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THE STUDY DYNAMICS OF THE SLOPE OF LANDSLIDE AREAS OF LVIV CITY LANDFILL

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Formulation of the problem

In modern conditions, solid waste (solid waste) disposal takes place on (not) authorized dumps, solid waste landfills, which are mostly overcrowded and their operation does not meet the requirements of regulatory documents. For the city of Lviv, such a place is the Lviv city landfill of solid waste, which was exploited with violations of the requirements of sanitary legislation in the field of waste management (5). Therefore, during the operation of the landfill, the stability of the site of waste storage is the most significant engineering problem, the neglect which in the future may lead to landslides that may be caused both by external factors and the physical and geographical location of the landfill (8,9,10,12, 13,15). The conduct of geodetic monitoring of such objects has its own characteristics, which depend on the observation methodology, the accuracy of the devices, the qualifications of the performer, and so on.

Setting objectives.

After the fire and landslide in May 2016, employees of the Institute of Geodesy during June 2016 completed 10 cycles of observation of the shifting area of the Lviv city landfill of solid waste. According to the results of the observations, significant movements of the garbage body were detected, which in some places reached several meters (2). In order to prevent a possible new offset in a timely manner and reduce the damage from its consequences, it was decided to continue geodetic monitoring of a landslide site. In addition, in the near future it is planned to carry out at the landfill reclamation, laying drainage channels, installing degassing plants for biogas, etc., which also requires reliable information on the stability of the landslide slope.

The purpose of this publication is to study horizontal and vertical movements on the slope of a landslide site of the Lviv city landfill solid household waste.

An analysis of recent research and publications addressing this issue

Offsets are a land movement that may be caused by various factors: earthquakes with magnitude greater than 4.0, excessive snow cover on slopes, accumulation of rock deposits in dumps or artificial objects, and additionally load weak slopes that can lead to catastrophic consequences, and and sometimes even to the death of people and the loss of a significant amount of property (18).

One recent recent shift was in California (USA) in January 2018. It was caused by heavy rainfall that destroyed hundreds of homes and killed 13 people.

Sedimentation processes can be formed on both functioning and non-functioning solid waste landfills, so the latter also require periodic monitoring. Long-term geodetic and geotechnical monitoring of five nonfunctioning MSWs provided an opportunity to obtain a continuous series of data and to interpret the deformation processes that took place during 1998-2009 (14). On the basis of the data received, Kudrna Z. stresses the importance of conducting geodetic observations even after the closure of landfills. Similar studies for the Czech Polygon of Stepanovice were carried out using special sensors that were installed in the body of landfills at depths of 0.1, 0.5, 0.75, 1.0 m (17).

Desiccation at landfill sites may take several years after closure, and the rate and magnitude of this sediment depend on many factors, including post-post placement, waste storage thickness, morphometric composition of waste, geographical location, humidity, temperature and availability of biogas generated at the landfill.

In the United States, there is a requirement that a company that operates a landfill is obliged to continue its monitoring after recultivation for 15 years (16). The US Environmental Protection Agency has developed scientific regulations to increase this term for more than 30 years, enabling to take into account a wide range of appropriate conditions for the functioning of solid waste landfills (6, 7).

Regarding the shift study at the Lviv municipal solid waste landfill, from May 31, 2016 to June 5, 2016 (1), observation was carried out using an electronic station in a non-reflector mode. For 7 points, the bias in the X-X plane is +2 m, Y-Y -0.5 m and in the Z-Z plane -2.5 m. However, it should be noted that such a number of points could not sufficiently provide a sufficient description of the processes occurring in the shifting area of the Lviv municipal solid waste landfill.

Main material

According to the agreement between the Lviv Municipal Enterprise Zybranka and the National University "Lvivska Polytechnika" 3 monitoring monitoring cycles (4 August, 7 November, 2 December 2017) were carried out in order to continue the monitoring of the landfill landfill site.

The camera was based on the 3 stations, which were laid out during the previous observation cycles (Fig. 1) (2). The determination of the coordinates of the stations was carried out by the two-frequency GNSS receiver Trimble R7 in real-time with an accuracy of 0.05 m in plan and 0.1 m in height. When selecting sites for shooting camps took into account the maximum proximity to the scan area (Fig. 1), as well as the safety of the passage to the stations and the stability of their position.

