GEODYNAMIC CONDITIONS OF THE TERRAINS FROM THE EASTERN ZONE OF THE TOWN OF ORYAHOVO

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ABSTRACT. A considerable area of the town of Oryahovo is situated on an ancient landslide that affects the middle and the lower zones of the bank of the Danube. The ancient landslide circus extends from the central and eastern zones of the town and goes outside the town regulation. Secondary sliding movements are periodically triggered in zones from the ancient landslide body. In 2006 and 2014, two landslides were triggered that disturbed practically the entire river bank slope, being the largest in this country for the past years. Massive shearing zones and ground settlements we induced resulting in the complete destruction of buildings and infrastructure, including the main road Oryahovo – Leskovets. The article analyses the actual geodynamic conditions of the sliding processes, their mechanism and development pattern, the geometry of the two landslide circuses. The results of the study are used in the landslides stabilization design.

Keywords: landslides, stability, reinforcement

ГЕОДИНАМИЧНО СЪСТОЯНИЕ НА ТЕРЕНИТЕ В ИЗТОЧНАТА ЧАСТ НА ГРАД ОРЯХОВО

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РЕЗЮМЕ. Значителна част от град Оряхово е разположена върху древно свлачище, което е засегнало средната и долна част на долинния склон на река Дунав. Древният свлачищен циркус обхваща централната и източна част на града и продължава извън пределите му. В тялото на древното свлачище периодично се активизират вторични свлачищни процеси, които обхващат отделни части от него. През 2006 и 2014 година в източната част на града се активираха две свлачища, които обхванаха практически целия долинен склон и са най-големите по обхват, формирани на територията на нашата страна в последните години. Те причиниха мащабни срязвания и пропадания на земната основа, придружени с цялостно разрушаване на сгради и инфраструктура, включително и главния път Оряхово – Лесковец. В статията е направен анализ на съвременното геодинамично състояние на терените в източната част на гр. Оряхово, анализирани са причините, които са обусловили активизацията на свлачищните процеси, изяснен е механизмът и динамиката на развитие на свлачищните процеси, геометрията на двата свлачищни циркуса. Резултатите от изследването са използвани при изготвянето на проектните решения за стабилизиране на свлачищата.

Ключови думи: свлачища, устойчивост, укрепване

Introduction

The town of Oryahovo is located in the western part of the Danube hilly plain. A major part of the town is located on the high Danube bank that is affected by landslide processes. They are of two types – ancient, temporarily stabilized, and contemporary, active. The origin and development of the ancient landslides are related to the paleo-valley of the Danube, embedded at a much lower hypsometric level than the present erosion base. The ancient processes began with the formation of a prism (or prisms) at the bottom part of the paleo-valley of the Danube, as the landslide process was of spreading type and developed along a weak zone (or surface) embedded into the calcareous Pliocene sediments from the basis of their geological profile. The sinking of the prism caused gradual upstream loosening of the massif and realization of new concessive surfaces up the slope with approximate circular configuration. These surfaces developed to the depth the basic one, but some ran through the massif at a higher level, into the hard-plastic Pliocene clays. There are also analyses that these sliding processes were accompanied by seismogenic events. The dynamics of the landslide processes during the late Holocene subsided due to the change of the paleographic environment and the landslide bodies were erosionally denudated. The original mechanism of the landslide processes had formed stepped landslide levels most of which gradually altered their terrain contours to circular shapes due to superimposed sliding processes. The constant slow movements of the landslide body (without considering the faster ones localized in different smaller areas), point out to the fact that this large ancient landslide structure is unlikely to be completely stabilized over time and to the present day.

The contemporary stability of the terrains in the town is highly influenced by active landslide processes. They are developed into separate areas from the body of the ancient landslide. The sliding surfaces are developed most commonly in the ancient landslide body without reaching its basic sliding area. The contemporary landslides lead to disturbances in the resistance of the buildings and facilities and to destruction of the infrastructure. The contemporary landslides which affect the eastern part of the town are with the largest range in the region of Oryahovo. They fall within the ancient landslide structure – landslide Quarters "Iztok" (Fig. 1). Two larger circuses are distinguished into the body of the ancient landslide: one of them is circus "Iztok", registration No. VRC 31.54.020.02.22, and the other is "Voynishki poroi", registration No. VRC 31.54.020.02.17. The circus "Sredna zona" is inserted as a smaller one between them. The circus "Voynishki poroi" (the easternmost part of the ancient landslide) is outside the urban territory. All three circuses are structurally and geodynamically bound together and the temporary activization of each one affects the neighboring ones. Numerous smaller or larger secondary circuses are superimposed on them.

