih« podataka pri konačnom oblikovanju geotehničkih modela složenih višeslojnih klizišta. Fotogrametrijska mjerenja na nizu detaljnih nepromjenjenih točaka omogućuju jasna razgraničenja kretanih od nepokrenutih dijelova terena. U radu je prikazan niz praktičnih i teoretskih saznanja omogućenih adekvatnom interpretacijom rezultata fotogrametrijskih mjerenja na detaljno istraženom klizištu s utvrđenim klizanjem u tri nivoa. Polučeni rezultati istraživanja ukazuju na potrebu uvođenja primjenjene metode u tretiranju predmetne problematike, kao standardnog postupka.

Introduction

Stability analyses are preceded by shaping of geotechnical models. An adequate geotechnical model is the basic precondition for the successful stability analysis and for the efficient landslide improvement. Deep landslides are particularly complex since clear discontinuities of minimum shear resistance parameters can not be determined in advance. The problem becomes even more complex in the case of landslides composed of several layers (multi-layer landslides). In such situations, geotechnical model solutions may be so imaginative that their reliability may become questionable. It is in such cases that the old and the repeated aerial survey prior and after the landslide activation may prove valuable. Donassy (1984) stresses the significance of using the old aerial photos representing the »conserved« state, as well as the possibilities of their multidisciplinary use.

The possibilities of photogrammetric measurement of a number of detailed points, whose configuration remained unchanged in the studied period, will be presented on an example of landslide situated in Podsused near Zagreb.

Brief landslide description

The cement plant »Croatia« (later called »Sloboda«) was first opened in 1908 in the locality of Podsused. This plant was closed in 1988 after the authors of this paper proved that the plant is located on a large landslide (Ortolan et al., 1987).

An area of approx. 1.2 km^2, where roughly 500 residential and industrial structures are located, is influenced by sliding of the sides and north part of the Kostanjek open-cast mine. It was established that the landslide is of three-layer type. The maximum depth of the deepest sliding surface is about 90 m, the depth of the intermediate sliding surface is 65 m, while the superficial sliding surface is about 50 m deep. The total rock mass movement amounts to approx. 32.6×10^6 at the deepest sliding surface, while it is about 12.8×10^6 at the intermediate sliding surface and about 7×10^6 at the superficial sliding surface. Sliding surfaces are subparallel, they coincide with the position of the layer discontinuities and follow the structural-tectonic elements.

1963 was adopted as the year in which the landslide first started, since it is then that some greater damages of structures at the old part of the plant (at the foot of the landslide) were observed.

Approx. 2.1×10^6 m^3 of marl was excavated at the foot of the landslide from the time the plant exploitation started to the year of 1963. The volume of the foot part of the landslide was further reduced by 3.2×10^6 until 1988 when the plant was closed.

The landslide geometry, the state of pore pressures on sliding surfaces and shear resistance parameters were determined with the high level of accuracy. A detailed view of the landslide is presented in figure 1. The characteristic engineering geological cros-section A-A' is presented in figure 2. A detailed explanation of geotechnical zones including the procedure for determining zones of minimum shear resistance parameters is given by Ortolan (1990).

Due to the vastness and complexity of the approach to the complete geotechnical model forming, this review will only be limited to the contribution of photogrammetric measurements to such problem solving.

Approach to problem solving

Horizontal landslide displacement amounting to approx. 3 m (fig. 1) was discovered in 1985 on a

