Methods of Performing Rescue Work In Slope Processes Affected Areas

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Abstract. **Because of various reasons in naturally as well as in artificially formed slopes the rosks can lose their stability and, under the influence of gravitational force, move down, forming landslides, screes and earth creeps.[1] Such processes are classified as slope processes. They create constant threat to human activities, exploitation of buildings and construction works. That is why it is necessary to know the preventive measures and safe methods of performing rescue works in the areas affected by slope processes.**

State Fire and Rescue Service of Latvia (further in the text – SFRS), their functions being enhanced, get calls for the rescue works, where people get buried in the ground or there exists the risk of their sinking into unstable ground. Therefore it is required to work out the methodic materials.

Keywords: **rescue works, slope processes, landslide, scree, earth creep.**

I. Introduction

Although SFRS does not separately summarize the statistical data of such rescue works performance, the risk of their arising is high enough also in our country and this fact does not allow leaving the course of such process unnoticeable.

24th April, 1999 – Brivibas Str., Riga. Two workers died in landslide while digging a sewerage trench.

5th November, 2007 – Ogre. During the reconstruction works on Brivibas Str. a trench caved in. Two workers were buried there. The ground fell on one of them only partially, but the other one was buried to neck and died because of injuries.

On 25th April, 2008 around half past two in the afternoon a tragic accident happened on a building site in Liepaja. The edge of a foundation pit fell down on a worker. At 14.40 rescue works had been started. The victim has been dug out under the supervision of emergency medical assistance workers. Unfortunately, the rescue operation was not successful – the man died during the process of digging him out.

On 29th April, 2008 in Valdlauchi, Riga a worker fell into a trench where he got buried. Other workers tried to set the victim of the accident free of sand. SFRS officers helped to lift the man from the trench.

In its turn, on 7th September, 2009 in Jekabpils a trench was dug in Liepajas Str. to change drains. At the moment when a man was in the trench there happened a landslide and he was covered with sand 2m deep. Rescuers dug out the landslide, but the man was already dead. On 6th April, 2010 in Kepova rural municipality of Kraslava region, a person in charge of water supply, died because of the edge of the trench having fallen down while performing repair works in a trench,.

In Turaida castle mound, on 7th and 8th February, 2002 two large landslides with approximate volume of 30,000m^2 have been developed. About 30 trees fell, the landslide was 40m wide and 100m long and the castle was endangered within the radius of 50m. Undrained rainfall and melting snow waters were the main reason of the landslide. As well, the specialists acknowledged that there is no information, whether the 14th century builders built the castle on sandstone bedrock or on an artificial mound.

It is known, that Bauska castle ruins with a park and Bauska medieval castle are the part of cultural and historical heritage, as well as they are the Federal monuments of architecture and archeology. Bauska castle ruins are situated on a castle mound, which makes an upright slope towards Memele River. The slope leans on a 3-4m high dolomite rock, where holes up to 3.7m deep were developed under the influence of ice, water currents and erosion. At present the lower end of the slope is on the console of the dolomite rock. It can break any time and cause a catastrophic slope slide followed by the collapse of castle walls. After especially heavy rains in 2001 three landslides in the slope of the Memele at Bauska castle have been already developed and there is still a threat that the castle walls can collapse.

Children's games in sand holes and digging graves should also be mentioned, as in the first case parents often do not pay attention to the fact that their children dig tunnels and caves in these sand holes and, as a result, the children get buried there and die. But grave diggers perform their work violating labour protection requirements, in this way causing additional threat to health and life of themselves and their colleagues. [4]

Mostly, every country elaborates the complex of methods for more efficient prevention of definite processes and/or phenomenon influence according to its peculiarities. Methods of evaluating landslide risks are elaborated in France, Italy, Sweden and Switzerland, but in seven countries, including Latvia, there exist no guidelines of the methods mentioned. (Figure 1.) [3]

Fig. 1. Stage of development of landslide Risk Assessment Methodologies in the European Union