Geological and tectonic structure

The region of the town of Oryahovo falls into the Lom's graben depression where the axis to the Ogosta River valey directs southeast. The Kozloduy structure and its adjoining Kozloduy-Glozhen synclinal are overlapped in the region's depression. On top of the upper Cretaceous sediments, the syncline limb takes the shape of a graben, as it lies southeast with an inclination of 5-7.5 degrees. The upper stratigraphic horizons of the Neogene complex are occupied mainly by two formations – Furen /Sarmath/ and Beloslatina Formation /Meot-Pont/, which covers it. The Furen formation, with an average thickness of about 50-70 m, includes clayey-sandy horizons banded by sandy limestones and calcareous sandstones. The clayey layers are represented by ochres, grey-green and rusty coloured clays, mainly silty and sandy plastic. They are irregularly but relatively often banded by terrigen coarse-graded deposits – lenses and bands of clayey sands, from aleuritic to coarse water saturated sands. Bands, coatings, and grains of iron hydroxides, as well as organic admixtures, are often found in the layer.

During the Miocene-Pliocene period, the fine-grained deposits of the Furen formation were mainly transgressively deposited over the Beloslatina formation. Their facies is continental, including plastic clays with layers of slightly cemented brecco-conglomerates or clayey sandstones. They have an average thickness of about 20-30 m. The Pliocene basin ends with alternating rusty colored clays and sandy layers that mark the end of the sub-aquatic sedimentation. The coarse-grained composition, the rhythmic shift, and the increased ferrite content of these sediments suggest significant shallowing cycles of the basin. At a depth of about 30 m in the Danube river terrace and beyond a depth of 100 m at the top of the slope of the valley, the described formations lie over a calcareous complex from organogenic and detritic limestones and soft (chalk) limestones, banded by calcareous clays and clayey marl from the bottom horizon of the Furen Formation or the Florentine Formation. The Neogene deposits are covered by loess from the so called Danube loess province. Its thickness next to the Danube bank is in the range of 50-60 m. The maximum thickness of up to 85 m of loess is in the area of the town of Oryahovo.

Hydrogeological conditions

The hydrogeological conditions in the area of the ancient landslide are determined by the groundwater accumulated in the Pliocene complex. The groundwater is bound to the sandy deposits and the limestone-sandstone layers. The water-bearing complex is multilayered, pressurized. It is structurally built by continuous alternations of low-permeable clayey layers and the more permeable sandy and rocky water-bearing layers. The high plasticity of the clayey layers creates local aquitards. At a depth of over 100 m from the terrain, the aquifer complex hydraulically contacts with the underlying calcareous horizon.

The recharge of the aquifers is infiltrational, coming from the extensive loess plateau and the landslide slope surface. The groundwater flow is generally directed north with an average gradient of 0.15-0.20. The groundwater drains in the Danube. The aquifer is spatially well-developed. The local disruptions of the aquifer intervals due to the landslide processes create partially pressurized zones. The clayey layers in the aquifer structure in some sections are partial aquitards, but the hydraulic connection between the aquifers is rapidly recovers as a result of the sediment composition and their disruption from the landslide processes. The infiltrational recharge of the groundwater from the ancient landslide area is about 13.0 l/sec. (Kuzmanov, K. et al., 2014, Stoynev, S. et al., 2017).

Geodynamical conditions

The first registered problems and corresponding geological surveys in the area are from the mid-twentieth century. The stabilization activities during these years are mainly related to the construction of water draining facilities. New cyclic activations were periodically recorded until the realization of the largest ones, affecting significant territories in the eastern part of the town – the landslide named "Iztok" in 2006, and the landslide named "Sredna zona" in 2013-2014. Despite the activities undertaken and the numerous supporting structures, the contemporary landslide processes are still active, affecting new terrains in westerly direction. As a result of the contemporary landslides, the infrastructure and the living houses in the area are practically destroyed, as well as a significant part of the supporting facilities.