Fig. 1. Scheme of location of shooting stations.

For each scan cycle, the Robotic Topcon IS-301 is equipped with a scan resolution of 0.25 m in horizontal and vertical directions. The results of the scan from three stations for each cycle were obtained from 30 000 to 40 000 points. Cross-linking and filtering of received scans was done in the Topcon Image Master for IS software package. Since there was no possibility of fixing clear contours on the sloping area of the slope, it was decided to operate the digital surface models and their differences in order to detect movements on the slope. Digital models for the study area were built in the software product Surfer 13 with a 0.25 m mesh.

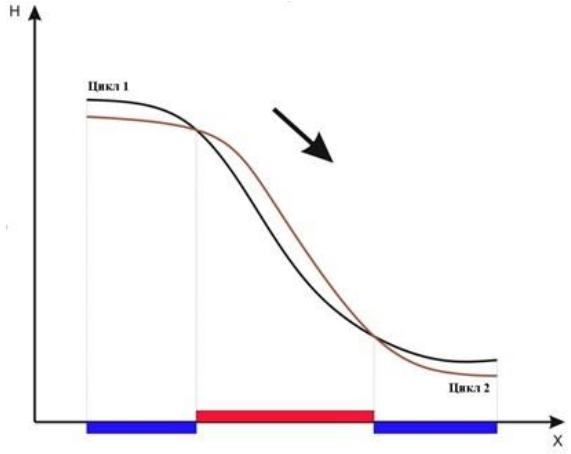

Fig.2 Interpretation of surface differences

In fig. 2 shows two conditional surfaces, built on the results of scanning two cycles. Depending on the differences in such surfaces, it is possible to determine the zones of accumulation and accumulation.

The red color indicates areas with a positive gain, where the amount of garbage has increased compared to the previous cycle (accumulation). This can be interpreted as moving a garbage body down the slope, where the mark was smaller, and on the difference in the surfaces is an increase. The blue is marked with areas where the amount of garbage has decreased compared to the previous cycle (precipitation). This option is possible in cases where the fragment of a garbage body under its own weight is inactive or moved to another location, and another fragment (4) has not moved in its place.

In this way, the mapping of surface differences for the above-mentioned scanning cycles in the UTM-35 projection was constructed (Figures 3-5). It should be added that on the basis of (2), during June 2016-March 2017, the movement on the landslide area slowed down compared to the 10 observation cycles of June 11-30, 2016. In all the drawings, the yellow color indicates the areas in which the movement takes place in the range from -0.10 m up to 0.10 m.

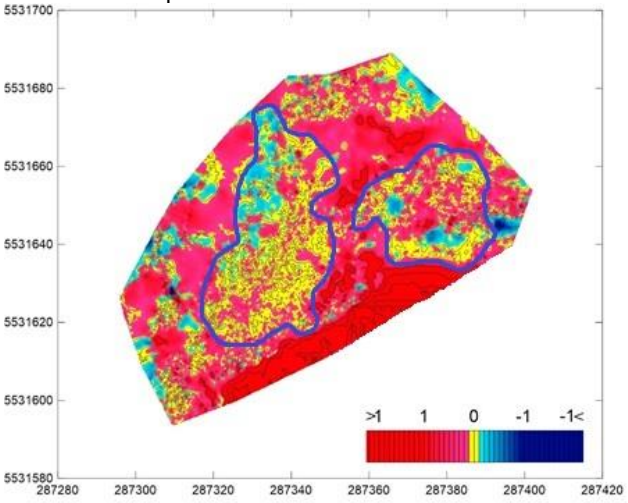

Fig. 3 The difference between the DML and the shifting area of the Lviv city landfill of solid waste (04.08.17-25.03.17)

According to the difference between the DML difference (Fig. 3) from March 25, 2017 to August 4, 2017 (4 months), it can be seen that the vertical shifts ranged from -1.68 m to +1.48 m, the average monthly traffic was -0.42 m, and + 0.37 m

By analyzing the differences in the DMLs for the corresponding period in the central part of the landslide area, two stable blocks (blue color of Fig. 3) with values close to zero can be distinguished, as well as the area where the small accumulation of waste is +1.5 m.

Similar actions were performed to find differences in DML from August 4 to November 7, 2017, which determined that the vertical shifts ranged from -1.51 m to +0.60 m, the average monthly traffic was -0.50 m and + 0.20 m.