Landslide processes are influenced by geological, morphological and human reasons. In most cases the processes were influenced or advanced by a complex of factors and, thereby, a number of slope stability loss forms can be developed simultaneously, what makes these processes more serious. (Figure 2.) [3]

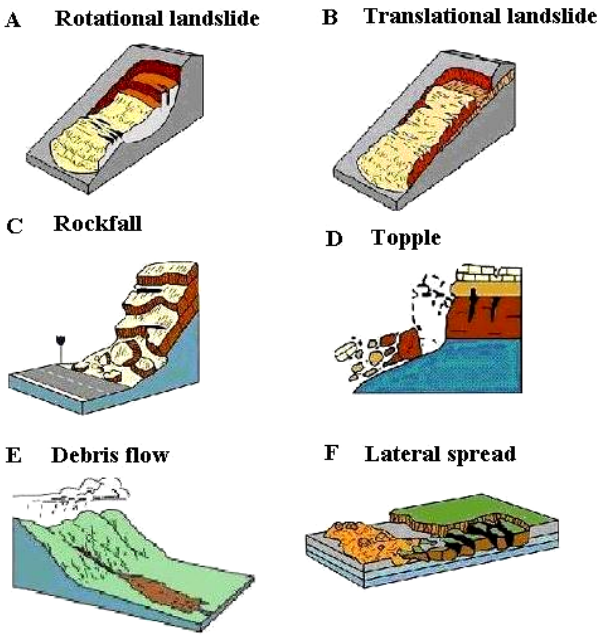

Fig. 2. Schematic classification of landslides according to the way of movement [3]

Landslide is a separation of rock massive and quick movement down the upright slope, making part of the way with overthrow.

Scree is a wreckage material that agglomerates on slopes and moves down under the influence of gravitation force.

The angle of its surface is formed according to the angle of natural slope of screed material, which, depending on the frictions between scree parts, changes within the limits from 25° to 40º. The rougher is the screed, material, the more upright the slope is formed. When as the result of material collection the angle of scree surface exceeds the angle of natural slope, the material moves smoothes out to stable position. Scree mobility is characterized by mobility coefficient (k), expressed by such formula:

$$k = \frac{\alpha}{\varphi},$$

where α – angle of a slope surface;

φ – angle of scree material natural slope.

Scree is very active if k >= 1, but if k < 0, 5, scree is relatively still.

Landslide is a rock massive that breaks away from a slope, sliding or has slid down it. Sliding is caused by loss of rock massive balance in a slope, when gravitational forces exceed the inner resistance forces of a rock massive. Slope stability is characterized by correlation of endurance and movement forces. Ground inner friction forces are directly proportional to ground gravitational force P component N, which is perpendicular to a slope. (Figure 3.)

Loss of balance and sliding can start if slope ascent grows, rosk resistance decreases, rock mass grows, hydrodynamic pressure, outer static or dynamic load work. [1]

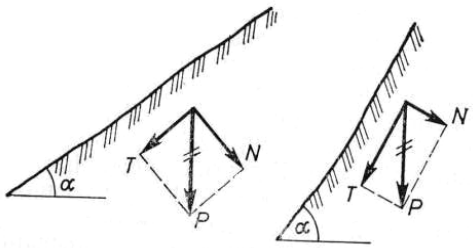

Fig. 3. Division of ground gravitational force P into components deon slope ascent:

N– component of gravitational force perpendicular to slope,

T– component of gravitational force parallel to slope,

α– angle of slope surface.

The expansion of human optional activities on the slopes cause activization of landslide, scree and earth creep processes, which considerably overtake positive results of strengthening activities.

That is why the prevention activities for these processes are considered to be important environmental protection activities. The most efficient is the use of complex of several methods aimed to prevent the cause of event and not to fix sliding masses.

Primary preventive activity for landslides is not to allow performing works on non-fixed slopes, in trenches and/or in foundation pits, observing the rules of ground placement distance from trench and/or foundation pit edge and its fixation.