The landslide development of the terrains within the ancient landslide is divided into three stages - from 1954 to 2005, from 2005 to 2011, and after 2011.

- *1st stage* – the deformations of the ancient landslide were quite even, at a rate of – 0.10-0.25 mm/d. The total displacements of the terrain alternate in a small range – from 97 cm to 102 cm, i.e. within about 600 m of the length of the landslide, the total movement was within 1.0 m. The displacements of the terrain were almost parallel in direction and gradually increased from the north to the south. The rate of the deformations in the steep Danubian slope was the slowest – it varied between 0.03-0.05 mm/d, which indicated slight activity. In a southerly direction, towards the gentler landslide slope, where the average inclination of the terrain is between 6-12 degrees, the terrain deformations were considerably greater – the average rate was 0.20 mm/d. The main movement of the landslide was north-northeast with a zone affected to the approximate elevations of 75-78. Local active slides that are usually located on the more steep slopes were formed over the years within the range of the landslide, such as the landslide processes realized north from "N. Obretenov" Str. in 2004. In order to ensure the stability

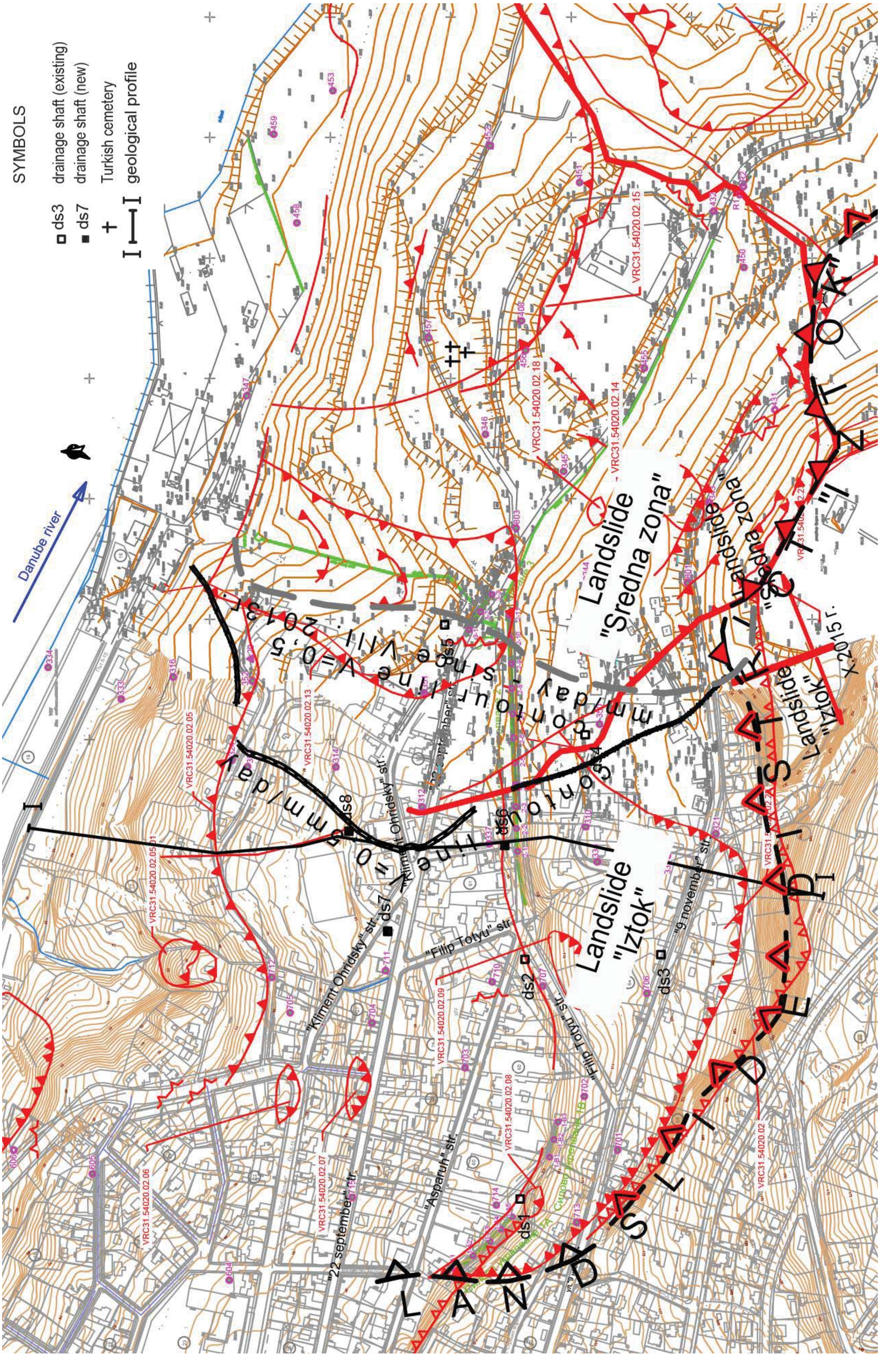


Fig. 1. Geodynamic map of the landslide area in the eastern part of the town of Oryahovo

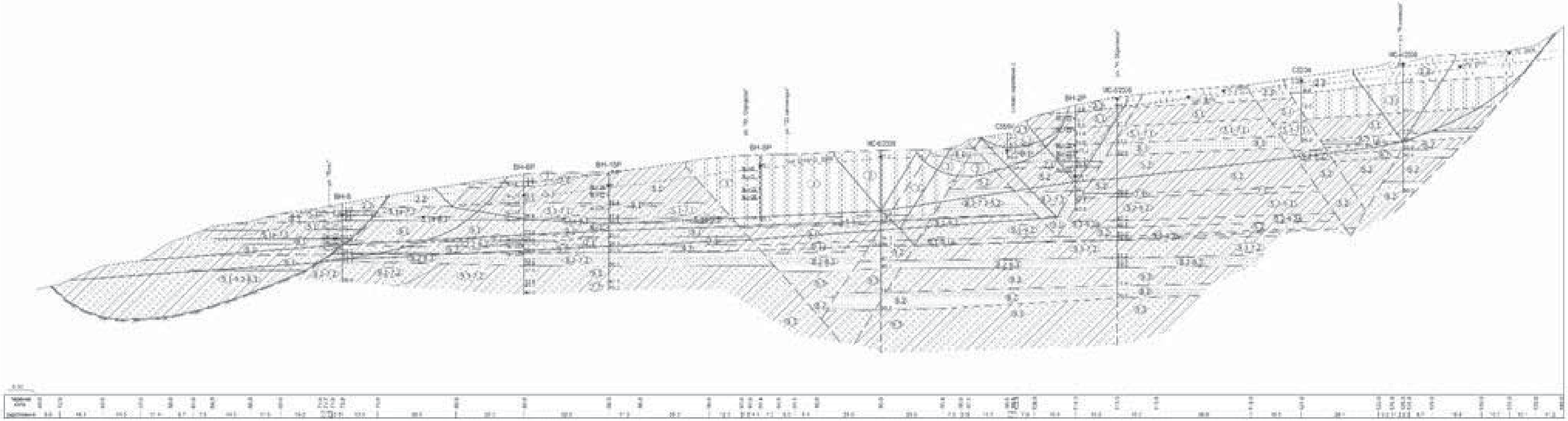
of the terrains, numerous ground water draining activities were carried out. In the 1950s, trench drains with a depth of 4.0 - 5.0 meters were built in the area of the main landslide. Subsequently, several groups of horizontal drainage boreholes (HDB) with a length of up to 150-160 meters were drilled up. During the 1980s, a construction of drainage shafts with built-in HDBs began. In the eastern part of the quarter, in "9th November" Str., a section of the so-called 'dropping wells' that conducted the drained groundwater from the Pliocene horizon within the Sarmatian limestones was drilled (KNIIBKS "Vodokanalproekt", 1989).

