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OVERVIEW ON LANDSLIDE DISTRIBUTION ALONG BULGARIAN DANUBE RIVER BANK BETWEEN VIDIN AND NIKOPOL

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INTRODUCTION

Bulgarian Danube river bank has a length of 467.8 km. There are located 11 towns and over 20 villages, large industrial, energy and irrigation systems. At the same time, a large part of the shore is covered by landslides, which cause considerable damage to the real estates, communications, facilities and fertile lands (D e m i r e v et al., 1981; A n g e l o v et al., 1983). Mostly affected part is western one - a strip of 200 km from Tsar Simeonovo Village (Vidin region) to Nikopol Town. Catastrophic landslides often occur in this region and the consequences of which are heavier and counteramesures are more difficult and more expensive.

The characteristic features of catastrophic landslides are: speed of movement of earth in the active stage of landslide processes ranging from few cm per 24 h to few meters per minute; total change of field configuration after landslide action with the formation of typical landslide relief forms – steps, small hills, reverse slope inclinations at some parts, depressions, ponds, wide cracks, landslide shafts; significant landslide masses moving down the slope reaching tens of meters; serious damages or complete destruction of buildings, roads, disruption of communications and others.

GEOLOGY AND GEOMORPHOLOGY

The Danubian plain is characterized by plain-hilly relief, genetically and spatially predetermined by the structural geological base of the Moesian plate, mainly as a result of the negative development of the western part of the Moesian superstructure plate and the slight positive development of its eastern part during the Neogene-Quaternary. The research area, Calafat-Vidin – Turnu Magurele-Nikopol sector, is situated entirely within the western part of the Danubian plain, defined as Lom Depression.

Lom Depression is built mainly of Neogene sediments and is characterized in geomorphological aspect by slightly hilly, almost plain relief and well expressed asymmetric river valleys (Table 1). The Danube river have steep right and inclined left slopes. Vast watershed areas with an altitude of 100–150 m predominate.

The geology of area is characteristic by Neogene and Quaternary formations.

The Neogene sediments are represented by Furen, Byala Slatina and Brusartsi Formations. Furen Formation (K o y u m d z h i e v a, P o p o v, 1988) is developed in the eastern part of research area and it is well known from outcrops in the valleys of the rivers Danube, Skat and Ogosta. It is represented by oolitic, sandy, detritic, shellfish and other calcareous clays and sand layers. Its thickness reaches 40 to 50 m.

The Byala Slatina Formation is developed east of Ogosta River. This formation is represented by yellow sands with variable particle size, conglomerate lenses and layers from aleurites and aleuritic clays. The greatest thickness of 143 m is observed in Oryahovo, and eastward it decreases to 40–50 m.

The Brusartsi Formation is presented by grey-greenish sandy clays. In the upper parts there are sand layers, and at lower parts there are lignite coal layers. Their total thickness is 50-70 m, the age is assumed to be Dacian-Romanian.

Quaternary system is represented by formations with a different genesis that are related to Eopleistocene, Pleistocene and Holocene age. The eolic formations of Pleistocene have relation to landslide phenomena

The eolic formations treat loess complex in the area are widespread and substantial thickness. The transition between them is gradual. Loess has a specific beige-yellowish to grayey-yellowish coloration with fine-grained, porous, chalky in varying degrees, with clayey-silty content. Porous texture of the loess sets a good water permeability in the vertical direction and pronounced sectility, in the same direction. Consequently, in loess, numerous vertical walls are formed near the banks of the Danube between Kozloduy and Oryahovo.

A characteristic feature of loess is its ability to collapse and reduces the volume when it is water saturated. The types of loess in research area is mainly sandy and typical. Sandy loess is seen as a very narrow strip, 2–3 km wide, along the Danube River, between Kozloduy and Oryahovo.

Paleosoil horizons are more or less dark brown to reddish brown humus soil, with modified and cleyey weathering horizons among loess. Loess complex has a thickness of 40 m near Kozloduy to 120 m in the east Oryahovo, which consists of seven and six loess paleosoil horizons (Y a r a n o v, 1956; M i n k o v, 1968, and others).

