Methods of stabilization of mountain slopes near highways against landslides

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Abstract. In today's transport sector, especially the highway sector, road safety remains an issue of high importance. Ensuring road safety, especially in mountainous areas, is one of the urgent problems of the industry. To increase the stability against displacement of landslides that may occur on highways and to ensure safe movement on roads. Road transport through mountainous areas faces a number of complexities and has to operate under several harsh conditions. Landslides are a constant threat to highways. In this regard, several countries have worked and presented their projects. This article proposes solutions to reduce the risk of landslides and landslides to highways. In this case, the statistics collected in the research were analyzed practically and engineering solutions suitable for different mountain conditions were used. The results and statistics collected as a result of field research and the proposed engineering solutions are specific to the mountain slopes and slopes of the "Kamchik" Pass, which passes through the mountainous region of the A-373 "Tashkent-Osh" highway of the Republic of Uzbekistan. The engineering solutions proposed in this paper, in accordance with the research findings, serve to effectively protect highways from landslides and to prevent economic losses caused by landslides on highways.

1 Introduction

The development and construction of highway projects that can meet world standards and compete with the leading countries in the field of roads in our country, the development of new technologies to increase the service life of existing highways, and its introduction into the field are being intensively carried out. Decisions and decrees of the President serve as a basis in this matter. In particular, in the new development strategy of Uzbekistan for 2022-2026, among other things, the tasks of "Improving road infrastructure and rapid development of the highway network" are defined at the level of the state program [1].

In addition, in the decision of the President of the Republic of Uzbekistan dated October 10, 2023 No. PQ-330 "On measures to further improve the road industry", the works to be performed in the field of highways, in particular, "Tashkent - Andijan" and "Tashkent - Samarkand" toll cars important assignments on the development and construction of road projects were mentioned [10].

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From this decision, we can see that in the process of designing and building a toll road, it will be necessary to carry out work in mountainous areas. This in itself requires the development of measures and innovative solutions for the impact of landslides on highways and the prevention of landslides.

Landslides are exogenous geological processes. Exogenous geological processes occur mainly as a result of the interaction of rocks with the external environment [7]. In addition, landslides can be interpreted as the movement of soil and rock masses along mountain slopes and steep slopes under the influence of gravity. Landslides are often caused by slope erosion, heavy rainfall, earthquakes, or human activity [2,8]. The volume of soil displaced during a landslide can be tens or hundreds of thousands of cubic meters [3,9].

2 Materials and methods

Scientists have given different definitions of landslides in the process of studying this field. For example: N.F. Pogrebov came to the following conclusion about the landslide and described it as “the shifting of the mountain slopes under the influence of a certain force, in most cases under the influence of surface and underground water and as a result of gravity” [4,5,9,11].

A number of scientists have conducted research on landslides in the world, including: V.D. Kazarnovsky, B.B. Karimov, X.Ya. Muradov, Z.I. Rogozina, G.A. Fedetov, Mehmet PARLAK, Enes KABA, Beuglova Ekaterina Vyacheslavovna, Nefise AKCHELIK, Zuhal ETKESEN, Mavish AKYUZOGLU, Aslan JIHAT, Jemil SHEN, Fenemenko Igor Konstantinovich, V.O. Mikhailov, S.S. Chernomorets, Philip Blum, Zeljko Arbanas, Sanja Dugonjic Jovanjevic and others have developed conclusions and recommendations on the causes of this problem, their impact on infrastructure facilities and their prevention.

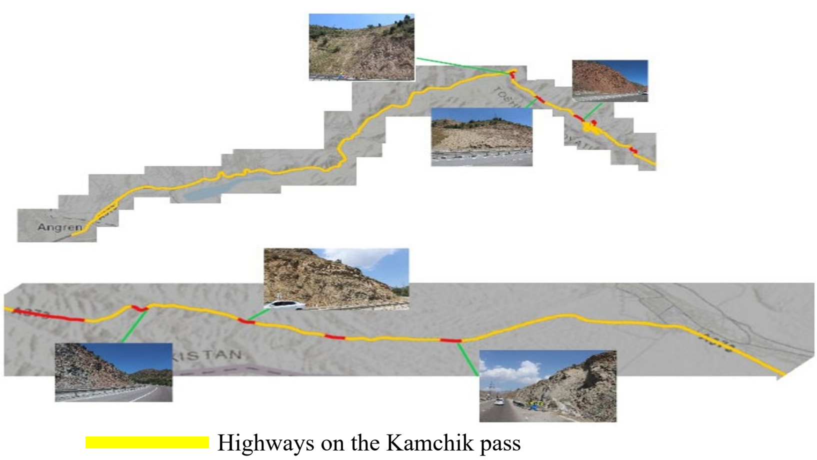

Fig. 1 A-373 “Tashkent-Osh” highway “Kamchik” pass map description of slopes with the possibility of displacement (Source compiled by the authors).