- *2nd stage* – it began with the activation of the landslide processes in the western part of the ancient landslide and the formation of the "Iztok" landslide. The activation began in December 2005 and the most intensive landslide deformations were in the period February-April 2006. The landslide impacted an area of about 550 meters wide and about 250 meters long, as it covered the valley between "Asparuh" Str. and the main scarp of the ancient landslide (fig. 1). The formed contemporary landslide was embedded within the ancient one, with a well-expressed prism at the head contoured by vertically stepped fractures with a gap of 0.5 to 1.0 meters. In the north direction, towards the Danube bank, the terrains were visibly more stable and influenced only by the deep sliding movements. The data from the investigations show that the activation of the landslide processes developed on two levels – deep, in the area of the ancient sliding surfaces, and shallow, in the upper parts of the ancient landslide body (fig. 2). In the range of the head prisms, weak zones were found at a depth of about 90 meters, and in the north direction they were at a depth of about 60 meters. The contemporary deep sliding surfaces were formed along the ancient disturbed areas, also probably associated with old prisms of active pressure. Their inclination was about 5 degrees and they developed in the Pliocene Sarmatian clays and the mottled limestone-carbonate layers. The toe passive prism was in the Danube and was related to its contemporary erosion base of the river. The slope stability analysis showed that the safety factor along the deep surfaces was near the equilibrium limit F=1.02, which also corresponded to the processes of slow movements. The shallower landslides, which determined the contemporary geodynamical state of the terrain, covered the slope area above "Asparuh" Str., reaching the prisms of active pressure in the south ("9th November" Str.). The terrains were heavily cracked, as the buildings that fell within reach were completely destroyed. The maximum deformations of the terrain reached a speed of 30-40 cm/day. Its development was related to natural factors, such as the geological structure and the primary structural disturbance of the bank from the ancient landslides, the significant infiltration of groundwater, and the additional hydrostatic pressure resulting from the torrential rainfall in this period (a total of 1073 mm), as well as to technogenic factors, such as damage of the water-supply pipeline along "Asparuh" Str. and, above all, to the non-operating drainage system built in the area of the ancient landslide scarp. Due to lack of maintenance and prevention, the drainage sewers were blocked and this caused them to fill up with water, resulting in additional water saturation of the Pliocene materials (Stoynev, S. et al., 2006).

To ensure the stability of the landslide emergency drainage activities were undertaken to restore the functioning of the existing drainage system. New vertical drop wells were drilled in the area of the landslide main scarp and also two drainage shafts with 50-70 meters lengths of HDBs were constructed. To ensure the stability of the shallow contemporary landslides, four anchored pile systems were constructed. As a result of these, the terrains in the area of the landslide were stabilized and the deformations returned to levels close to those before the activation of landslide processes – 0.1-0.5 mm/day ("Geozashtita Pleven", 2016).

- *3rd stage* – it began with the activation of the landslide processes east of the "Zelena bara" gully, in the area of the "Sredna zona" water basin. The active landslide processes started in 2011, but by 2013 they had a relatively low movement rate – 2.5 mm/day, starting to form a prism of active pressure in the area directly below the "Sredna zona" water basin. Significant activation of the landslide processes occurred in the spring of 2014. The main landslide scarp was formed at about 20 meters north of the "Sredna zona" reservoir. The width of the scarp reached up to 250 meters and the developed systematic cracks in this area formed a distinctive prism of active pressure. Another heavily cracked area of the terrain started from the main road Oryahovo-Leskovets and ended under the Turkish cemetery. The cracks with an azimuth between 110-130 degrees and 70-80 degrees formed two sinking prismatic blocks, and the northern one was more distinctive (Fig. 1). In depth, the two described prisms may have formed a common peak of the prism of active pressure. In general, the terrain in and around the former town park area was heavily cracked, as smaller or larger cracks rapidly changed their direction and the area got a mosaic pattern of terrain deformations. The formed landslide body had a typical circular shape, appearing in a well-defined arc of the main scarp and pear-shaped body in the northern direction. Its width reached up to 700 m, as its length was within that range or more. There were three main areas of the landslide – a sunken upper part with a length of up to 200 m; a central plain area, and an elevated toe zone (the "Iztok" park) at the slightly inclined terrains in the north extending to the steep valley slope and strip from the Danube aquatory with a length of about 200 m. The total deformation in the range of the toe zone increased to over 11.5 m and a corresponding rate of 20 mm/d. Similar numbers were detected in the western part of the "Iztok" park. The main road to Leskovets between the gorges of "Zelena bara" and "Voynishki poroi" was shifted in the north-northeast direction by 10.3 and 6.8 meters respectively. (Kuzmanov, K. et al., 2014; "Geozashtita Pleven", 2016).