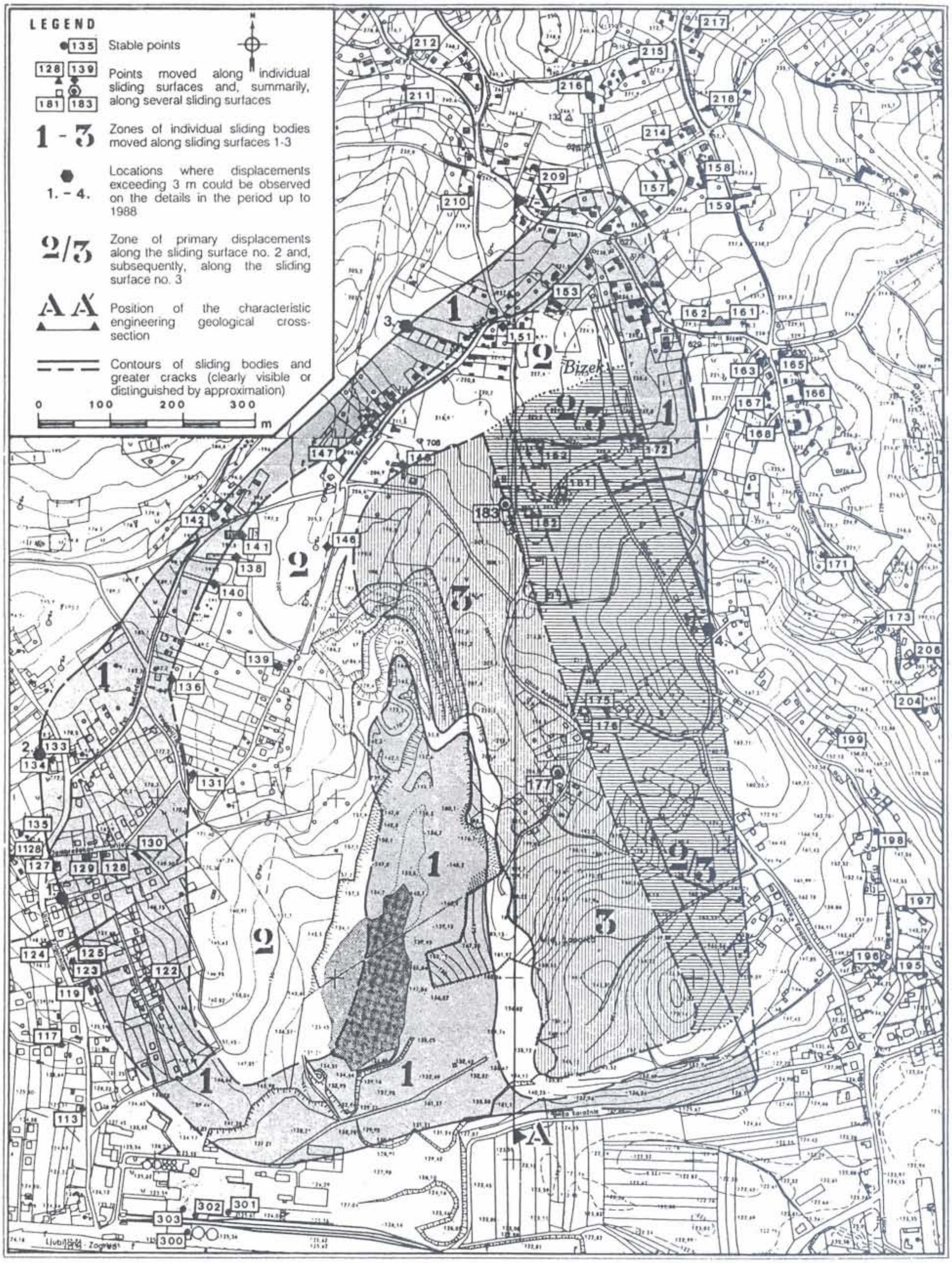

Fig. 1 T.C. »Sloboda« landslide with the location of detailed photogrammetric points

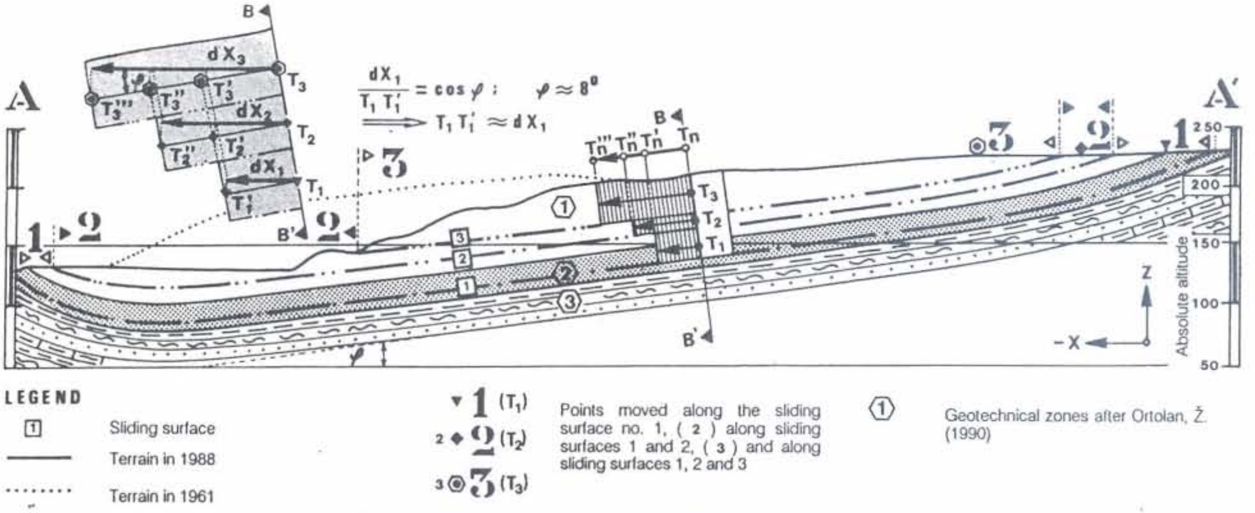

Fig. 2 Characteristic engineering geological cross-section A–A'

number of observed points. Due to the size of displacement and to the fact that aerial surveys from 1963 and 1985 were available, an attempt was made to make a distinction between the landslide and the unmoved part of the terrain by photogrammetric measurement on a number of detailed points. It was established through survey and photosketches made on a large scale that the aspect of points remained unchanged. Displacement values for detailed points (details of structures – house ridges, piers, foundations etc.) were derived from the differences of coordinates of the same points obtained by block aerial triangulation of aerial photographs from the above mentioned years. It was established that the values of displacement vectors from different parts of the sliding body do not coincide, while the more detailed engineering geological investigations pointed to the presence of several sliding surfaces – as shown by Ortolan (1990). The scope of photogrammetric measurements was then widened so that the same and a number of new points from 1979, 1981 and 1988 were measured.