LANDSLIDE PROBLEM

The most favorable conditions for geological-geomorphological considerations arise where there are landslides in the geological profile having significant quantities of clay, clayey or weak layers, slightly sloping to the Danube river. Landslide movements occur mostly in these geological strata. The other sediments as sands, marls, clayey and sandy loess complex are involved in landslide process with their geological load that create slip surface.

At least 21 catastrophic landslides have occurred in the last 50 years along the Bulgarian Danube river bank (Table 1). Concentration of high-speed landslides is

within Lom depression - between the towns of Dunavtsi and Oryahovo, near Tutrakan and Nikopol (L u k a n o v, 1979). The western part of the coast is dominated by active landslides with a volume of over 1 million cubic meters.

The distribution of catastrophic landslides is not constant in time. There is a certain cycle, which is more pronounced in landslides with a larger scope – the depth of the slip surface h>20 m and volume V>1 million m^3. There are activations every 6–8 years – in 1972, the period 1978–1980, 1988 and 1991 suddenly shallow landslides and smaller volume occur relatively frequently – usually every 1 year. Predisposing to this type of landslides in the hills and have half of Danube bank: mainly at Oryahovo and Nikopol. Shallow earth-flow type landslides with low speeds occur almost every year in Oryahovo. According to seasonal distribution, shallow catastrophic landslides trigger usually in the periods March-April and October-November, when the main role is played by the spring and autumn rains (B r u c h e v, F r a n g o v, 2000; B e r o v et al., 2002; B r u c h e v et al., 2006).

The higher number of landslides in the March-April compared to autumn period is associated with an additional influence of snowmelt, as well as technogenic waters from constantly flowing taps during the winter period. In deep-seated catastrophic landslides, time of occurrence varies in a wide range – from February to May and from October to December. Their distribution by month is almost uniformly – it shows that the reasons for their occurrence are related not only to flood the slope and is the result of the combined influence of various factors.

The most common causes activation of deep earthquakes and landslides have penetrated the body of the landslide rainfall and technogenic waters. Coastal erosion has great influence on the landslide in Boruna quarter, Lom Town. Other deep landslides are separated by 2–3 km away from the river and virtually no erosion affects them. In shallow catastrophic landslides also play a major role in their storage and artificial rainfall waters. River erosion driven mostly shallow landslides in the areas closest to the nut. Deep erosion has a significant impact on landslides in Oryahovo, Ostrov and Nikopol.

