

Assessment of Seismic Risk Level Related to Landslides of Mountain Rocks on Railways Passing through Mountainous Areas

Nurmatov H. M. ¹, Sulaimanov S. S. ², Botirova M. M. ³

^{1, 2, 3} Department of Naval architecture and offshore Engineering, Bangabandhu Sheikh Mujibur Rahman Maritime University, Bangladesh

Abstract:

The article discusses the high seismic risk (threat and damage) level of railway objects passing through mountainous regions, emphasizing the relationship between the duration of repair works and the extent of damage to structures, their type, design, and degree of damage. It highlights how, during an earthquake, railway objects and mountain rocks are forced to undergo mechanical vibrations, changing the static (stability) conditions of the elements involved in the vibration process (such as mountain rocks and cliffs). The analysis focuses on how the inertial forces of stationary mountain rock masses on slopes, under the influence of internal and external friction forces, are generated, altering the balance of forces that ensure the stability of mountain rocks. The paper also discusses the movement of mountain rocks on the slopes during an earthquake of 6-7 intensity on the Richter scale.

Keywords: earthquake, transport, man-made structures, road infrastructure, man-made, tectonic shift, seismic area, seismic stability, tectonic wave, seismogravitational effect, railway, level of damage, secondary effect.

It is known that the mountainous regions of our republic are characterized by high seismic activity. The Angren-Pop railway line is located in such a region. Therefore, it is crucial to assess in advance the negative impact of earthquakes on transport infrastructure in this area and the level of their associated risks. During an earthquake, the degree of damage to transportation vehicles depends on the physical destruction caused by the effects of the atmosphere, hydrosphere, and lithosphere, as well as technogenic influences. Additionally, the degree of compliance with special requirements for the construction and monitoring of transport infrastructure in seismic regions plays a significant

role. For this reason, the damage levels of railways are classified based on their seismic stability as unstable, low seismic stability, and stable seismic levels. Despite the fact that railway objects passing through mountainous and foothill regions may have different indicators, the likelihood of significant damage caused by seismic threats and vulnerabilities is high. [1, 2, 3, 4].

The need to impose restrictions on the speed of transportation vehicles and the weight of moving trains arises from the potential for rockfalls and landslides in mountainous areas. When rocks and debris, such as large stones, gravel, and coarse sand, fall from the mountain slopes, they block the railway tracks, making it difficult to operate the railway lines. This process has been analyzed in relation to the intensity of earthquakes and the patterns of its dependence.

The main sources of non-structural hazard factors in the "Railway-Mountain Environment" system are rocks, mountain rocks located on slopes, structures, and others. The causes of non-structural hazards include landslides, collapses, and destructions. If the weight vector, vertically dropped from the mass center, intersects the contour formed by the support area (Figure 1), and if the magnitude of the sliding friction force is sufficient, the stability of the mountain rocks located on the slope is considered stable. During an earthquake, railway objects, including their non-structural elements, as well as the mountain rocks, will inevitably begin to undergo mechanical vibrations.

