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ACTIVITY TO PREVENT EMERGENCY SITUATIONS OF CASCADE TYPE OF SPREADING RELATED TO SOIL LANDSLIDE

N. Rashkevich[1], V. Koloskov[1], I. Fedyuk[1]
[1]National University of Civil Defence of Ukraine, Kharkiv, Ukraine

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Abstract

Landfills for solid waste with liquidation energy-intensive technological equipment, due to emergencies of the cascade type of distribution associated with the landslide of landfills, pose a man-made environmental hazard.

Experimental studies to determine the effect of humidity, density, temperature of landfill soils on the stability of slopes on landslides have shown that with increasing humidity and temperature, the resistance of the array to displacement decreases. The lower the density, the greater the ability to penetrate and saturate with moisture, which creates additional shear load.

According to the results of experimental research, a method of prevention of cascade-type emergencies related to landfill landslides at the landfill with liquid energy-intensive technological equipment has been developed to prevent the consequences of danger from escalating from site to higher levels of distribution. The method consists of measures "before" and "after" the fact of moving the landslide.

Key words: landfill soils, humidity, temperature, density, landslide.

Problem statement.

Today, despite efforts to reduce the generation of municipal solid waste (MSW), the most common waste management strategy still remains storing wastes on landfills. Taking into account the environmental hazards of the waste landfills in the context of air pollution with greenhouse gases, there is a tendency in the world to introduce on landfill territory the liquidational energy-intensive technological equipment (LETU) for biogas utilization. Such equipment is commonly used as an alternative energy source.

However, it should be taken into account that LETU may pose an additional technogenic hazard to the environment and the population. As a result of dangerous events and emergency situations related to fires or landslides of the landfill soils there is a high probability of technogenic hazards spreading to LETU. Such situation may be characterized as emergency situation of cascade type of spreading. The main danger of such events is both in environmental pollution due to the spreading of environmentally hazardous substances outside of the facility, where environmental measures are not provided, and the presence of dead or injured people same as those people with impaired living conditions.

Thus, the unresolved part of the problem of ensuring technogenic and ecological safety at landfills equipped with LETU is the lack of an effective complex technique for counteracting the occurrence of emergency situations of the cascade type of spreading related to landfill soil landslides.

Analysis of recent research and publications.

The processes that take place in the MSW landfill are described using equations (models) of methane formation (methane generation), mass and heat exchange, and landfill soil motion.

An extended classification of methods for calculating the stability of slopes, which are based on a mechanical-mathematical approach, is described in [1]. According to the normative document [2], the most tested in geotechnical practice are the methods of boundary equilibrium (differential methods) [3], the estimation of the stress-strain state by the finite element method (integral methods) [4].

The mechanism of destruction and the regime of instability of the MSW landfill are studied with the help of field research, testing of physical models, simulation modeling [5].

Slope resilience is a function of many factors. Each of them, separated or in combination with another ones, may lead to the mechanism of slope destruction reaching critical conditions [6]. Therefore, the selection of these critical factors, causing landfill soil landslide and following extreme situation, is considered as a fundamental step in modeling of slopes susceptibility to loss of stability [7]. The authors of [8] classify instability factors in the following way:

1) internal factors of instability, such as the properties of waste and structural features of the landfill body structure;

2) external factors of instability, such as earthquake, rain, filtrate recirculation, earthworks, and overload.

The resistance of the landfill soils to shear is determined by the forces of internal friction and adhesion. MSW due to the content of fibers are characterized with mechanical (structural) connectivity, and on the presence of wet sticky components – with adhesion [9, 10].

The authors of [11] in order to study the influence of physical properties on the stability of slopes developed an installation and research methodology to identify a qualitative picture of crack formation on model materials and cover deposits of landslide slopes when moistened by precipitation of varying intensity. The work is aimed at studying of the effects of humidity. Changes in the initial density, temperatures are not taken into account.