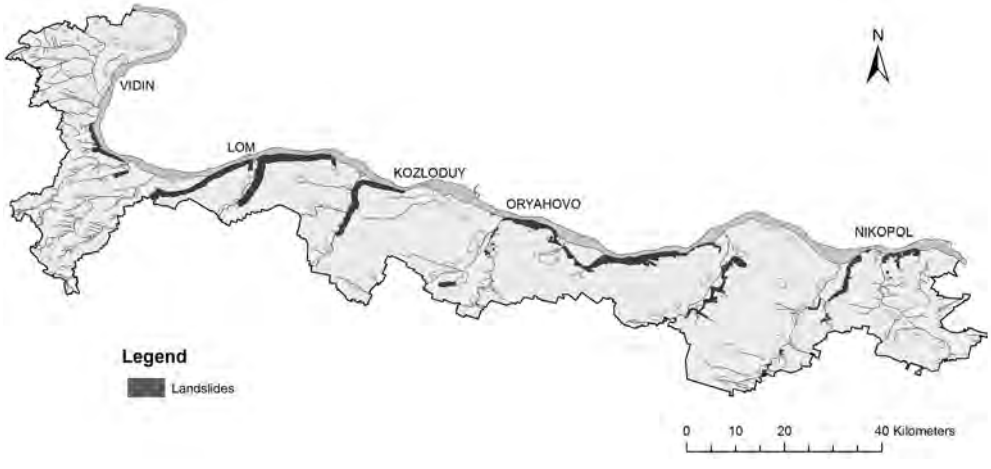

Fig. 1. Landslide distribution map of research area

Table 1

Manifestation of catastrophic landslides along the Danube river bank

№	Landslide, location	Year of activation	Month	Volume x10^3 m^3	Triggering cause of the event	Damages
1	Gorni Tsibar Village	1940 1980	XI II–III	2000 2450	Earthquake Earthquake, water saturation	Unknown Destroyed and deformed 432 houses
2	Moesia Town, below the local reservoir	1972	IV	1000	Water saturation	Affected agricultural lands 500 dka
3	Oryahovo Town – numerous massive landslides – area around the station – lodge “Chayka”, East from the town – East part of town	1973 1977 1981 2006	III–IV IV unknown I and IV	90 150 290 	Infiltration of precipitation waters Earthquake, precipitations Water saturation Infiltration of precipitation waters	Destroyed 200 buildings Destroyed 100 buildings Cracking of the lodge
4	Orsoya Village	1978 1988	XII X	19000 16000	Complex Complex	Destroyed 195 buildings and facilities Destroyed road Vidin-Lom
5	Nikopol Town – numerous massive landslides – “Russian monument” Quarter – Landslide at Shipka street	1973 1985 2006	III–IV X I and IV	30 17 	Water saturation Water saturation Infiltration of precipitation waters	Unknown number of buildings destroyed Destroyed 2 buildings
6	Lom Town, Boruna Quarter	1979	II	30400	Complex	Destroyed 2 buildings and communication facilities
7	Ostrov Village	1980	IV	85	Water saturation from the piping	Heavily deformed 10 buildings
8	Dunavtsi Town	1980	V	4800		Wastewater treatment plant destroyed
9	Slivata Village	1991	X	9000	Complex	Destroyed 4 buildings and road Vidin-Lom

Landslides in Lom area

In 2012–2013, landslide movements have been established at many places along the road Lom-Archar with subsiding of some section, which is a sign of ongoing landslide activity. The mayor of the village of Dobri Dol has shown a new formed fresh crack in the ceiling of the building indicating recent activity. To the west direction, landslide is still active almost to the village Archar. The neighboring landslides can be characterized as potential.

Potentially unstable slope is located in the western part of the Lom Town (information from Lom Mayoralty.

Few landslides affect the villages Botevo and Tsar Simeonovo westward from Dobri Dol Village. They are developed in gentle slope not exceeding 5° to Danube River. Slight creep movements are noticed at Tsar Simeonovo Village at the eastern part of the village. Movements are associated with fluctuations in the shallow groundwater table and the poor condition of the drainage system.

Landslides in Gorni Tsibar area

Landslide strip covers the right bank of Tsibritsa River at its lower course and slope above Gorni Tsibar Village. This is the most active part of the landslide in this sector. Continuing activity of this landslide is demonstrated by the deformations affecting road Lom – Kozloduy (Fig. 2). These are subsidences on the road and fresh cracks in places that show a high risk to to be interrupted if the

Fig. 2. Deformations affecting the road Lom – Kozloduy (30.10.2013)

movements continue. In the village, there are also observed cracks in buildings suffered as a municipality, where, according to the mayor, cracking continues in present days.

Landslides in Oryahovo area

The town of Oryahovo is highly affected by landsldies. In most part of houses can be seen cracks and deformations. Most intense movements have been established at the eastern part of Oryahovo (Figs. 3 and 4). On the road trace, fresh cracks showing serious subsiding have been identified. In this part there are destroyed old houses. The recent deformations reach the ferry port. There is a marshland between the road and the Danube river, which indicates that landslide is deep seated and the slip surface extends almost to the level of the river. Active landslide section has been established at Zelena Bara area, also at nearest Center for technical inspection of cars where the cracks in retaining walls and in asphalt road are exceeding 15 cm per year (measured for period March-November 2013).

Movements affect almost the whole section of the high bank of Danube River from the west side of Oryahovo, reaching almost to the village of Leskovets.

In the village Leskovets traces of relic landslides have been found, i.e. without recent movements.

Fig. 3. Retaing wall damaged by landslide movements (22.10.2012)

Fig. 4. Deformations on the road at the Center for technical inspection of cars (07.02.2013)

Landslides in Dolni Vadin – Ostrov area

Landslide road between the villages of Ostrov and Dolni Vadin also shows movements. The most significant are they in the northeast of the village of Ostrov and the villages of Gorni Vadin and Dolni Vadin. Some indications for activities on the river bank near the village of Baykal. However, observations and countermeasures are missing in these areas.