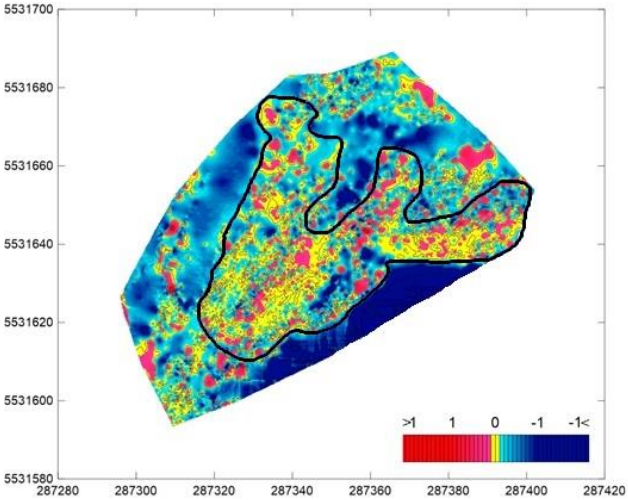

Fig.4 The difference between the DML and the shifting area of the Lviv city landfill of solid waste (07.11.17 - 04.08.17)

For this period of observation it can be argued that the union of two stable units into one and an increase in its area, which is stable almost on the whole slope (black in

Fig. 4). We select the areas where the subsidence occurs, namely: in which the cracks formed and the area located at the level of the second storage area of waste.

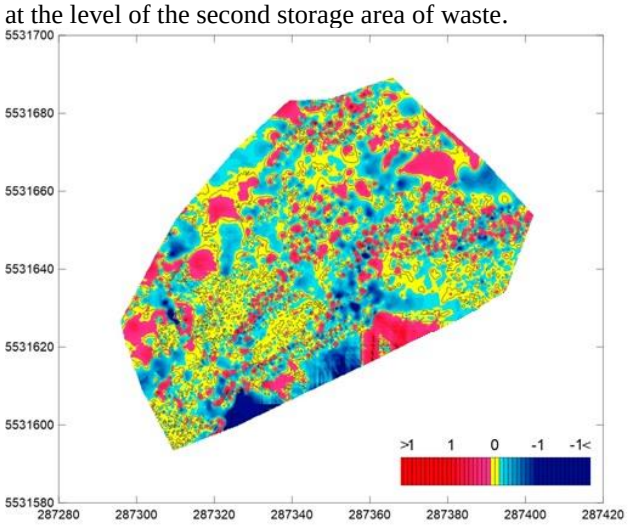

Fig. 5 The difference between the DML and the shifting area of the Lviv city landfill of solid waste (2.12.17 - 7.11.17)

As can be seen from Fig. 5, the most part of the landslide area of the slope of yellow and blue, indicating the stabilization of the slope and the slight accumulation of waste. It should be noted that due to the prohibition of operation and storage of waste at the landfill, the studied area actively overgrown with grass cover. In addition, high vegetation also appears near the shooting stations, limiting the visibility to the landslide area (Fig. 6). As a result, the laser beam of the meter was reflected from the vegetation, which caused accumulation, especially in the lower part. This assumption can be confirmed by rice. 6.

Fig. 6. View of a landslide section of the Lviv City Police TPV on August 4, 2017 from the shooting station

In fig. 5 shows the difference between the slopes from 07.11.17 to 02.12.17, where both observation cycles were carried out roughly in identical weather conditions (air temperature, low rainfall, and no grass cover on the slope). As you can see, on the slope there is mostly gradual fragmentation in the range from -1.1 m to +1.00 m and slight accumulation along the crack, indicating the movements in these places.

The method described above allows vertical movements, such as settling, to be clearly identified, but it is much more difficult to interpret accumulation, which is often a manifestation of horizontal movements. In order to detect horizontal movements, such as those of extinction, we have chosen another frame of reference, as shown in Fig. 7.