The analysis of scientific sources have shown that the results of most works are aimed at solving the geotechnical problem that is relevant at the stage of construction of solid waste disposal facilities, but not during their operation. Therefore the needs of technogenic and ecological safety of adjacent areas if LETU is present, being additional source of accidents with biogas emissions, is not taken into account.

Problem statement and its solution.

The aim of the work is to develop a comprehensive methodology for the prevention of cascading type of emergency associated with the landslide of landfills at the landfill from SUMMER.

To achieve this aim, special laboratory installation was designed [12] (see Fig. 1) and experimental studies were conducted to determine the effect of physical properties on the stability of slopes. The shear of the experimental blocks of the landfill soils was modeled. During the study of the mechanical properties of landfill soil the results of field [12] and laboratory [13] studies were taken into account (see Table 1).

Table 1 – Natural values of factors selected for experimental investigation

Factor	ρ , kg/m^3	T , ^{0}C	w , %
Main level	950	35	55
Top level	1300	45	80
Bottom level	600	25	30

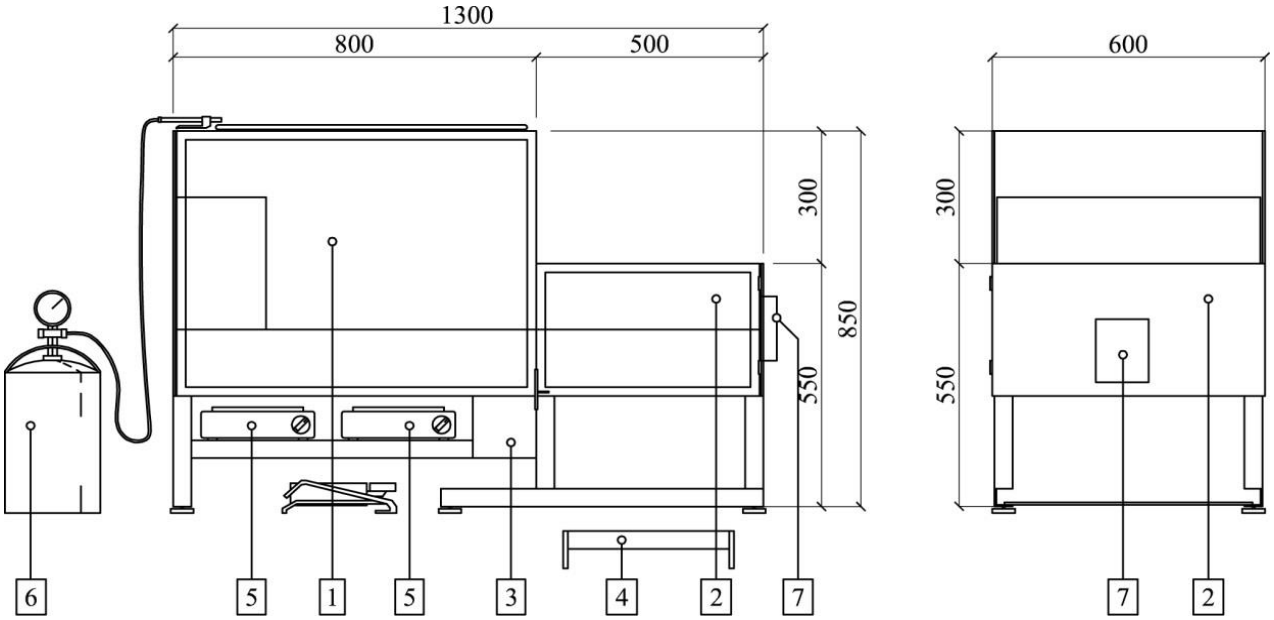

Figure 1 – Scheme of laboratory installation for investigation of influence of physical properties of landfill soils on stability of slopes:
rectangular test box with rotating (1) and fixed (2) parts, rotating (3) and fixing mechanisms (4), on-table heating plates (5), spraying device (6), tangential load system (7)

Experimental material for the formation of the horizontal sliding surface and experimental blocks was taken manually from a closed map of the landfill. The test samples were taken from the landfill soil layer with the depth of 3 m. The age of the layer is more than 15 years. The set value of density is reached due to manual ramming of the metal mortar applying layer by layer epy predetermined weight to the fixed size of molds.