Landslides in Somovit area

In the vicinity of Somovit Village two sectors in unstable conditions have been established. They are located in two large bodies of huge landslide cirques, which are in relatively stable condition ("dormant" type). But at some places fresh cracks in the houses of the village show an activity in present days (Fig. 5).

Landslides in Nikopol area

Recent activation of landslides occurred in 2006. A landslide is located about 300 meters east of the Russian monument. This slide however was relatively shallow, flow type, as much of the land mass been removed. At present there are no signs of moving, although some typical landslide geomorphological elements are clearly distinguishable in the field (Fig.6).

Fig. 5. Cracked house in Somovit village. The concrete slab is cut (21.10.2012)

Fig.6. Landslide damages of stadium terrain, “Shipka street” Landslide, Nikopol Town (16.04.2013)

SEISMICALLY ACTIVATED LANDSLIDES

As a part of the Alpine-Himalayas seismic zone, the territory of Bulgaria is characterised by a relatively high local seismicity. In North Bulgaria, these are the regions of Veliko Turnovo – Gorna Oryahovitsa and the Dobroudja Black Sea coast, the Shumen district (all are outside the project area), as well as the seismic foci in neighbouring Romania (Vrancea and Timishoara). Seismic hazard in the region is mostly related to the events of Vrancea seismic zone where earthquake hypocenters are at depths mostly from 80 to 120 km (B r a n k o v, ed., 1983). Maximum expected magnitudes do not exceed 4.0 for the almost whole area.

Earthquakes in this zone reach the Danube river bank of Bulgaria and subject it to macroseismic effects. This part of the territory of the country had been subjected to strong historic and contemporary earthquakes causing great human losses and destruction (Table 2, Fig. 7). A number of secondary seismogravitational phenomena and deformations of the Earth's crust are known which cause additional destruction (I l i e v, 1967; B r a n k o v, ed., 1983; R i z z o et al., 1986; F r a n g o v et al., 2007).

The Vrancea earthquake (1940) (M=7.3) was felt on the whole territory of Bulgaria. The highest degree was observed in Nikopol – VIII, and in the whole area along the Danube the intensity was of the VII degree (B r a n k o v, ed., 1983). Some landslides along the bank of the Danube (the Gorni Tsibar village, etc.) were activated.

T a b l e 2

The most significant earthquakes in the region

Strong earthquake	Date	Magnitude	Max. Intensity MSK in N. Bulgaria	Consequences in the region of Northern Bulgaria
Vrancea, Romania	01.11.1940	7.3	VIII	Destroyed buildings and constructions in the towns along the Danube river bank
Vrancea, Romania	04.03.1977	7.2	VIII	More than 100 people killed in the town of Svishtov, 3 buildings fully destroyed, a lot of damages. The Svishtov-Nikopol area is the most affected one
Vrancea, Romania	30.05.1990	6.8	VII	Two people killed; cracked buildings; many rockfalls triggered along the plateau scarps

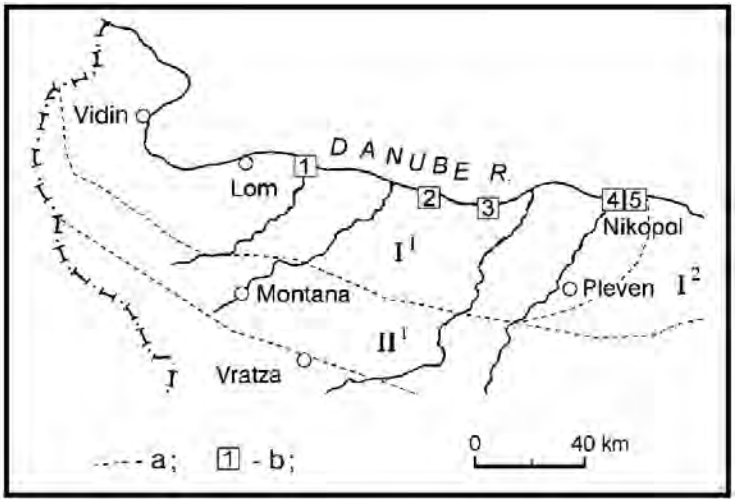

Fig. 7. Known seismogravitational phenomena in research area (modified after F r a n g o v et al., 1998): a – boundaries of the regions: I^1 – Lom depression; I^2 – North Bulgarian rising; II^1 – Fore-Balkan area; b – case histories (macroefects): 1 – Gorni Tsibar; 2 – Oryahovo; 3 – Gorni and Dolni Vadin; 4 – Somovit; 5 – Nikopol