In the first step, the depth of all three sliding surfaces was determined and the structural tectonic structure of the terrain was established. Theoretical sectional lines of the planes of sliding surfaces and of the ground surface were established. Field investigations have shown that collapsed or badly damages structures are located precisely on these sectional lines or very close to such lines. In other parts of sliding bodies, the structure were displaced without visible damages. At that time, geotechnical model was already quite clear, but it seemed to be too complex.

Location of detailed points covered by photogrammetric measurements is shown in figure 1.

Figure 2 shows movements of individual points in sliding bodies 1–3. Three points (T_1, T_2, T_3) in the B–B' cross-section were observed. If we assume that the sliding bodies move as rigid blocks, then these points also indicate the itinerary of individual points on the ground surface.

Plane displacement vectors in the X–Z vertical plane are presented in the picture. Their horizontal and vertical components were measured photogrammetrically. Horizontal components were determined with greater accuracy since they were to be used in the following stage of the analysis. Figure 2 shows relationship (1–3) between displacements that occurred, for instance, in 1985 and those from the »zero survey« made in 1963.

$$T_1 T_1' (\text{'}85) = dX_1 (\text{'}85) \quad (1)$$

$$T_2' T_2'' (\text{'}85) = dX_2 (\text{'}85) - dX_1 (\text{'}85) \quad (2)$$

$$T_3'' T_3''' (\text{'}85) = dX_3 (\text{'}85) - dX_2 (\text{'}85) \quad (3)$$

At that, dX_{1-3} are photogrammetrically measured summary horizontal components of the displacement vector of points located in the X–Z plane. Corresponding relations are valid for any other year observed in relation with the »zero year« of 1963. The difference (4)

$$T_2' T_2'' = T_2' T_2'' (\text{'}88) - T_2' T_2'' (\text{'}85) \quad (4)$$

represents the partly realized displacement of field points along the sliding surface no. 2, while the difference (5)

$$dX = dX_2 (\text{'}88) - dX_2 (\text{'}85) \quad (5)$$

represents the summarily realized displacement of field points along sliding surfaces 1 and 2. Similar relations are also valid for the summarily or partly realized displacements along the sliding surface no. 3, while the summary displacement for the sliding surface 1 is equal to the partial displacement.

The displacement of characteristic details according to aerial surveys made in 1963 and 1988 are shown in figure 3.

Measurement results and their interpretation

The main data base contains more than 100 points. Average errors in displacement measurement were calculated using standard geodetic procedures (Klak, 1982). In order to obtain a more realistic estimate, 45 points situated outside of the sliding body (where there is no displacement) were defined (table 1). Since their location is fixed for all annual aerial surveys, it is possible to conclude from the average values of components of plane displacement