Depending on the circumstances, scree prevention activities envisage growing forests and planting trees on slopes, regulation of over ground and underground waters drain in the places of scree development, lessening ascent of slopes by collecting wreckage materials, fixing up support walls and shields.

Passive landslide prevention activities envisage different limitations of engineering and technical as well as of optional activities on slopes, where engineering and geological circumstances are not favorable for slope stability. While active measures envisage different engineering and technical methods for fixing and supporting grounds, as well as leveling landslide rocks [1].

Thereby, to more professionally perform rescue and immediate consequences liquidation works at the place of event, **the aim** of the research is to improve methodic recommendations for performing rescue works applied at landslides, screes and earth creeps by integrating the methods of performing rescue works in other countries, as well as integrating the analytical calculation expressions to characterize the peculiarities of landslide and scree formations.

To achieve the aim of the research work, the following **tasks** have been completed:

- slope processes and their preventive activities were studied and systematized;
- the information on fire-fighting technologies and equipment suitable for performing rescue works was gathered;
- information about reconnaissance, victim searching methods, principles and safe methods of performing rescue works in places affected by slope processes was studied and systematized;
- information about traumas having appeared in the result of slope processes influence and possibilities of providing first aid was summarized;
- guidelines for lab our protection requirements were elaborated for performing rescue works in landslides, screes and earth creeps.

Literary sources and normative documents of different origin have been used in the research. Theoretical research and empirical methods were required for performing such works as, lowering of a rescuer, victim's raising/ transportation out of a trench/ foundation pit with the help of a rescue automobile (IVECO Trakker) manipulator, tripod and fire-fighting portable articulated ladder were imitated.

II. RESEARCH RESULTS

Rescue works connected with slope processes in trenches and/or foundation pits and the works, where employees run the risk of being covered with it, are one of the most complicated SFRS functions, as performing such works is not a daily routine.

Lack of professional experience and theoretical knowledge, training and practical activities, as well as hidden dangers of an event create high dangerousness. [4]

Methods of performing reconnaissance and searching for victims in landslides, screes and earth creeps are influenced by badly predictable limits of cataclysms, dimensions of hardly accessible territory and performing the reconnaissance with the help of over ground devices is difficult.

Reconnaissance clarifies:

- number of victims, if they are fully or partly buried;
- the number of possible victims, the character of their injuries;
- necessity to illuminate the risk zones;
- meteorology that can influence the situation in the place of event;
- the facts that would indicate the slope processes can repeat and/or continue;
- forms and amount of expected rescue works;
- character of landslides, screes and earth creeps, their basic parameters (speed of movement, amount and duration of slide);
- degree of object damage, presence of buildings and their character, presence of utilities - power systems, their condition and distance;
- peculiarities of the site;
- possibility to use municipal power systems for performing rescue works;
- and other questions depending on the opinion of work superintendant and situation on the place of events.

Such information about the situation is acquired using complex reconnaissance methods and applying technical means envisaged for such purposes. Searching is the basic method of reconnaissance to find injured and/or dead, who need help or detection, specifying their situation and defining rescue procedures.

Different technical means are applied in searching people. They can state breathing, heartbeat, movement, infra-red and electromagnetic radiation. Those devices are of different types and they vary according to statement kinds – acoustic, optical, radio wave and registration of metabolism products.

The most wide-spread kinds of search devices are:

- optical;
- acoustic;
- thermal picture making cameras (Figure 4.);
- radars;
- devices in which analyzers of chemicals are used;
- devices based on neuropsychological peculiarities in human organism.

To state the position of a person in caving in, acoustic devices are mostly used. They can detect weak sound signals (shouts, moaning and beating elements of construction) and state the directions of the emission. Sensors with two microphones give the possibility to define the distance to sound source, as well as to use infra-red radiation cameras for searching victims (not corpses).