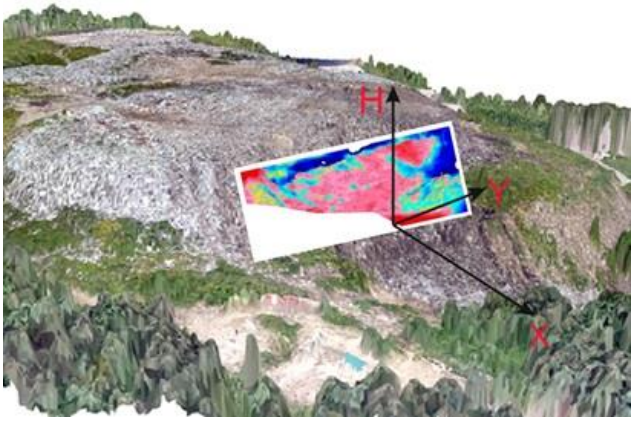

Fig. 7. Reference frame to detect horizontal movements

The axis X of this system is oriented perpendicularly to the slope, and the Y axis is parallel. The digital model is constructed in the YH plane with a 0.25 m mesh. Due to such a turn of the axes, it is clearly possible to see the zones where the movements are in the horizontal plane (Fig. 8). The blue is marked with zones with negative values, that is, it has become smaller than it was (outcropping). The red is marked with zones with positive values, that is, it has become larger than it was (imitation).

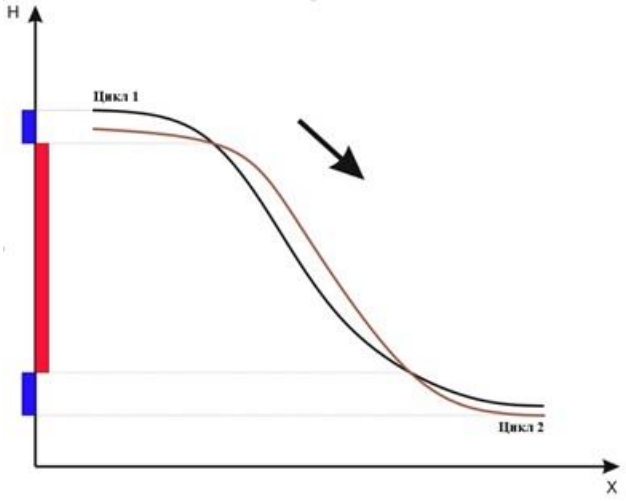

Fig. 8. Interpretation of surface differences to detect horizontal movements

In fig. 9-11 shows the surface differences of the above observation cycles for finding horizontal movements. The yellow color indicates a relatively stable zone with movements within ± 0.10 m.

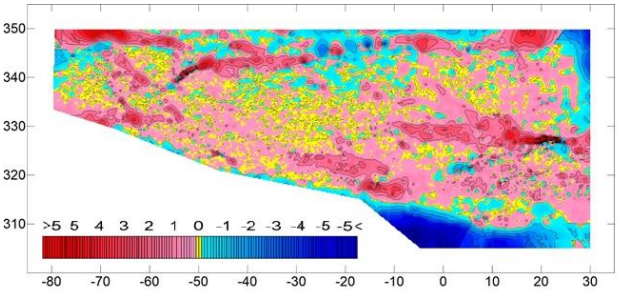

Fig. 9. Differences in surfaces (15.08 - 25.03.2017)

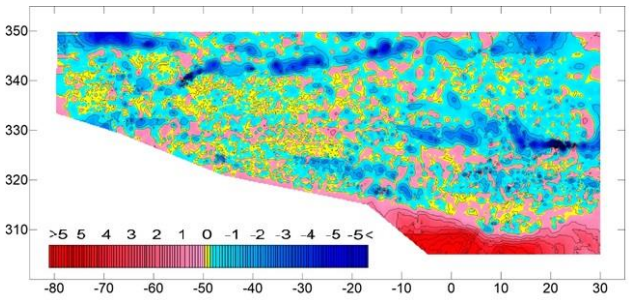

Fig. 10. Differences in surfaces (15.08 – 07.11 2017)

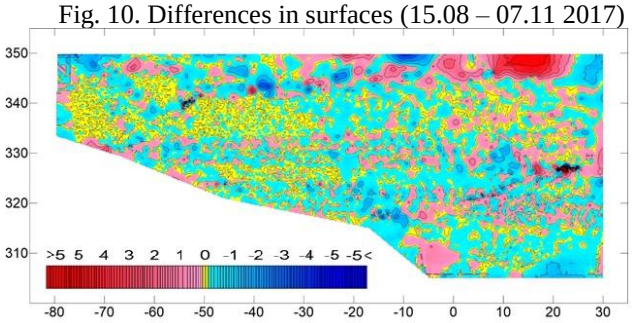

Fig. 11. Differences in surfaces (07.11 – 02.12 2017)

From Fig. 9-11 it can be seen that the most intense horizontal movements were observed from March to August 2017, where their value was +4.7 m in the place of the crack at the markings 340-350 m. Further observations make it possible to see that there is a slowdown in horizontal movements and an increase in the stable area in a landslide area (Table 1), and the slope tends to stabilize.