If we look at the importance and results of the research on landslides, we can see that there is still much work to be done on this topic and that the work done on studying the impact of landslides on highways is not enough.

The total area of our republic is 448,978 km^2, and 1/5 of the total territory is occupied by mountainous areas [7]. The part of the A-373 “Tashkent-Osh” highway of international importance between 183-283 km, that is, the “Kamchik” pass, also passed through the mountainous region, which was taken as the object of the study.

The purpose of taking this “Kamchik” pass as a research object is that this road is a road that does not have alternative routes connecting the regions of the Fergana Valley with other regions of our republic.

As a result of field work and their analysis in the research area, it was determined that there is a risk of landslides on the rocks on the side of the highway at a total of 24 points of the A-373 highway “Kamchik” pass (Figure 1).

In the process of determining landslide-prone slopes, the type of ground in the rock, height, slope slope and factors influencing the movement were studied (Table 1).

Table 1. Landslides on the side of a highway.

№	Location on A-373 highway	Slope height, m.	Slope value	Geological structure of the slope
1	222-km.	120 m.	50^0	The upper part is loess, the lower part is granite, granodiorite rocks of Paleozoic age.
2	222.8-km.	30 m.	65^0	The upper part is loess-like up to 5 meters, the lower part is granite, granodiorite rocks belonging to the Paleozoic period.
3	225.9-km.	20 m.	40^0	Loessous rocks
4	228.9-km.	120 m.	60^0	The upper part is up to 5 meters of stony mixed soil, the lower part is granite, granodiorite rocks of the Paleozoic period.
5	230-km.	150 m	55^0	The upper part is loess soil, the lower part is granite, granodiorite rocks of Paleozoic age.
6	233.8-km.	50 m.	85^0	The upper part is man-made rocks, the lower part is granite, granodiorite rocks belonging to the Paleozoic period.
7	238.3-238.6-km.	20-40 m.	$50\text{-}60^0$	Stone and soil mass
8	239-km.	40 m.	65^0	Paleozoic granite, granodiorite rocks
9	243.7-km.	100 m.	60^0	The upper part is loess soil, the lower part is granite, granodiorite rocks of Paleozoic age.
10	244.3-km.	80 m.	40^0	The upper part is loess from the Quaternary period, and the lower part is granite and granodiorite rocks from the Paleozoic period.
11	244.5-km.	60 m.	$55\text{-}65^0$	The upper part is delluvial rocks, the lower part is granite, granodiorite rocks belonging to the Paleozoic period.
12	244.7-244.8-km.	45 m.	$45\text{-}50^0$	The upper part is loess from the Quaternary period, and the lower part is granite and granodiorite rocks from the Paleozoic period.
13	245.4-km.	60 m.	$65\text{-}70^0$	The upper part is loess-like up to 2 meters thick, and the lower part is granite, granodiorite rocks of Paleozoic age.
14	245.7-km.	80 m.	$60\text{-}65^0$	The upper part is loess-like up to 2 meters thick, and the lower part is granite, granodiorite rocks of Paleozoic age.
15	246.0-km.	40 m.	$55\text{-}65^0$	Paleozoic granite, granodiorite rocks
16	246.8-km.	40 m.	$65\text{-}70^0$	The upper part is loess from the Quaternary period, and the lower part is

				granite and granodiorite rocks from the Paleozoic period.
17	249-294.4-km.	50-60 m.	55-65^0	The upper part is loess with a thickness of up to 1.5 meters, and the lower part is granite, granodiorite rocks belonging to the Paleozoic period.
18	250.5-km.	25 m.	60^0	Stone and soil mass
19	251.5-km.	50-60 m.	60-70^0	The upper part is loess-like up to 2 meters thick, and the lower part is granite, granodiorite rocks of Paleozoic age.
20	254.5-km.	50-60 m.	60-70^0	The upper part is loess-like up to 2 meters thick, and the lower part is granite, granodiorite rocks of Paleozoic age.
21	255.0-km	30-40 m.	50-60^0	The upper part is delluvial up to 6 meters thick, and the lower part is granite, granodiorite rocks belonging to the Paleozoic period.
22	258-259-km.	45 m.	60^0	The upper part is delluvial up to 6 meters thick, and the lower part is granite, granodiorite rocks belonging to the Paleozoic period.
23	258.2- km.	70 m.	65^0	Loessous and fragmental rocks
24	260-261.3-km.	150 m.	70^0	Paleozoic granite, granodiorite rocks

Source compiled by the authors

When the analysis of previous landslides on the road was carried out, it was found that the factor causing most of the landslides in the research object is the influence of underground and rainwater.