Another strong earthquake with an epicenter in Vrancea occurred in 1977 (M=7,2). In the whole area along the Danube Floodplane the intensity was of the VIII degree. Affects several damaged buildings in Vidin, Lom, Kozloduy, Oryahovo, Nikopol and many other places, cracks in the terrain built of clay and loess sediments cracks in landslide areas in villages Gulyantsi, Shiyakovo and Lenkovo. Loess massifs on vertical slopes collapsed under its action (to the southeast of Nikopol, etc.), as well as many landslides triggered (Gorni Tsibar, Oryahovo, Gorni and Dolni Vadin, Somovit, Nikopol). Only in the Oryahovo town within old landslide nearly 900 buildings are affected, 102 of which are unsuitable for habitation. The number of affected buildings in the Somovit are 240, as unfit for habitation 40, in the Gorni and Dolni Vadim are affected 166 buildings, 60 of which have become unusable and in Nikopol ratio is 1087 to 144 (B r a n k o v, ed., 1983). As secondary seismic events occur liquefaction and flow of water saturated clayey and sandy-clayey alluvial sediments and a series of sandy-clayey cones with a length of 2–3 m to 300 m along the terraces of the Danube River and its major tributaries (B r a n k o v, ed., 1983; I l i e v – B r u t c h e v, ed., 1994).

DISCUSSION

Stability of the landslides is determined by the erosive effects of the Danube River, the fluctuation of groundwater levels and surface water, earthquakes, rainfall and technical activities. Putting the dominant factor for the occurrence of catastrophic landslides is very difficult without specific multiannual observations, and in many cases the reserve of stability of a slope is exhausted from all the relevant factors in complex proportions and ratios.

The preventive activity in the expression of instability on the slopes of the high Danube banks should be directed at eliminating or reducing the effects of destabilizing factors.

Useful measures increasing slope stability are: drying of landslide slopes with different types of drainage, avoiding saturation the land by removal the surface runoff, sewage system construction in the settlements, checking and sealing all canals and pressure pipes passing through or over the landslide slopes, reducing the erosive action of the Danube River.

To avoid artificially increasing the lateral river erosion should be carefully selected locations for extraction of inert materials from the river. When erosion activity at the base of the slope is manifested, a lining from roughcast stone can be made with a suitable, depending on the flow speed, size of individual pieces. The lining can be turned into a buttress, which besides erosion control, there will be a static function, helping to increase retention forces in the heel of the slope.

Should not allow an adverse change in the ratio of the active and passive forces providing the minimum reserve of stability. Undercutting the slope to form a level surface (for track of road) should be undertaken only after computational verification on the factor of safety under the new conditions, respectively after the construction of appropriate strengthening measures. Still the same purpose must not be allowed increasing the load on the upper (active) part of the slope, for example due to deployment of the embankments, heavy construction machinery, buildings, etc. Only preventive measures will not ensure the stability of slopes and prevent the occurrence of a catastrophic landslide, but it will help a lot in this regard. The preventive measures on landslide slopes in combination with reliable strength constructions will be able to solve the problem on stabilizing of the creeping slopes along the Danube shore and preventing of catastrophic landslides.

REFERENCES

Angelov, K., D. Yordanov, R. Angelova. 1983. Geodynamic analysis of detrusive process of landslide at Orsoya Village, Mihaylovgrad region. – Hidrotehn. i Mel., 8, 11–16 (in Bulg.)

Berov, B., N. Dobrev, I. Brouchev, T. Fukuzono. 2002. Landslides in Bulgaria. Lansdlide Society of Japan. – Landslides, Vol. 38, No. 4, pp. 34–43.