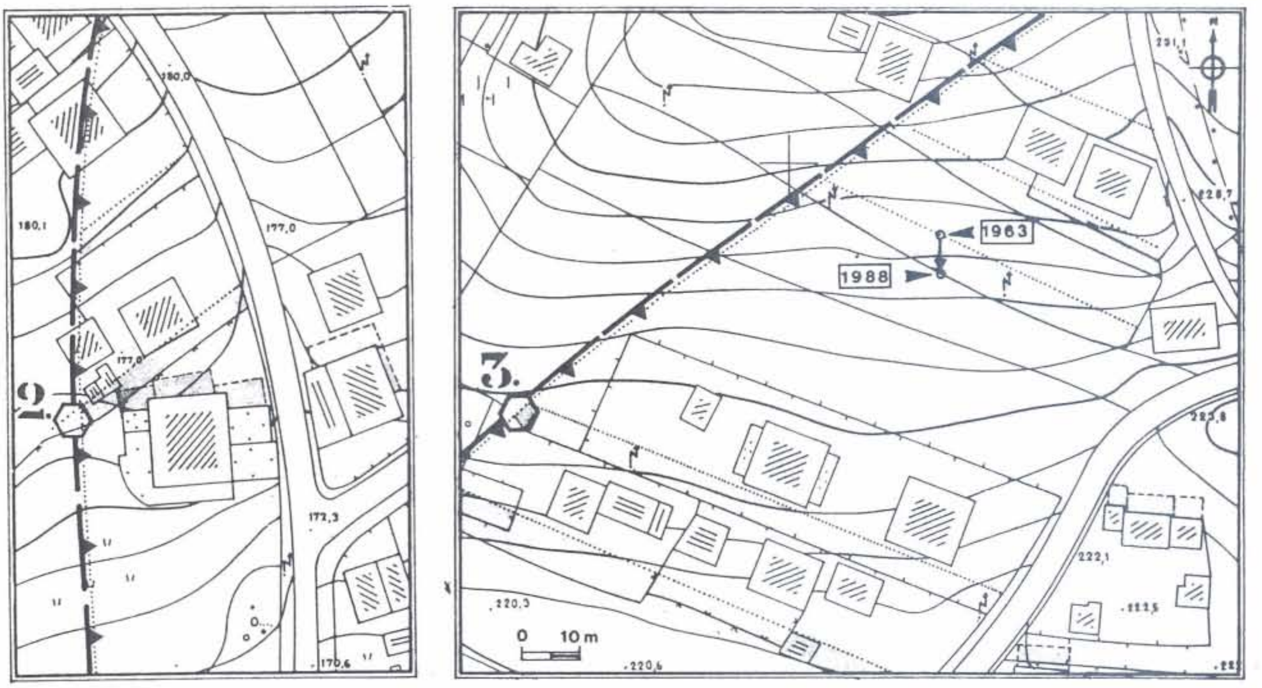

Fig. 3 Displacements of characteristic details defined on the basis of aerial surveys performed in 1963 and 1988 (zones around points 2 and 3 from figure 1)

vectors in horizontal plane that the most accurate measurements were made in 1985 and 1988. It was established that the measured displacements on the moved points practically spread for north towards south. The above facts indicate that the horizontal component of the displacement vector dX well represents the value of the spatial displacement vector.

Table 2 shows the calculation of average values of the measured summary horizontal components of the displacement vector (dX) on a number of detailed landslide points for the years 1985 and 1988, as compared to the state in 1963. The same data are graphically presented in the diagram given in figure 4. It is evident that the behavior of the groups of points is quite similar, within limits of the accuracy of measurement. The location of points is presented in figure 1. Unfortunately, the entire landslide surface is not uniformly covered by an adequate number of points since the configuration of many points changed or they were destroyed due to the great time gap (1963–1985/88).

The activity of individual sliding bodies, based on average values from table 2, is presented in table 3.

Conclusion

Repeated photogrammetric measurements constitute a valuable source of information in the process of shaping the engineering-geology and geotechnical models and in investigation of even the most complex landslides.

During study of the deep and spacious multi-layer landslides (particularly those situated in urban areas) through the block triangulation of aerial photographs taken in different years, numerous precise data, indications and logical assumptions may be obtained:

- delimitation of the displaced from the stable parts of the ground,
- delimitation of individual areas characterized by different displacement values at complex multi-layer landslides,
- logical explanation of the behavior mechanism of individual sliding bodies at complex landslides as well as reconstruction of the sequence of landslide-related events,
- activity of individual sliding bodies in the period between the two subsequent aerial surveys,
- indications on the position and shape of sliding surfaces or sliding zones.

A particular advantage of the old repeated photogrammetric surveys resides in the fact that the complex landslides may be studied despite the great time distance, i.e. in the period when the landslide has not as yet been determined. Furthermore, only the shallowest sliding surfaces (zones) may be determined using conventional methods (inclinometer measurements). In addition, thin clayey intercalations of up to several centimeters in thickness can not practically be registered on the basis of the borehole data, if there are no thicker continuous zones having low shearing resistance parameters.

The abundance of information, the possibility of reconstructing geotechnical model of even the most complex landslides and the sufficient accuracy of the method are the main points in favor of the use of the repeated photogrammetric measurements. It should however be noted that the basic preconditions for using this method are the availability of the aerial survey data from several years and the sufficient displacement values so as to enable sufficient accuracy of measurement.

Once reconstructed, geotechnical model enables rational positioning of a minimum number of geodetic points on the surfaces of individual sliding bodies and their observation from stable points using conventional geodetic procedures.

Table 1 – Photogrammetric measurements of displacement vector components (dX, dY) made at stable detailed points