Slope stability is based on the Mohr-Coulomb theory of strength:

$$\tau = \sigma \cdot \mathrm{tg}\varphi + C, \quad (1)$$

where τ – the magnitude of the tangential stresses, kPa; σ – the magnitude of the normal stresses, kPa; φ – angle of internal friction of landfill soil, deg; C – the magnitude of adhesion, kPa.

The area or slope is considered safe from landslides if the following conditions are met:

$$K_{st} = \frac{F_{res}}{F_{sh}} \geq K_{sn}, \quad (2)$$

where K_{st} – stability coefficient; F_{res} – soil resistance to displacement, kN; F_{sh} – shear force, kN; K_{sn} – normative (minimum required) coefficient of stability margin:

$$K_{sn} = \frac{\gamma_n \cdot \gamma_{fc}}{\gamma_c}, \quad (3)$$

where γ_n – reliability factor, which takes into account the class of consequences (liability) of engineering protection objects (was taken equal to $\gamma_n = 1$, minor consequences); γ_{fc} – load combination factor (was taken equal to $\gamma_{fc} = 1$, main); γ_c – coefficient of working conditions (was taken equal to $\gamma_c = 1$, those that satisfy the conditions of equilibrium).

The analysis of the obtained results shows the influence of the physical properties of the landfill soils on the stability of the slopes to shear. As the humidity increases, the angle of internal friction and adhesion decreases due to the weakening of the structural bonds and the effect of the liquid on the contact of the particles. The higher the density, the less moisture is absorbed, and the more stable the temperature. The loss of stability of the slopes of the landfill soils leads to their low density, excessive moisture, high temperatures (see Fig. 2 and Fig. 3).

The process of preventing of emergency situations of cascading type of spreading is described by the system of equations (4) [14]:

$$\begin{cases} q_1(w,\rho,T,L) = 0; \\ q_2(w,\rho,T,L) < q^{ob}; \\ q_3(w,\rho,T,L) \leq q^{ob}; \\ \Psi(q_1,q_2) = f_{q_1,q_2}(\varphi_1,\varphi_2,\varphi_3,\varphi_4). \end{cases} \quad (4)$$

where q_1 – number of dead people; q_2 – number of injured people; q_3 – number of people with impaired living conditions; q^{ob} – quantitative indicators of the consequences of emergency situations, corresponding to the object level; (w,ρ,T) – humidity, density and temperature of the MSW located at the landfill; L – the actual distance from the slope of the soil to LETU.

The resolution of the problem φ_1 – assessment of landfill soil humidity – is an analytical dependence that describes the relationship of landfill soil humidity according to the variation of the input Q_{in}^{L} and output liquid flows Q_{out}^{L}.

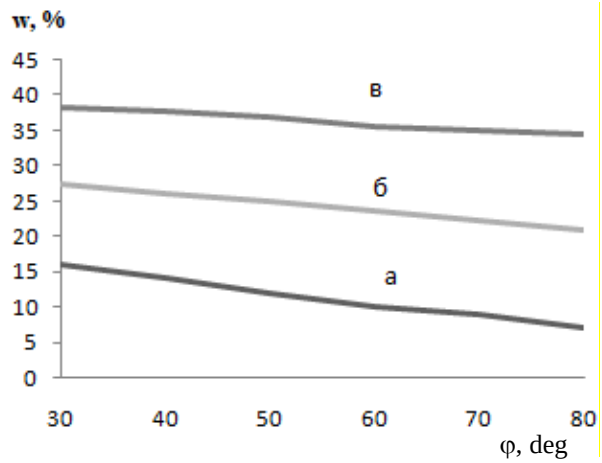

Figure 2 – Change of the magnitude of adhesion of landfill soils depending on the magnitude of their humidity and initial density (temperature is T_{start} =25 ^{0}C):
а) density equal to 600 kg/m^3;
б) density equal to 950 kg/m^3;
в) density equal to 1300 kg/m^3