According to the precipitation data obtained from the Kamchik Pass hydrometrological station, the average maximum amount of precipitation is observed between November and February, and the mountain slopes are more likely to move due to the high amount of precipitation in these months (Figure 2).

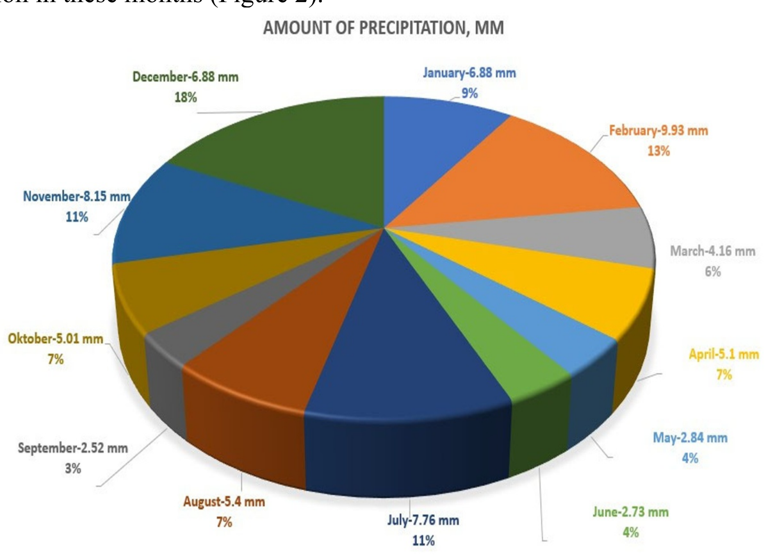

Fig. 2. The amount of annual precipitation in Kamchik pass, in months. *Source* compiled by the authors.

Due to the fact that the relative height of the mountainous regions above the sea level is slightly higher than other regions, precipitations are observed a lot. For this reason, as the height increases, the air pressure decreases and the amount of precipitation increases [6,12]. A similar process is observed in the "Kamchik" pass, and more snow and rain are observed in the upper part of the highway in the pass. We can clearly see the relative height of the highway in the "Kamchik" pass above sea level in Figure 3. The highest point of the "Kamchik" highway is 2178 meters.

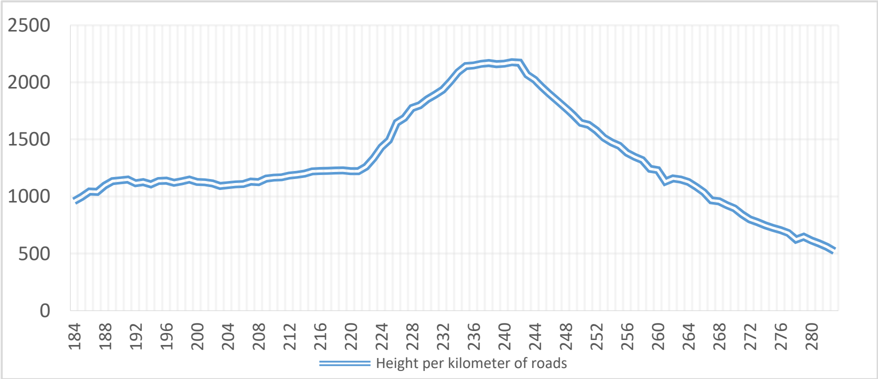

Fig. 3. Kamchik Pass is the height above sea level along the entire length of the highway (Source compiled by the authors).

It is proposed to use the following engineering solutions to increase the strength of the slopes located on the slopes of the highways and to reduce the risk of displacement of the slopes by camera processing of the data collected during the field work:

- Construction of drainage systems in order to reduce the impact of underground and rainwater on rocks;
- Limiting the movement of the moving mass with the help of a retaining wall on the slopes;
- Strengthening of the places with a large displacement depth of the rock slope surface with anchors;
- To prevent the rock slopes from sliding due to their own weight, removing the mass on the slope and erecting piles;
- Use of gabion constructions against sliding on loess soil slopes.