Point No.	Displacement vector components in horizontal plane (m)							
	1963–1979		1963–1981		1963–1985		1963–1988	
	dY	dX	dY	dX	dY	dX	dY	dX
113	−0,157	−0,343	−0,097	−0,313	−0,082	−0,076	−0,137	−0,303
117	−0,125	−0,713	−0,035	−0,583	−0,029	−0,436	−0,025	−0,543
119	−0,949	−0,859	−0,279	−0,389	−0,258	−0,124	−0,319	−0,339
123	−0,315	−0,733	−0,295	−0,303	−0,223	−0,218	−0,405	−0,053
124	−0,278	−0,629	−0,228	−0,309	−0,132	−0,299	–	–
125	−0,344	−0,503	−0,254	−0,163	−0,056	+0,107	−0,294	−0,073
135	−0,380	−0,654	−0,220	+0,236	−0,169	+0,050	−0,310	−0,244
157	−0,262	−0,211	–	–	+0,315	−0,436	–	–
158	−0,455	+0,160	–	–	+0,248	−0,209	–	–
159	−0,505	+0,327	–	–	+0,235	−0,060	–	–
161	−0,403	−0,062	–	–	+0,018	−0,077	−0,123	+0,068
162	−0,273	−0,414	–	–	−0,034	−0,304	−0,123	−0,214
163	−0,307	−0,099	–	–	−0,064	+0,242	−0,047	+0,091
165	−0,303	−0,100	–	–	+0,230	+0,026	−0,143	+0,590
166	−0,332	−0,293	–	–	+0,044	−0,093	−0,132	+0,595
167	−0,316	−0,606	–	–	−0,031	−0,136	−0,276	−0,466
168	−0,378	−0,589	–	–	−0,175	−0,360	−0,298	−0,459
171	−0,738	−0,472	–	–	−0,300	−0,559	–	–
173	−0,878	−0,740	−0,978	−0,660	−0,546	−0,414	−0,648	−0,370
195	−0,799	−0,496	−0,979	−0,416	−0,671	−0,295	−0,669	−0,356
196	−0,675	−0,357	−0,715	−0,157	−0,584	+0,033	−0,535	−0,047
197	−0,736	−0,168	−0,546	−0,058	−0,668	+0,011	−0,356	−0,088
198	−0,601	−0,289	−0,591	−0,259	+0,153	−0,395	−0,461	−0,019
199	−0,437	−0,343	−0,477	−0,393	+0,399	−0,537	−0,167	−0,563
204	−0,892	−0,450	−0,892	−0,320	−0,016	−0,408	−0,692	−0,110
205	−0,760	−0,200	−0,720	−0,240	+0,271	−0,320	−0,730	−0,140
206	−0,325	+0,106	−0,315	−0,146	+0,633	+0,136	−0,305	+0,206
209	–	–	–	–	−0,027	+0,274	–	–
210	–	–	–	–	+0,109	−0,211	–	–
211	–	–	–	–	−0,360	−0,292	–	–
212	–	–	–	–	−0,062	−0,197	–	–
213	–	–	–	–	+0,238	−0,244	–	–
214	–	–	–	–	−0,030	−0,101	–	–
215	–	–	–	–	+0,100	+0,407	–	–
216	–	–	–	–	−0,062	+0,270	–	–
217	–	–	–	–	−0,207	+0,239	–	–
218	–	–	–	–	+0,040	+0,082	–	–
300	−0,371	−0,499	−0,291	−0,129	−0,536	−0,102	−0,381	−0,449
301	−0,294	−0,942	−0,184	−0,512	−0,067	−0,551	−0,314	−0,712
302	−0,526	−0,517	−0,416	−0,237	−0,342	−0,255	−0,606	−0,517
303	−0,243	−0,843	−0,143	−0,483	+0,179	−0,536	−0,053	−0,663
308	−0,410	+0,340	–	–	−0,240	+0,180	−0,035	+0,042
309	−0,230	+0,110	–	–	−0,030	+0,680	−0,067	+0,216
310	−0,190	+0,380	–	–	–	–	−0,181	−0,075
1128	−0,376	−0,440	−0,286	−0,230	−0,269	+0,112	−0,246	+0,030
Average Value	−0,44	−0,34	−0,42	−0,27	−0,07	−0,10	−0,30	−0,16

Table 2 – Average values of the summary horizontal displacement vector components (dX) at detailed points of the landslide

Point No.	Summary displacement along the sliding surfaces ⟶ – dX (m)							
	dX_1		dX_2		dX_2/dX_3		dX_3	
	1963–1985	1963–1988	1963–1985	1963–1988	1963–1985	1963–1988	1963–1985	1963–1988
122	2,752	2,968						
127	2,556	3,144						
128	3,027	3,629						
129	2,482	3,017						
130	3,047	3,732						
133	3,385	3,891						
134	2,607	3,344						
142	3,055	3,823						
153	3,289	3,688						
131			3,498	4,343				
136			3,563	4,441				
138			3,658	4,453				
139			3,491	4,429				
140			3,325	4,128				
141			3,626	4,070				
146			3,489	4,008				
147			3,557	4,124				
148			3,876	4,542				
151			4,038	4,663				
152					4,433	4,959		
175					4,531	5,049		
176					4,572	5,177		
181					4,539	5,212		
182					4,588	5,214		
177							5,078	Destroyed
183							5,206	6,087
Average Value (dX)	2,911	3,471	3,612	4,320	4,533	5,122	5,142	6,087

Table 3 – Activities of individual sliding bodies determined on the basis of average values from tab. 2

Year	Average summary displacement values (m)			Partial displacement along individual sliding surfaces (m)		
				1	2	3
	dX_1	dX_2	dX_3	$T_1T_1' = dX_1$	$T_2'T_2'' = dX_2 - dX_1$	$T_3''T_3''' = dX_3 - dX_2$
1963.–1985.	2,911	3,612	5,142	2,911	0,701	1,530
1963.–1988.	3,471	4,320	6,087	3,471	0,849	1,767
Difference 1988.–1985.	0,560	0,708	0,945	0,560	0,148	0,237