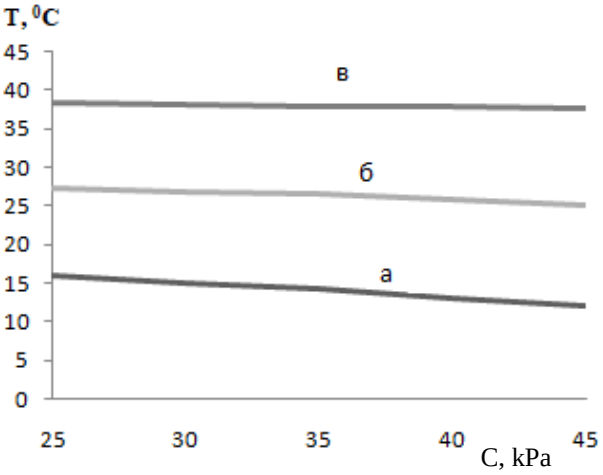

Figure 3 – Change of the magnitude of adhesion of landfill soils depending on the magnitude of their temperature and initial density (humidity is w_{start} =30 %).):
а) density equal to 600 kg/m^3;
б) density equal to 950 kg/m^3;
в) density equal to 1300 kg/m^3

The resolution of the problem φ_2 – assessment of landfill soil density – is an analytical dependence that describes the relationship of landfill soil density according to the variation of the loading force P, porosity n, height of wastes amount stored at the landfill h.

The resolution of the problem φ_3 – assessment of landfill soil temperature – is an analytical dependence that describes the relationship of landfill soil temperature according to the variation of the input (or generated) heat $Q_{in(gen)}^{H}$ and output heat Q_{out}^{H}, and is the actual equation of temperature balance.

The fourth problem φ_4 – hazard assessment of the landfill soil landslide – involves determining the volume of the landslide V_{ls}, its velocity υ_{ls}, trajectory of movement L_{ls}.

The results of experimental studies have shown that the basis of the process of limiting the spreading of the consequences of emergency situations are measures aimed at changing the physical properties of the landfill soils, taking into account the conditions of their safe management.

The implementation of the methodology for the prevention of cascade-type emergency situations related to the landslide shift involves the implementation of measures at different stages "before" and "after" the fact of movement of the landslide.

"Before" the fact of movement of the landslide.

Here we include the activities related to the design and construction of the facility. At all stages of selection of favorable land plots for the placement of the main elements of the landfill (access road, storage area, economic zone, engineering structures and communications, LETU), during their design and construction must follow the requirements of current legislation aimed at ensuring durability and safety of the facility as a whole.

Measures related to the operation of the facility to ensure the stability of the slopes of the landfill soils to landslide include:

- control of morphological composition, temperature, humidity of waste entering the landfill;
- control of volumes of acceptance and accumulation of waste;
- compliance with waste storage technology (limiting air intrusion due to proper compaction, timely intermediate or final coating);
- compliance with landfill filling operations. Filling plans should be based on the forecast of waste disposal and ensure effective installation of the biogas collection system on separate landfill maps as they are filled in order to reduce fire and explosion hazard;
- control of the geometric shape of the site and the allowable height of waste storage;
- control of internal temperature, humidity of the waste mass, concentration of carbon monoxide in biogas;
- fire control (appearance of open flame, smoke, sagging and cracking of the surface, the formation of holes);
- redistribution of the volume of the geotechnical array;
- regulation of surface runoff – interception, acceleration or deceleration of runoff due to embankment, arrangement of channels (ditches), trays, etc .;
- reduction of precipitation infiltration – surface compaction, sowing of perennial grasses, use of geosynthetic rolled materials (geocomposites, anti-erosion mats, etc.);
- strengthening of slopes – installation of anti-landslide, retaining structures (piles, retaining walls, anchor structures, etc., planting shrubs);
- maintenance of structures and objects of engineering protection in proper technical condition;
- artificial change of physical and mechanical properties of landfill soils through the use of deep methods based on injection pressure of injection solutions (cementation, clay, bituminization, silicate) and surface methods (geogrids, geogrids, etc.)