Fig. 4. Search device Vibrascope ® BVA-6

Searching with the help of acoustic devices has limited use possibilities, as noise, working devices and technical means, people moving around the site, dropping ground or dripping/leaking water greatly affects precise measuring and search results. Efficient application of acoustic devices is possible only when people are able to let know about their position by shouting, moaning or knocking.

Seismic devices have acoustic and also seismic transmitters that are placed on a solid ground in the process of working. Beating (also weak knocking) transmitted by people buried get to the surface through construction elements like seismic vibrations registered by seismic device.

One of people searching kinds is also using specially trained dogs. [2] There are no such specially trained dogs in Latvia for working in landslides, screes and earth creeps, but exist dog searching resources that can be involved into searching dead bodies. Dog specialists present in our country mostly take part in searching lost people and criminals, as well as corpses.

It should be added that such kind of victim searching is widely used in the world and there are specially trained disaster dogs used for searching people in different kinds of crashes, whirlwinds and earthquakes. Special dogs are trained to find dead bodies (cadaver dogs), they are trained in finding human remains.

Victims that are underground are set free with the help of instruments and small mechanization means. They do not make great vibration and additional load on the edges of a trench/ foundation pit or a slope. (Figure 5.)

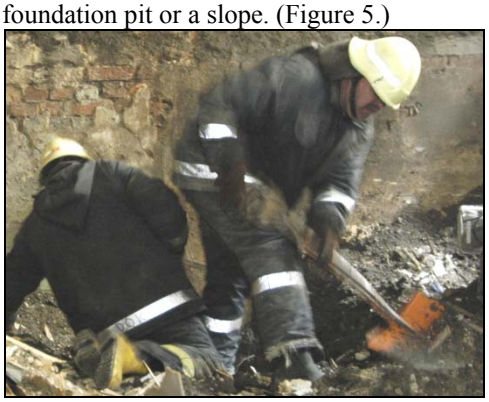

Fig. 5. Setting the victim free from ground caving in using spades

For transferring or evacuation of victims different carrying, withdrawal methods can be used, depending on injuries and situation on the spot. (Figure 6.)

Fig. 6. Carrying a victim on a stretcher for two or four rescuers

Immobilization boards, portable fire-fighting ladders, auto ladders, automatic lift forks and rescue automobiles with manipulators are used observing placement regulations next to trenches, foundation pits and slopes. (Figure 8., Figure 9.)

Fig. 7. Raising a victim out of a trench/ foundation pit with the help of a tripod

Fig. 8. Raising a victim out of a trench/ foundation pit with the help of a manipulator

It is vitally important to clarify whether the victim is partly or fully underground, duration of its stay there, as well as approximate depth of its position.

Full capacity rescue works are performed only after landslides, screes and earth creeps happen and the situation becomes stable, when the possibility of repeated landslides, screes and earth creeps is prevented.

It is advisable to co-operate with building work superintendent or the person in charge to get additional information about the peculiarities of a landslide, victims and activities performed, as well as to make decisions about the placement of technical devices. After getting the information, one should decide if any devices are necessary for rescue works and the number of rescuers is sufficient.

During rescue works one should constantly observe and evaluate the situation on the spot and bear in mind climate situation.

Rescue works are performed with the aim to rescue endangered people and are conditionally divided into seven basic stages:

1. **Immediate activities –** include getting information about the event and activities performed not to allow or lessen and/or prevent further expansion of dangerous factors.
2. **Clarifying the position of victims –** include the complex of activities performed to define people's positions and their situation, establishing communication and clarifying the character and volume of necessary help.
3. **Safe reaching the risk zone, approaching victims –** safe reaching of fire-fighters to the risk zone is secured by maintaining radio communication and constantly being within the scope, keeping visual contact, as well as using individual means of protection, making unstable part of the landslide stable and securing themselves from falling.

Fig. 9. Lowering the rescuer into the landslide to a victim with the manipulator of a rescue automobile and mountain climber's bandage/ fire-fighter's belt with a carbine

Lowering/ rising rescuers into and out of a trench/ foundation pit and for working on slopes fire-fighting portable articular ladders are used. Such method of working can be used in rural settlements where there are less fire-fighting machines and all the necessary security activities connected with slope processes continuation are performed.