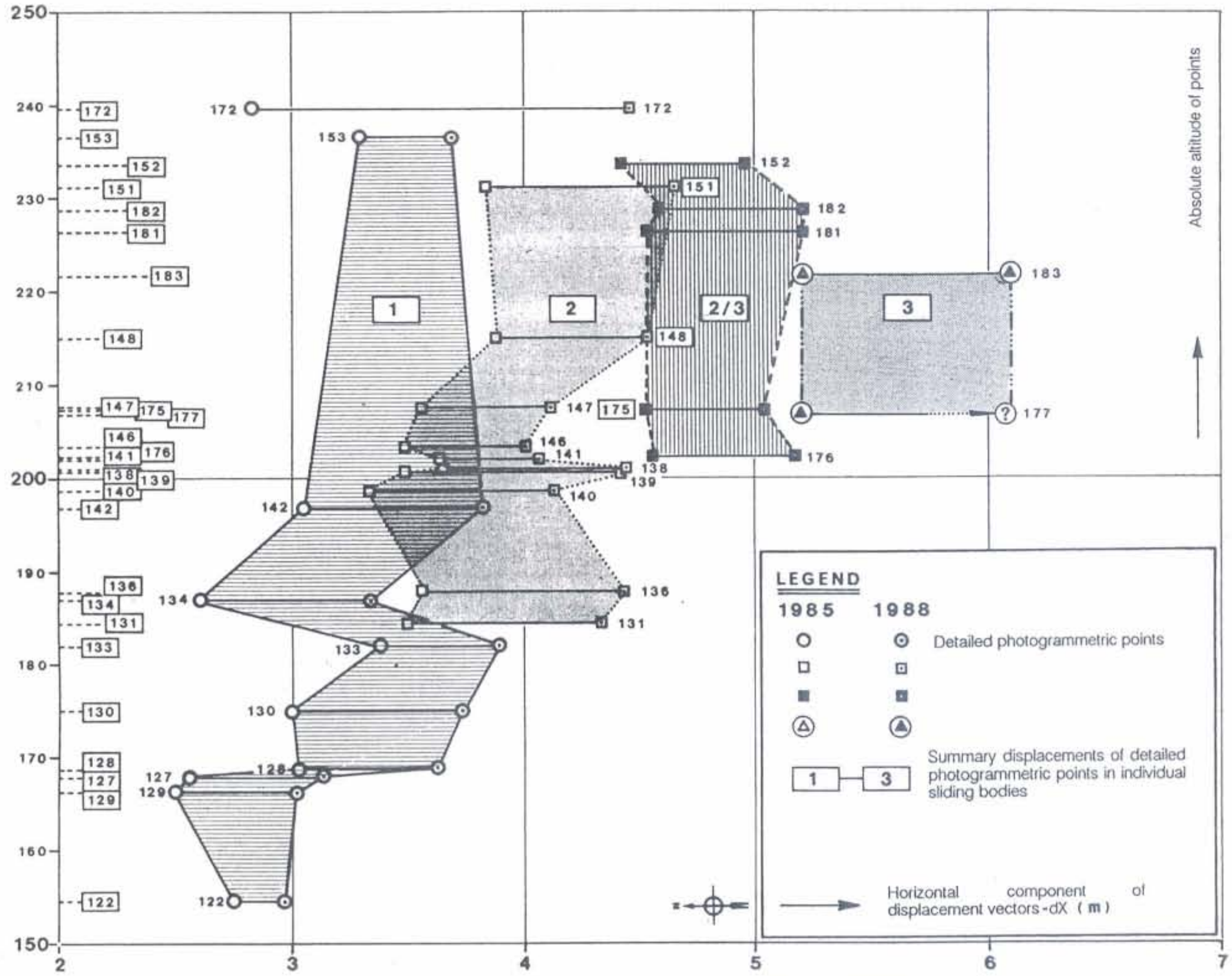

Fig. 4 Diagram of summary horizontal components of displacement vectors (dX) of detailed photogrammetric points for 1985 and 1988

Although this paper concentrates on the plane aspect of displacement, it should be stressed that spatial displacements may also be calculated using a very simple procedure.

An average measurement error should be evaluated on the basis of photogrammetric measurements of detailed points that have not been moved.

Received: 19. XII. 1991.

Accepted: 9. VI. 1992.

REFERENCES

Donassy, V. (1984): Daljinsko istraživanje u prostornom planiranju – korištenje starog materijala (Aerial Survey in Spatial Planning – The Use of the Old Material). *Zbornik radova Geodetskog fakulteta Sveučilišta u Zagrebu* (Proc. Faculty of Geodesy – University of Zagreb), Sv. *26,* Zagreb.

Klak, S., (1982): Teorija pogrešaka i račun izjednačenja (Theory of errors and calculation of balance state). Geodetski fakultet Sveučilišta u Zagrebu (Faculty of Geodesy – University of Zagreb), Sveučilišna naklada Liber: 345 p., Zagreb, Croatia.

Ortolan, Ž., (1990): Le rôle de la mèthode de corrèlation dans la dètermination des zones de paramètres minimaux de rèsistance au cisaillement. Proceeedings of the 6th International Congress IAEG: 1675–1679, Amsterdam, the Netherlands.