Some of the solutions mentioned above have been used in the "Khamchik" pass and are showing their results in increasing the strength of the slopes (Figure 4).

a) b)

Fig. 4. Engineering solutions used to increase the stability of slopes against sliding in the "Kamchik" pass: a) construction of piles while reducing the frictional mass on the slope; b) use of gabion structure to prevent sliding on a loess slope (Source compiled by the authors).

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3 Results and discussion

A discussion of the proposed engineering solutions allows for a more in-depth approach to each solution, analyzing the theoretical results with a view to their practical application. In order to reduce the negative effects of water on the rocks, it is necessary to build drainage systems on the slopes. In this case, it is necessary to lower the level of underground water much below the sliding limit of the slope.

The first method of lowering groundwater levels on slopes is to pump groundwater away from the slope (Figure 5). Using this method, it will be possible to lower the underground water level from 60 cm to 150 cm. The amount of precipitation is also important. However, since this method is a bit more economical, it is also recommended to build horizontal drains to reduce the impact of underground water (Figure 6). That is, in this case, horizontal holes are drilled from the surface of the slope, drainage pipes are installed, and underground water is removed from the surface of the slope through the drainage system on the side of the road.

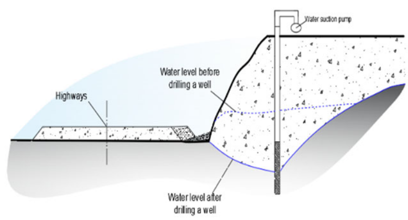

Fig. 5. Removal of underground water from the slopes using a pump (Source compiled by the authors).

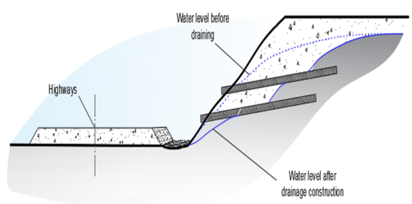

Fig. 6. Reducing the impact of groundwater on the slope using horizontal drains (Source compiled by the authors).

By strengthening the thrust of the sloping slopes with the help of walls, the downward movement of the mass on the surfaces identified in the field investigations is prevented (Figure 7). A small drawback of the retaining wall is that this construction is not useful in stabilizing deep slopes in the thrust zone. In such cases, the reinforcement of sloping slopes with anchors is effective (Figure 8). In this case, fixing anchors are fixed to hard rocks deeper than the thrust limit.

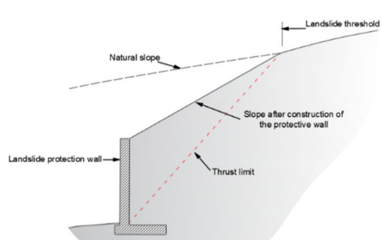

Fig. 7. Reinforcement of the slope with the help of a wall (Source compiled by the authors).

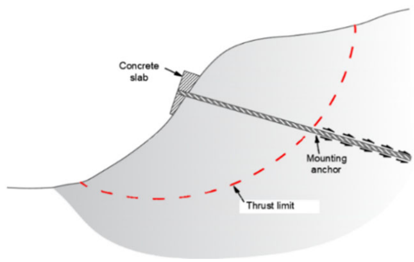

Fig. 8. Strengthening the slope of the mountain slope with the help of anchors (Source compiled by the authors).

One of the effective ways to increase the sliding resistance of hillside slopes is to reduce the sliding mass on the slope and reduce the slope angle (Figure 9c). In this case, it will be possible to reduce the sliding load on the slope by removing the ground mass from the top of the landslide-prone areas on the mountain slopes or by building piles along the surface of the slope (Figure 9a, b). The use of gabion structures is highly effective in increasing the stability of the slope against sliding in places where it is not possible to remove or repair soil masses on the slopes or when the slopes are composed of flowable soils (Figure 9d). The gabion structure is made in the form of a parallelepiped filled with natural stone material inside strong wire nets.