"After" the fact of movement of the landslide.

The peculiarity of the measures related to the localization and elimination of the negative consequences of the landslide, taking into account the recommendations of the Statute of actions in emergency situations of management bodies and units of the Civil Protection Rescue Service [15] are:

- conducting reconnaissance of the emergency zone around the clock with the involvement of aircraft, unmanned aerial vehicles and other technical means;
- search for victims, rescuing people, providing home care, organizing psychological care and, if necessary, life support;
- change of physical and mechanical properties of landfill soils;
- if necessary, blocking the operation of the biogas collection and utilization system;
- change the speed, volume and trajectory of the landslide;
- compliance with the requirements for the safe conduct of rescue operations in areas of destruction, rescuers take additional safety measures, ensuring timely assistance to injured rescuers;
- keeping the reserve search and rescue formations in constant readiness for carrying out emergency rescue and other urgent works.

Also, measures related to the elimination of the danger of further landslides and stabilization of the facility. Most of the work is aimed at restoring environmental systems. The group of works includes construction and (or) restoration of access roads, leachate collection and management systems, biogas collection and control system, as well as based on effective solutions of individual problems to assess the physical properties of GHG and landslide hazards taking into account technological indicators of LETU – redistribution of the volume of the geotechnical array, strengthening of slopes, artificial change of physical and mechanical properties of landfill soils.

Conclusions.

Based on the results of experimental studies to determine the impact of physical properties of landfill soils (humidity, density, temperature) on the stability of slopes to landslides developed a method of preventing emergencies of cascade type of distribution associated with landfill landslides at landfills with liquid energy-intensive equipment.

In the interests of preventing the consequences of danger from escalating from object to higher levels of distribution, measures for periods "before" and "after" the fact of movement of the landslide must be provided, namely:

- related to the design and construction of the object;
- related to the operation of the facility;
- associated with the localization and elimination of the negative consequences of the landslide;
- associated with the elimination of the risk of further landslides and stabilization of the facility.

The implementation of the developed methodology will reduce the level of ecological danger of the areas adjacent to the landfills of solid waste – to limit the spreading of environmentally hazardous substances outside the facility, where unforeseen environmental measures of environmental components.

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Рашкевич Н. В., Колосков В. Ю., Федюк І. Б.

ЗАХОДИ З ПОПЕРЕДЖЕННЯ НАДЗВИЧАЙНИХ СИТУАЦІЙ КАСКАДНОГО ТИПУ ПОШИРЕННЯ ПОВ'ЯЗАНИХ ЗІ ЗСУВОМ ЗВАЛИЩНИХ ҐРУНТІВ

Полігони твердих побутових відходів з ліквідаційним енергоємним технологічним устаткуванням, внаслідок виникнення надзвичайних ситуацій каскадного типу поширення, пов'язаних зі зсувом звалищних ґрунтів, становлять техногенно-екологічну небезпеку.

Проведені експериментальні дослідження з визначення впливу вологості, щільності, температури звалищних ґрунтів на стійкість схилів на зсув показали, що з ростом вологості та температури опір масиву зміщенню падає. Чим менша щільність, тим більша здатність до проникнення та насичення вологою, що створює додаткове навантаження на зсув.

За результатами експериментальних досліджень розроблено методику попередження надзвичайних ситуацій каскадного типу поширення, пов'язаних зі зсувом звалищних ґрунтів на полігоні твердих побутових відходів з ліквідаційним енергоємним технологічним устаткуванням, в інтересах недопущення переростання наслідків небезпеки з об'єктового на більш високі рівні поширення. Методика передбачає заходи «до» та «після» факту переміщення зсувного масиву.

Ключові слова: звалищні ґрунти, вологість, температура, щільність, зсув.

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