Tripod can be used if rescue works should be performed in narrow trenches, pits and wells, as well as for lifting the ground dug out. For the pressure from tripod legs not to be great, supports can be used. Hand winch facilitates rescuer's lowering down and victim's lifting. (Figure 7.)

4. **Digging out victims** – covers the complex of organizational, technologic activities to ensure approach to victims who are underground, in locked spaces with the aim to provide them aid and evacuate them to a safe place. Performing the digging works, it is considered that the victim is alive and that is why the digging is performed by hands and measuring the distance (conditionally) to the victim. Digging out a trench / foundation pit is performed with sloping walls of natural caving. (Figure 10.)

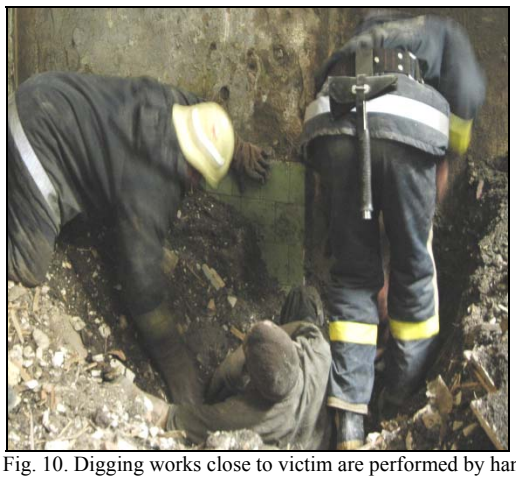

Fig. 10. Digging works close to victim are performed by hands

5. **Providing first aid to victims** – is provided in their positions after ensuring the access to them and setting them free. Influence of dangerous factors is suspended and such situation which allows performing the evacuation of a victim from the zone is ensured. In case of landslides, screes and earth creeps varied character traumas are possible. Mainly mechanical traumas and fractures, lasting pressure syndrome, cooling, frostbite, overheat, drowning and eye traumas are observed.
6. **Evacuation/ transportation of victims from risk zone** - it is a complex of activities for organized and accelerated transportation of victims to a safe place or medical institution. Evacuation of victims is made after providing first aid to them.

Evacuation of victims can be performed in two stages: 1) evacuation from caging place to a safe place and preparation for further evacuation or 2) evacuation to victim division point or directly to medical institution.

The kind and means of evacuation depend on the positions of stuck victims, types of access to them, type and amount of first aid provided, character of traumas and their conditions, victims psychological conditions, outer danger factors for victims and fire–fighters, profebackground of rescuers, resources, transport means and possibilities to use them, length of evacuation ways and other factors

depending on a season, time of the day and working conditions.

7. **Separation of accident place and its security after the liquidation of rescue works** - it is necessary to avoid repeated falling of people, animal and transport means into the hole.

Rescue works in landslides, screes and earth creeps should be performed in full fire-fighter's rescuer clothing as cavings are formed from different construction wreckages, ground, stones, mud and even ice and it is necessary to secure oneself with the help of rescuer reserves.

It is forbidden:

- to jump into a hole or bottom of a slope (forming artificial vibrations or even jumping over a victim);
- move around the hole;
- be on the slope of a hole;
- squashing on separated landslide part;
- to move or leave transport means on the slope or near to the edge of a trench/ foundation pit, where collapse is possible;
- throw necessary instruments (they are given with the help of a rope);
- widely use engineering and technical means for digging out victims;
- for rescuer to be alone in collapse zone, without securing oneself with a rope and not keeping visual contact;
- in rescue works to use devices that make great pressure on the edges of a trench/ foundation pit and artificial vibrations. [4]

During rescue works it is forbidden to place the dug out rocks (ground) closer than 0.5m from the edges of a trench, foundation pit.