The structure of the landslide body, depending on the construction of the landslide slope and the spatial arrangement of the sliding surfaces, was of a block-type type (Fig. 2). The entire eolian-delluvial horizon and the Pliocene-Sarmatian sediments were affected. The main deep sliding surface has also entered the layered calcareous-marl horizon. The thickness of the landslide body varied from 90-95 meters to 110 meters, and the area with the most active movements was at a depth of 20-42 meters. They were of a mixed mechanism– both formed bottom to top and top to bottom, with translational and cylindrical type sliding surfaces. Embedded smaller and with different volumes, landslide bodies were developed inside the main landslide: above the main road Oryahovo-Leskovets, along the "Zelena bara" gorge, and down the steep Danube slope.



SYMBOLS

Layer 1 - Embankment /Embankment materials/

Layer 2.2 - Si. Silty formations - sandy and typical loess, with macrospores, subsident, slightly moist to moist.

Layer 2.3 - Si. Sandy formations - sandy and typical loess, slightly subsident to non-subsident, moist to water-saturated.

Layer 3 - clSi. Uniform to mottled delapsive formations, priority including loess soils, as well as colluvial clayey sands and Pleistocene and Pliocene clays.

Layer 4 - siCl. Loess clays, brown to red-brown, hard.

Layer 5 - siCl. Clays, silty, medium to hard-plastic, beige-rusty with whitish streaks and spots, grey-whitish to grey-green in some areas, stiff to hard. Rusty-brown and grey clays are included, as well as brown with dark streaks and spots. There are concretions and deposits of dark hydroxides and organic admixtures.
Layer 5.1 - decompressed layers with lower density and **layer 5.2** - well-compressed.

Layer 5.1a (9.1a) - Cl. Clays with high plasticity, dark-rusty, dark-brown to grey-black and multicolored, stiff to hard with organic admixtures, with disturbed structure in some areas.

Layer 6 - siCl. Gravely clays, medium-plastic, hard to very hard with presence of fine and medium-grained angular gravel, often with amorphous limestone deposits.

Layer 7.1 - sasiCl. Clays with low plasticity and clayey sands, rusty with whitish streaks and spots in some areas, stiff to hard. Nests of well-graded sands, fine to coarse-grained, clayey to varying degrees are limited in the layer. The texture is laminated in some sections - alternation of light and dark streaks. The variety has a predominant Pliocene age.

Layer 7.2 - sasiCl. Clays with low plasticity and clayey sands, rusty with whitish streaks and spots in some areas, predominantly very hard. Nests of well-graded sands, as well as thin bands of sandy limestones are limited in the layer. The variety has a Sarmatian age.

Layer 8.1 - siMSa. Sand - predominantly medium-grained, rusty to whitish, silty to coarse in nests and lenses, well-graded, variously sorted, medium-dense to dense, slightly moist to moist. The formation has a predominant Pliocene age.

Layer 8.2 - siFSa/saCl. Sand - predominantly fine, silty, well-graded, variously sorted, rusty, ocher to whitish, very dense, water-saturated. Bands of clayey sands and rarely clays with low plasticity are included. Thin bands of calcareous sandstones and limestones are episodically present. The formation has a predominant Sarmatian age.

Layer 8.3 - siFSa/saCl. Analogical to layer 8.2, but with higher percentage of limestones and calcareous sandstones (an average of about 30-50% from the layer), as well as aleruite sands and clayey sands, very dense (semi-bonded).