Ortolan, Ž., Stanić, B., Nonveiller, E. & Pleško, J. (1987): Posljedice rudarenja u laporolomu »Kostanjek« – Podsused (Consequence of mining in the marl deposit »Kostanjek« – Podsused). Zbornik simpozija o hidrogeologiji i inženjerskoj geologiji 2 (Proceedings of the 9th Yugoslav symposium on hydrogeology and engineering geology 2), 117–128, Priština, Yugoslavia.

Opetovana fotogrametrijska mjerenja pri oblikovanju geotehničkih modela višeslojnih klizišta

Ž. Ortolan i J. Pleško

Analizama stabilnosti prethodi oblikovanje geotehničkih modela. Korektan geotehnički model osnovni je preduvjet uspješnih analiza stabilnosti i sanacije klizišta. Posebno su složena duboka klizanja, gdje apriori nije moguće utvrditi jasne diskontinuitete minimalnih parametara otpornosti na smicanje. Problem se višestruko komplicira ukoliko se radi o klizanjima u više nivoa (višeslojna klizišta). U takvim slučajevima rješenja geotehničkih modela mogu biti maštovita do granica neuvjerljivosti. Tada mogu biti dragocjena stara opetovana aviosnimanja prije i nakon aktiviranja klizišta. Na značaj korištenja starih aerosnimaka i mogućnost njihove multidisciplinarne primjene upućuje Donassy (1984), istražujući mogućnosti njihove upotrebe u prostornom planiranju. Mogućnosti upotrebe fotogrametrijskih mjerenja na nizu detaljnih točaka, koje u promatranom periodu nisu mijenjale svoju konfiguraciju, prikazane su na primjeru klizišta u Podsusedu kraj Zagreba.

U Podsusedu je 1908. g. puštena u rad tvornica cementa »Croatia« d. d., kasnije nazvana T. C. »Sloboda«. Radom je prestala 1988. g., nakon što je istraživanjima predmetnog područja dokazano klizanje velikih razmjera (Ortolan et al., 1987).

Klizanjem bokova i sjevernog zaleđa površinskog kopa »Kostanjek« zahvaćeno je područje površine oko 1,2 km^2 s oko 500 stambenih i gospodarskih objekata. Utvrđeno je klizanje u tri nivoa. Maksimalna dubina najdublje klizne plohe je oko 90 m, srednje oko 65 m i najpliće oko 50 m. Ukupno je u pokretu po najdubljoj kliznoj plohi oko 32,6$\times 10^6$ m^3, po srednjoj oko 12,8$\times 10^6$ m^3, a po najplićoj oko 7$\times 10^6$ m^3 stijenske mase. Klizne plohe su subparalelne i koincidiraju s položajem slojnih diskontinuiteta, prateći strukturno-tektonske elemente. Kao početak klizanja usvojena je 1963. godina, od kada datiraju veća oštećenja na objektima starog pogona tvornice, u nožičnom dijelu klizišta. Od početka rada tvornice do 1963. g. iskopano je oko 2,1$\times 10^6$ m^3 lapora u nožici (stopi) klizišta. Do zatvaranja tvornice 1988. g. smanjen je volumen nožičnog dijela klizišta za daljnjih 3,2$\times 10^6$ m^3.

Geometrija klizišta, stanje pornih pritisaka na kliznim plohama i parametri otpornosti na smicanje utvrđeni su s visokim stupnjem korektnosti. Detaljni prikaz površine klizišta prikazan je na slici 1. Na slici 2. prikazan je karakteristični inženjerskogeološki profil A–A'. Detaljno obrazloženje geotehničkih zona s načinom utvrđivanja zona minimalnih parametara otpornosti na smicanje dao je Ortolan (1990).

Obzirom na opsežnost i složenost pristupa oblikovanju cjelovitog geotehničkog modela, ovaj rad ograničen je na korištenje fotogrametrijskih mjerenja u tretiranju ove problematike.

Veličine pomaka detaljnih točaka (detalji objekata – sljemena kuća, stupovi, temelji, itd.) određene su iz razlike koordinata tih točaka dobivenih blokaerotriangulacijom aerosnimaka za više godišta snimanja. Korištene su samo detaljne točke, koje nisu mijenjale izvornu konfiguraciju.

Na slici 1. prikazan je položaj detaljnih točaka, na kojima su izvršena fotogrametrijska mjerenja.

Na slici 2. prikazan je način kretanja pojedinih točaka u kliznim tijelima 1–3. Promatrane su točke (T_1, T_2, T_3) u presjeku B–B'. Uz pretpostavku da se klizna tijela kreću kao kruti blokovi, ove točke opisuju i putanje pojedinih točaka na površini terena. U konkretnom slučaju pokazano je da horizontalne komponente vektora pomaka u ravnini X–Z (dX) dovoljno dobro aproksimiraju putanje prostornih vektora pomaka, za koje su izvedene i odgovarajuće jednadžbe.

Na slici 3. prikazani su pomaci detalja na osnovu aerosnimanja iz 1963. i 1988. g.