III. Conclusion

Digging out a trench/ foundation pit is made observing natural angle of slope when ground is balanced and does not fall. Angle of a slope is defined depending on the kind of ground, its level and humidity. The biggest angle of slope for a just dug out trench 3m deep can be 45^o, but for 3-5m deep – 38^o. [2]

Placing the lift fork near to a slope or a trench, distances described in its documentation should be observed. (Figure 11., Table 1.) If it is impossible to observe the distances mentioned, the edges of a trench or a foundation pit should be fixed according to the project. [5]

During setting the victim free, it is considered that he or she is alive and digging out is mostly performed by hands, observing the natural angle of slope when ground is balanced and does not fall down.

While performing rescue and immediate result elimination works, regulations on technical means

Fig. 11. Working range of rescue automobile (IVECO Trakker) manipulator (F190A.24) depending on the mass lifted

TABLE 1

MINIMAL PLACING DISTANCE OF A LIFT FORK FROM THE EDGES OF TRENCHES AND FOUNDATION PITS (IF EDGES ARE NOT FIXED)

Depth of a trench, m	Distance* (m) from the beginning of the slope to the nearest sliding stanchion depending on the kind of the ground				
	sand	loamy sand	sandy loam	loam	dry loess
1	1,50	1,25	1,00	1,00	1,00
2	3,00	2,40	2,00	1,50	2,00
3	4,00	3,60	3,25	1,75	2,50
4	5,00	4,40	4,00	3,00	3,00
5	6,00	5,30	4,75	3,50	3,50

* The distance is measured from the trapeze top forming the configuration of a trench or a foundation pit.

Before performing rescue works, as well as after the end of them the hole is separated or completely filled and separated to avoid people, animals or transport means falling into it. [4]

In rescue works in landslides, screes and earth creeps one should use such technical means and devices that do not make great vibrations and additional load on the edges of a trench/ foundation pit or a slope, and do not add to victim's traumas.

During the reconnaissance of the spot all information possible about the number of victims, character of their traumas, positions and types and amount of envisaged rescue works should be quickly gathered.

Rescue works in places affected by slope processes are performed with special caution and operativeness, ensuring SFRS units reaching the place in possibly shortest time, as $1m^3$ of the ground weighs from 1590 to 2010 kg, 45 – 60 cm ground layer on person's back or chest weights ~ 318 – 454 kg. Every time when a victim exhales, free space around the chest lessens and restricts its expansion until the moment when the victim cannot breathe any more and dies of suffocation.

placement should be observed. During rescue works the situation on the spot should be constantly observed and evaluated and climate situation should be taken into account.