Layer 9.1 - siCl. Clays with medium and low plasticity, beige-rusty, ochre with whitish streaks and spots, grey-green or whitish in some areas, stiff and hard. Thin bands of clay with lower plasticity are rarely included. Thin bands of darker clays which refer to **variety 9.1a** (organic admixtures content) are found in the layer.

Layer 9.2 - siCl. Clays with medium and high plasticity, beige-rusty, ochre with whitish streaks and spots, grey-green or whitish in some areas, hard and very hard, tough. Thin bands of clay with lower plasticity are rarely included. They build lower layers of the Sarmatian formation.

Layer 9.3 - siCl. Clays similar to layer 9.2 with higher litification degree

BH-5P Borehole No.5, equipped as a piezometer (from this survey).
MC-6/2006 Archive borehole No.6 from 2006.
C35/04 Archive borehole No.35 from 2004.

Groundwater level
N=21 Penetration resistance - 21 percussions for an interval of 30cm.

Contemporary slipping surfaces and areas with a different active variety
Ancient disturbed areas

Fig. 2. Engineering geological sections. (The layer indices are given below)

Except for the natural geological causes, the significant activation of the "Sredna zona" landslide was provoked by the additional water saturation of the slope. During the spring and autumn of 2014, there was a significant amount of rainfall in the region, as the total amount in the same year reached high values of more than 1000 mm/m^2. The water quantities that leaked and infiltrated slowly into the soil from the "Sredna zona" basin should be considered as well.

The activation of the "Sredna zona" landslide grearly influenced the "Iztok" landslide as the boundary between them (Fig. 2) was shifted significantly in the western direction. The relocation exceeded 200 m along the "22nd September" Str. The landslide processes affected zones beyond "Bolnichno dere" and the deformations progressed towards the building of the secondary school. At its eastern end, the deformations were directed north at a rate of 0.06 mm/d, in total of 4.6 cm and a terrain elevation of 1.6 cm.

Just as during the period 1984-2004, the Danube steep bank north from the "Lale" Str., suffered from slow and relatively small deformations. The total extent in its middle area for the period was 6 cm, with an average displacement rate of 0.11 mm/d. Above it, at the top of the slope, along the "Lale" Str., the terrain displacements were considerably bigger –in total of 30-40 cm and corresponding rates of 0.5-0.6 mm/d (Stoynev, S et al., 2017).

Conclusions

The analysis of the state of the terrains located in the area of the ancient landslide "Iztok" allows for the following conclusions:

- The ancient landslide is not fully stabilized, as the terrain is subject to slow deformations, possibly due to creeping processes along a deep bedded sliding surface (65 to 110 m) that is lithologically predefined by the semi-calcareous limestone horizon;
- The current state of the terrain of the ancient landslide circus is defined by the activation of the "Iztok" and "Sredna zona" landslides. Their geometry is different as the active landslide surface of the "Iztok" landslide is in the depth range of 15-20 m and that of the "Sredna zona" landslide is in the depth range of 20-42 m;
- The basic reasons for the current activation of the landslide processes are connected with the natural geological conditions (strength properties of the Neogene deposits and their structural disturbance by the ancient landslides), as well as with the saturation of the slope from intensive rainfall, typical for the region of Oryahovo, and from the leakage of the water supply network. The accumulated stresses in the slope from the deep creeping processes along the ancient sliding surface have influenced the activation of the current sliding processes as well;
- The underground water balance in the landslide body shows that the constructed drainage facilities drain an insignificant quantity of the ground water – just about 30% of the rechargement of the landslide body coming from the loess plateau. This shows the incomplete efficiency of the constructed drainage shafts, dropping wells, and HDS;
- Due to the different geometry of the two contemporary landslides and their mutual influence, a significant part of the constructed anti-landslide structures and drainage systems are destroyed.