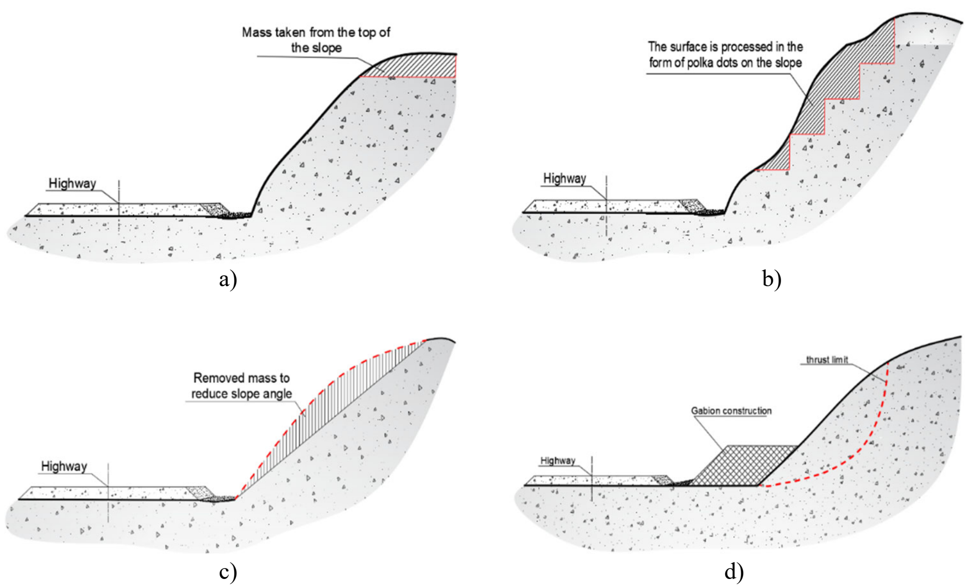

Fig. 9. Ways to increase the stability of the slope: a) remove the moving mass on the upper part of the slope; b) construction of poles on the slope; c) soil mass removed from the surface to reduce the slope angle; d) use of gabion structure to prevent displacement (Source compiled by the authors).

4 Conclusion

Protection of highways in mountainous areas from the effects of landslides and landslides serves to ensure the uninterrupted movement of vehicles in this area, the safety of road users, and to prevent economic damage to the highway. The following are the conclusions of this scientific article:

- the work to be carried out on the study of the impact of landslides on highways has not yet been completed;
- in addition to the measures proposed above against landslides, it is necessary to study the methods of adaptation to the conditions of Uzbekistan by studying the methods used by developed countries;
- the main factor causing landslides in the research object, it is necessary to achieve maximum reduction of water effects;
- the many years of work in the field of automobiles in our republic and their results show that there is no road map based on the measures to be taken against landslides in mountainous areas and specific solutions against landslides and landslides of highways, so research was conducted on this topic.

References

1. S. Fu, L. Chen, T. Woldai et al., Nat Hazards Earth Syst Sci **20(2)**, 581-601 (2020). https://doi.org/10.5194/nhess-20-581-2020
2. T. Görüm, S. Fidan, Landslides **18**, 1691-1705 (2021). https://link.springer.com/article/10.1007/s10346-020-01580-7
3. R.M. Khudaykulov, X.X. Xayitov, Architecture, construction and design **18**, 297-300 (2023)
4. Mehmet Parlak, Journal of Natural Hazards and Environment, 282-287 (2020)
5. E. Aristizábal, O. Sánchez, Disasters **44**, 596-618 (2020). https://doi.org/10.1111/disa.12391
6. S. Roy, R. Kshirsagar, Process Safety and Environmental Protection **148**, 358-369 (2020). https://doi.org/10.1016/j.psep.2020.10.021
7. N Abd Majid, R. Rainis, Sains Malays **48**, 1367-1381 (2019). http://dx.doi.org/10.17576/jsm-2019-4807-06
8. O.S. Vlasova, *"Dangerous natural processes" textbook* (Moscow, VolgGASU, 2014)
9. Fedor Konstantinovich Bufeev, *Modeling of sliding landslides confined to the slopes of historical natural-technical systems composed of technogenic soils* (Moscow, 2016)
10. R.M. Khudaykulov, X.X. Xayitov, Prospects of technology and technology development: problems and solutions **18**, 289-292 (2023)
11. European Commission (2021) Global overview of landslides with fatalities (1 August–31 December 2020). In: ERCC—Emergency Response Coordination Centre (2021)
12. Maxamadjan Miraxmedov, Azamat Khudoyorov, Khurshid Abdullaev, Mavjuda Muzaffarova, AIP Conf. Proc. **2432(1)** 030051 (2022). https://doi.org/10.1063/5.0091022