Table 1

Numerical characteristics of movements on the slope

		Од. вим.	Періоди спостережень		
			25.03-04.08	04.08-07.11	07.11-02.12
Площа	Накопичення	$м^2$	2123.18	1228.88	1116.69
		%	49.3	28.5	25.9
	Осідання	$м^2$	1269.48	2176.22	2016.48
		%	29.5	50.5	46.8
	Стабільна	$м^2$	913.72	901.28	1173.21
		%	21.2	20.9	27.2

Also, to track the tendency of movements on the slope, we conducted a profile line (Fig. 11), which confirms the displacement at certain points to about 5 m for the period from June 30, 2016 to December 2, 2017.

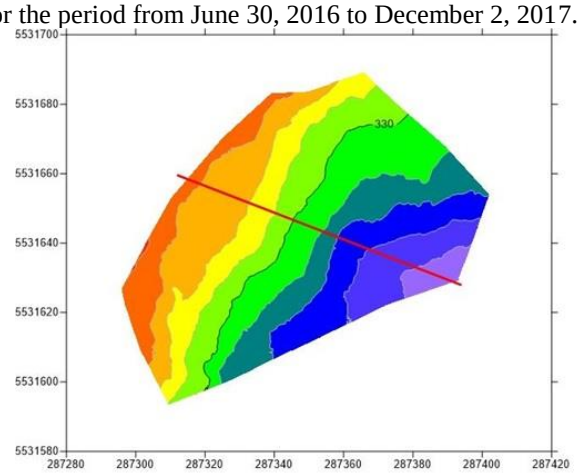

Fig. 11. The location of the profile line on the slope of the landslide section of the Lviv city landfill of solid waste

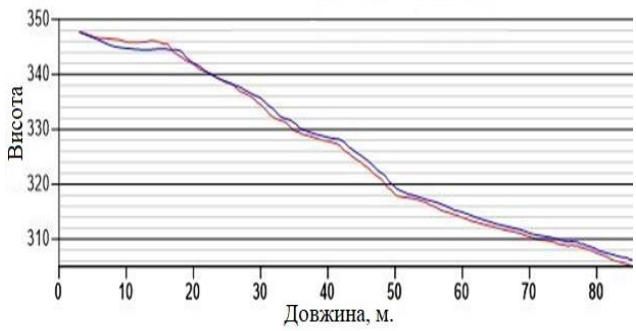

Fig. 12. Profile lines June 30, 2016 (red) and December 02, 2017 (blue color)

This research was carried out within the framework of the contracting theme № 696 from August 1, 2017 "Scanning of the landfill site of the Lviv municipal solid waste landfill by the robotic TOPCON IS-301 tacheometer during August-December 2017 (3 cycles of scanning)", commissioned by the Lviv Communal Enterprise " Assembler ".

Conclusions

1. From August to December 2017, 3 cycles of scanning of a landslide section of the Lviv city landfill of solid waste were performed using the Robotic Toponom IS-301. According to the results of the scan, DEM was constructed, and for the determination of horizontal and vertical movements, it was proposed to operate with surface differences.
2. According to the results, the central part of the landslide section remains the most stable. In general, the slope is stabilized, only partly there is a fragmentation settling within ± 1.00 m and slight accumulation along the crack.
3. A reference frame is proposed that allows tracking garbage movements in a horizontal plane. The results complement the general idea of the slope dynamics and show that the most active garbage moves occur in the area of the crack.
4. Despite the lack of requirements for monitoring of landfills in Ukraine, in practice there is a significant need for monitoring, which will allow reclamation, laying drainage channels, installation of degassing biogas plants and other types of work.

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The study dynamics of the slope of landslide areas of Lviv city landfill

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In the article presented the study dynamics of the slope of landslide areas of the Lviv city landfill. The horizontal and vertical movements that took place in the landslide area.