The current state of the terrains from the ancient landslide and the patterns of development of the landslide processes show that it is necessary to apply new approaches to reduce the landslide activity and stabilize the structure. For example:

- Priority shall be given to surface drainage facilities. Over the years, this approach has been neglected, but the analysis of the processes in the area suggests that such facilities are quite efficient. A large quantity of the drained groundwater in the area through deep shafts, drains, HDS, etc., is discharged into the "Zelena bara" and "Bolnichno dere" gorges. This constant flow maintains the adjacent landslides in continuous active state. It was not realized that over the years this practice resulted in draining away the groundwater from a higher level and recharging the lower landslide level with the same quantities. The upper landslide levels and the two gorges are elements from the large-scale landslide structure described, which is continuously drained in its lower parts. The constant active state of the "Zelena bara" and the "Bolnichno dere" landslide slowly disturbs the slope along the Danube bank and activates prisms of active pressure which restart slow landslide processes. The accumulation of stresses in the upper slope zones ("9th November" Str., "N. Obretenov" Str.) results in their cyclic movements (usually at intervals of 7-15 years). These are often triggered by increased infiltration of rainwater and, to a different extent, by leakage from the damaged water supply network. After the active movement stages, the slope is unloaded from the accumulated stresses and gradually falls in a state of intermediate stability.
- One general principle must be observed during the design of drainage facilities: all water (surface and groundwater) drained from the upper and lower sectors of the landslide area (through drainage, water catchments, deep shafts, etc.) must be led away from the landslides through a competent sewage system.
- It is necessary to construct three deep shafts in the sections with shallow groundwater – the "Boyana voivoda" Str., a "playground", and the site where the old hospital was located. The approach to the design and construction of these shafts should differ from the one used so far. The deep shafts must be combined with the constant drilling of an increasing number of short drainage rays inside it until a well-expressed reduction of the groundwater pressure around it is established by newly-constricted or existing piezometers. Further drilling of new short rays should be terminated. Long-length drilled rays from the shaft should be drilled at a much later stage, after the stabilization of the landslide processes and monitoring movement rates of no more than 0.10 mm/d.
- The construction of support structures must be carried out after reaching the reduction of the rate of terrain deformations due to the drainage facilities.
- In order to check the effectiveness of the power reinforcing structures, it is necessary to construct inclinometers for monitoring the deformations both on the ground surface and in depth.

References

„Геозащита Плевен" - Данни за отчетите на премествания на повърхностните геодезически земни репери, изградени в района на източната част на град Оряхово – архив „Геозащита Плевен", 2016 год. ("Geozashtita Pleven" – Danni za otchetite na premestvaniya na povarhnostnite geodezicheski zemni reperi, izgradeni v rayona na iztochnata chast na grad Oryahovo – arhiv "Geozashtita Pleven", 2016.)

КНИИБКС "Водоканолпроект", Укрепване свлачища в гр. Оряхово", работен проект – архив Водоканалпроект, 1989 г. (KNIIBKS "Vodokanalproekt", Ukrepvane svlachishta v grad Oryahovo, raboten proekt – arhiv Vodokanalproekt, 1989.)

Кузманов, К. и др. ИГП на свлачище с рег № 06.5402.02.23 (VRC 31.54020/02.23) на склона под водоем „Средна зона" от водоснабдителната мрежа на гр. Оряхово - Геофонд на «Геотехника АБС» ООД. 2014. (Kuzmanov, K. i dr. IGP na svlachishte s reg No. 06.5402.02.23 (VRC 31.54020/02.23) na sklona pod vodoem "Sredna zona" ot vodosnabditelnata mrezha na grad Oryahovo – *Geofond na* "Geotehnika ABC" OOD. 2014.)

Стойнев, С. и др. *Доклад за извършени инженерногеоложки и хидрогеоложки проучвания за укрепване на свлачище в кв. Изток, град Оряхово* – Геофонд на «Геотехника АБС» ООД. 2006. (Stoynev, S. i dr. *Doklad za izvursheni inzhenernogeolozhki i hidrogeolozhki prouchvaniya za ukrepvane na svlachishte v kv. Iztok, grad Oryahovo – Geofond na* "Geotehnika ABC" OOD. 2006.)

Стойнев, С. и др. Укрепване на свлачище в кв. „Изток", гр. Оряхово – II етап - Геофонд на «Геотехника АБС» ООД. 2017 (Stoynev, S. i dr. Ukrepvane na svlachishte v kv. "Iztok", grad Oryahovo – II etap – *Geofond na* "Geotehnika ABC" OOD. 2017.)

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