U tablici 1. prikazane su fotogrametrijski izmjerene komponente vektora pomaka u ravnini X–Y (dX, dY), na stabilnim detaljnim točkama. Time je utvrđeno da su horizontalne komponente vektora pomaka dX najkorektnije za godišta snimanja 1985. i 1988., koje su dalje korištene za oblikovanje geotehničkog modela.

U tablici 2. prikazan je proračun srednjih vrijednosti utvrđenih sumarnih horizontalnih komponenata vektora pomaka (dX) na detaljnim točkama u klizištu. U tablici 3. pokazan je proračun aktivnosti kliznih tijela duž pojedinačnih kliznih ploha, na osnovu srednjih vrijednosti iz tablice 2.

Na slici 4. prikazan je dijagram sumarnih horizontalnih komponenti vektora pomaka (dX) detaljnih fotogrametrijskih točaka za 1985. i 1988. g.

Tri grupe pomaka, međusobno različitih ali ujednačenih unutar grupa (najmanji pomaci na periferiji, najveći pomaci pri središnjem dijelu klizišta), pokazuju da se radi o klizanju po tri klizne plohe.

Međusobno bliske točke, različitih veličina pomaka, u raznim dijelovima klizišta, svojim položajima potvrđuju tezu da su klizne plohe slijedile međuslojne diskontinuitete s minimalnim parametrima otpornosti na smicanje.

Ponašanje grupe točaka (152–182, tablica 2) pokazuje da su se pojedini blokovi (slika 1) namještali s retardacijom. To pokazuje i ponašanje točke 172 (slike 1 i 4), koja se u prvoj fazi očito pomiče samo po kliznoj plohi 1 (do 1985. g.), da bi se dio kliznog tijela, kojem ova točka pripada, u 1988. g. kretao i po kliznoj plohi 2.

Izračunate srednje vrijednosti pomaka po pojedinim kliznim plohama ukazuju na nejednake intenzitete pomaka u promatranim razdobljima. Prema tablici 3. vidi se da je od 1963. do 1985. g. prosječni intenzitet pomaka po kliznoj plohi 1 (najdubljoj) 0,132 m/god., a od 1985. do 1988. g. iznosi 0,187 m/god. Vidi se aktivnost klizišta i po preostale dvije klizne plohe.

Iz slike 4. vidljivo je da hipsometrijski najviše točke u čeonom dijelu klizišta, kao i one najniže (pri stopi), pokazuju ujednačene iznose pomaka. Klizna tijela kretala su se dakle kao kruti blokovi. Ovo je jedna od važnih teoretskih pretpostavki za provođenje prostornih analiza stabilnosti.

Prezentiranim radom pokazano je da se prilikom izučavanja dubokih i prostornih višeslojnih klizišta, posebno u naseljenim područjima, blok-aerotriangulacijom aerosnimaka različitih godišta, može odgovarajućim opisanim postupkom dobiti niz egzaktnih podataka, indicija i logičnih pretpostavki, kao što su to:

- razgraničenja kretanih od stabilnih dijelova terena,
- razgraničenja površina s različitim iznosima pomaka,
- logično tumačenje mehanizma ponašanja pojedinih kliznih tijela u složenom klizištu, kao i rekonstrukcija redoslijeda događanja,
- aktivnosti pojedinih kliznih tijela od godišta do godišta snimanja,
- indicije o položaju i obliku kliznih ploha ili kliznih zona.

Posebna je prednost korištenja starih opetovanih fotogrametrijskih snimanja u činjenici da se složena klizišta mogu izučavati unatoč velikoj vremenskoj distanci, u periodu kada klizanje terena još nije niti utvrđeno. Nadalje, ako postoji više kliznih ploha (zona), na klasičan način (inklinometarska mjerenja), obično je moguće indicirati samo najpliće klizne plohe. Također, iz bušotinskih podataka, ako ne postoje deblje kontinuirane zone sniženih parametara otpornosti na smicanje, tanke zone glinovitih proslojaka do nekoliko centimetara debljine praktično nije moguće registrirati.

Obilje informacija uz mogućnost rekonstrukcije geotehničkih modela i najsloženijih klizišta, te dovoljna točnost metode, dostatni su razlozi za korištenje opetovanih fotogrametrijskih mjerenja. Osnovni uvjeti za uspješno korištenje metode su: postojanje više godišta aerosnimanja, dovoljne veličine pomaka da bi se mogli izmjeriti s odgovarajućom točnošću, i dovoljan broj detaljnih točaka.

Jednom rekonstruirani geotehnički model omogućuje racionalnu ugradnju minimalnog broja stalnih geodetskih točaka na površinama pojedinačnih kliznih tijela i njihova preciznija osmatranja sa stabilnih točaka klasičnim geodetskim postupcima.

Iako je u ovom radu bilo opravdano pomake promatrati ravninski, (komponenta dX), vrlo se jednostavno može izračunati i veličine prostornih vektora pomaka.

Procjenu srednje pogreške mjerenja preporuča se izvršiti iz rezultata fotogrametrijskih mjerenja na stabilnim detaljnim točkama, za koje je sigurno utvrđeno da nisu pomicane.