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Vladimirs Jemeļjanovs, Gunita Nikitina, Jeļena Sulojeva, Valentīna Urbāne. Glābšanas darbu veikšanas paņēmieni nogāžu procesu skartajās vietās
Gan dabiskajās, gan arī mākslīgi veidotajās nogāzēs ieži dažādu apstākļu dēļ var zaudēt stabilitāti un gravitācijas spēka iedarbībā pārvietoties lejup, veidojot nogruvumus, nobiras un noslīdeņus. Šādas norises klasificē kā nogāžu procesu. Tie rada pastāvīgus draudus cilvēku darbībai, būvju ekspluatācijai un būvniecībai, tāpēc nepieciešams pārzināt to profilaktiskos pasākumus un drošus glābšanas darbu veikšanas paņēmienus šo procesu skartajās vietās.
Valsts ugunsdzēsības un glābšanas dienests (turpmāk – VUGD), paplašinoties tā funkcijām, saņem arī izsaukumus uz glābšanas darbiem, kuros cilvēki tiek aprakti gruntīs vai pastāv risks to iegrimšanai nestabilā gruntī, lai gan līdz šim nav bijis metodiskā materiāla, nav arī apmācības šajā jomā.
Tādējādi pētījuma mērķis ir pilnveidot metodiskos ieteikumus glābšanas darbu veikšanai nogruvumos, nobirās un noslīdeņos, integrējot tajā citu valstu glābšanas darbu veikšanas paņēmienus ar VUGD materiāltehniskā nodrošinājuma iespējām, kā arī iekļaut tajā analītiskas aprēķina izteiksmes noslīdeņu un nobiru veidošanās īpatnību raksturošanai. Darba izstrādes procesā galvenokārt izmantoti angļu un krievu valodā pieejamie literatūras avoti, bet valsts valodā izmantojamā literatūra ir tikai nedaudzi Ministru kabineta noteikumi un pāris atgādnes par zemes darbu veikšanu.
Glābšanas darbi nogruvumos, noslīdeņos un nobirās ir komplicēti, jo 1m^3 grunts sver no 1590 – 2010 kg, toties 45 – 60 cm grunts slānis uz cilvēka krūškurvja vai muguras sver ~ 318 – 454 kg un cietušo izdzīvošana šādos procesos visbiežāk ir minimāla. To veikšanā aizliegts plaši pielietot inženiertehniskos līdzekļus (papildus slodze un vibrācija ietekmē aizgruvuma stabilitāti un darba apstākļus), bet notikuma bīstamie faktori ietekmē gan cietušos, gan glābējus.
Pētījuma rezultātā tiks izstrādāts VUGD iekšējā normatīvā akta projekts, ar mērķi sniegt VUGD amatpersonām ar speciālajām dienesta pakāpēm pamatzināšanas par darba aizsardzības prasībām, veicot glābšanas darbus nogāžu procesa skartajās vietās, tādējādi ugunsdzēsēji glābēji tiks nodrošināti ar sākotnējiem apmācības materiāliem.

Владимир Емельянов, Гунита Никитина, Елена Сулоева, Валентина Урбане. Способы проведения спасательных работ в местах, затронутых склоновыми процессами
На склонах, сформированных как естественным путём, так и искусственно, в силу различных причин порода может потерять стабильность и под воздействием сил гравитации перемещаться вниз, образуя обвалы, осыпи и оползни. Подобные явления классифицируют как склоновые процессы. Они создают постоянную угрозу деятельности людей, эксплуатации зданий и строительству, поэтому необходимо тщательно изучить профилактические мероприятия и надёжные способы проведения спасательных работ в местах, затронутых этими процессами.
Государственная пожарно-спасательная служба (далее - ГПСС), при расширении её функций получает вызовы также и на спасательные работы, когда люди оказываются погребёнными в грунте или существует риск их погружения в нестабильный грунт, хотя до сих пор по данному вопросу не существовало методических материалов, а также не проводилось обучение в данной области.
Таким образом, целью исследования является совершенствование методических рекомендаций для проведения спасательных работ при обвалах, осыпях и оползнях, интегрируя приёмы ведения спасательных работ в других странах в возможности материально-технического обеспечения VUGD, а также включить в данное исследование аналитические выражения рассчётов для охарактеризования особенностей образования оползней и осыпей. В процессе разработки данного исследования в основном были использованы источники литературы, доступные на английском и русском языках, а использованные источники литературы на государственном языке – это только некоторые правила Кабинета министров и несколько памяток о проведении земляных работ.
Спасательные работы при обвалах, осыпях и оползнях являются сложными, так как 1м^3 грунта весит от 1590 до 2010 кг, а слой грунта толщиной 45-60 см на грудной клетке или спине человека весит ~ 318 – 454 кг и выживание пострадавших в подобных процессах чаще всего затруднительно.
При проведении подобных работ запрещается широко использовать инженерно-технические средства (дополнительные нагрузка и вибрация влияют на стабильность завала и условия работы), а опасные факторы происшествия влияют как на пострадавших, так и на спасателей.
В результате исследования был разработан проект внутреннего нормативного акта VUGD с целью предоставить должностным лицам VUGD с особым рангом основные знания о требованиях охраны труда при проведении спасательных работ в местах, затронутых склоновыми процессами. Таким образом, спасатели – пожарные будут обеспечены начальным учебным материалом.