Branko v, G. (Ed.) 1983. Vrancea earthquake in 1977. After-effects in the Republic of Bulgaria. Publ. House of Bulg. Acad. of Sci., Sofia:428 p. (in Bulgarian).

Brouchev, I., G. Frangov. 2000. Erosion and landslide processes along Danube riverside. – Mining and geology. 5, 19–24 (in Bulgarian).

Bruchev, I., G. Frangov, R. Varbanov, N. Dobrev, P. Ivanov, C. Cekov. 2006. National programe 2007–2015 for landslide stabilization, erosion and sea-erosion protection of Danube and Blacksea coast and landslide control of technical infrastructure and settlements. – In: National Scientific and Technical Conference "State and Stabilization of landslide and erosion processes in Bulgaria", 30.XI–1.XII 2006, Sofia, Acad. Publishing House "Prof. M. Drinov", 9–22 (in Bulgarian).

Bruchev, I., G. Frangov. 2000. Erosion and landslide phenomena along the Bulgarian Danube riverside. – Minno delo i Geologia Journal, 5, 2000, 19–27 (in Bulgarian).

Demirev, A., L. Ilieva, K. Angelov, P. Stoeva. 1981. Forecasting of stability of High Danube River bank. Ann. MGI, 2, 290–300. (in Bulg.)

Frangov, G., I. Iliev, P. Ivanov, N. Dobrev. 1998. Seismogravitational effects in Northern Bulgaria. – In: Proc. 8th Congress IAEG, Vancouver, Canada, 703–708.
Frangov, G., I. Bruchev, P. Ivanov, N. Dobrev. 2007. Macro and micro displacements in Northern Bulgaria due to local and regional seismicity. – In: Proc. of International Project of UNESCO and BAS "Seismo-hydrogeological vulnerability of the environment and society in the Balkan region", Second Meeting, 22–26 November 2006, Sofia, 91–98.
Iliev, I. 1967. Certain regularities of the spread of landslides and the seismic areas in Bulgaria. – Rev. Bulg. Geol. Soc., 28, 1: 88-93 (in Bulgarian).
Iliev-Bruchev, I., Ed. 1994. Geological Hazards in Bulgaria. – BAS, Sofia, 1994, 143 p. (in Bulgarian, English Summary).
Koyumdzhieva, E., N. Popov. 1988. Lithostratigraphy of Neogene sediments in North-East Bulgaria. – Paleont. strat. and lithol., 25, 3, 26–47 (in Bulg.).
Lukanov, A. 1983. Evolution of landslides at Tutrakan. – Ann. SU, GGF, 2, 52–60 (in Bulg.).
Minkov, M. 1968. Loess in North Bulgaria. Sofia, BAS, 202 p.
Rizzo, V., I.Iliev, S. Tzvetkov. 1986. Seismogravitational phenomena along the Bulgarian Danube riverside. – In: Proc. of the Int. simp. on eng. geol. probl. in seismic areas, Bary, Italiy, 2: 383–390.
Yaranov, D. 1956. Loess and Loess-like Sediments in Bulgaria. – Bull. of the Soil Institute, BAS, 3; 37–76.

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ПРЕГЛЕД НА РАЗПРОСТРАНЕНИЕТО НА СВЛАЧИЩАТА ПО БЪЛГАРСКИЯ ДУНАВСКИ БРЯГ МЕЖДУ ВИДИН И НИКОПОЛ

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(Р е з ю м е)

Настоящото изследване разглежда разпространението на свлачищата по високия Дунавски бряг в участъка от Видин до Никопол. По-голямата част от тях са с дълбоко разположена хлъзгателна повърхнина и обеми над 1 млн. m^3. Основните фактори на свлачищната активност са валежите, ерозията от р. Дунав, земетресенията от Вранча, Румъния, както и от техногенни въздействия. Разгледано е състоянието на активността на свлачищата през 2013 г. в основните сектори на изследвания участък: при Лом, Горни Цибър, Оряхово, Остров-Долни Вадин, Сомовит и Никопол. Установена е активност при някои от свлачищата, като най-интензивна е тя в района на гр. Оряхово, където е измерена скорост от 15 cm за година в района на Центъра за технически прегледи. Други активни участъци са установени при с. Добри Дол, с. Горни Цибър и гр. Никопол.