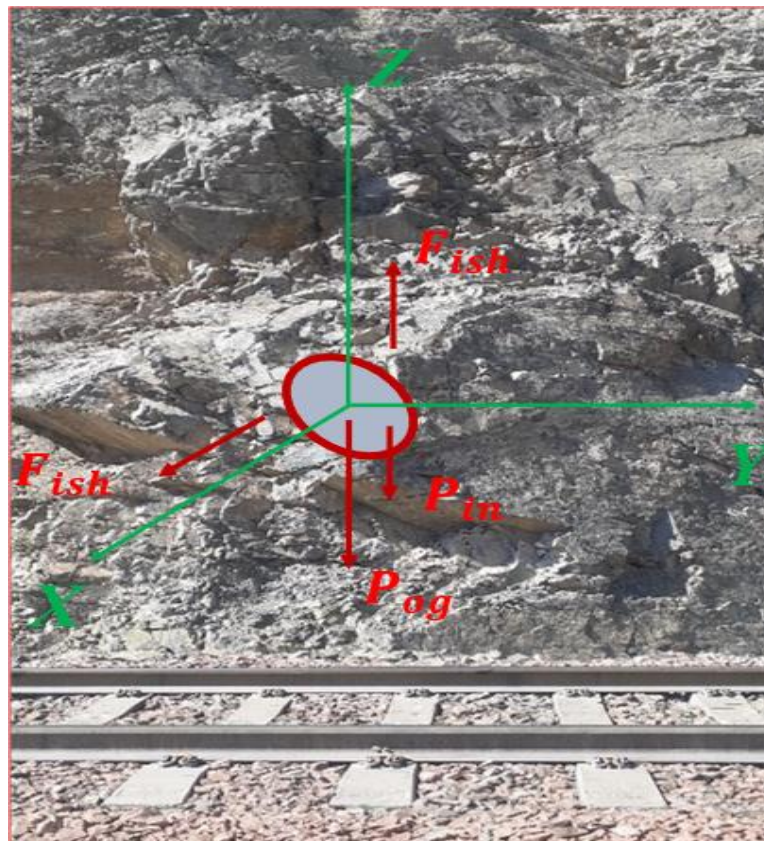


Figure 1. Scheme of internal and external forces acting on stationary mountain rock masses on slopes.

The amplitude, velocity, acceleration, and direction of vibrations depend on the nature of seismic waves. During the vibration process, the stability (stability) conditions of the elements involved (mountain rocks, cliffs) change, as the inertial forces of stationary mountain rock masses arise under the influence of internal and external friction forces on the slope. The overall force balance that ensures the stability of mountain rocks is altered. In such a case, the stability of the stationary mountain rock elements on the slope under the influence of internal and external friction forces is described by the following equations:

$$\begin{aligned} F_{mpx} + G_{nox} + P_{onx} &= 0 \\ F_{mpy} + G_{noy} + P_{ony} &= 0 \quad (1) \\ F_{mpz} + G_{noz} + P_{onz} &= 0 \end{aligned}$$

$$\begin{aligned} M_{mpx} + M_{nox} + M_{onx} &= 0 \\ M_{mpy} + M_{noy} + M_{ony} &= 0 \quad (2) \\ M_{mpz} + M_{noz} + M_{onz} &= 0 \end{aligned}$$

The analysis of the formulas (1) and (2) shows that for $F_{mpx} < P_{unx}$ the non-structural rock is along the X axis, for $F_{mpy} < P_{uny}$ - along the U axis, if for $M_{nox} > M_{noy}$ the non-structural rock is stable, for $M_{nox} < M_{noy}$ it is overturned, $M_{noy} > M_{ony}$, the non-structural rock is stable, for $M_{noy} < M_{ony}$ it bends forward or backward. The probability of overturning increases with the shift of the mass center relative to the geometric center of the support area of a non-structural element. The magnitude of the inertial force's overturning moment depends on the coordinates of the center of gravity of the non-structural rock and the seismic intensity. The value of the inertial force is directly related to the mass of the mountain rock and the magnitude of the seismic acceleration, which applies seismic shocks to the non-structural mountain rock. The mass of the non-structural element and the acceleration of seismic shocks can be calculated using the empirical formula proposed by authors [5,6,7,8]:

$$\lg \bar{a} = -0,21 + 0,34 \cdot I \pm 0,33, \text{ cm/c}^2, \quad (3)$$

$$\lg \bar{a} = 0,167 + 0,3 \cdot I \pm 0,43 \text{ cm/ c}^2, \quad (4)$$

where, $\bar{a}$ is the average acceleration of ground surface vibrations, cm/s²; I is the intensity of seismic vibrations, in points of MSK-64.

The value of intensity, in turn, depends on the strength of the earthquake; the distance between the epicenter and the location of the mountain rock formations, which are not structurally significant, the soil composition, the level of groundwater, and the depth at which the seismic source is located [10, 11, 12, 13]. The formulas (3) and (4) are written as follows:

$$\bar{a} = 10^{(-0,21+0,34 \cdot I \pm 0,33)}, \quad (5)$$

$$\bar{a} = 10^{(0,167+0,3 \cdot I \pm 0,43)}. \quad (6)$$

The inertia forces of the stable mountain rocks, which are independent of the slope and arise due to the seismic tremors, can be calculated using the following formulas (5) and (6):

$$P_{un} = m \cdot 10^{(-0,21+0,34 \cdot I \pm 0,33)} \quad (7)$$

$$P_{un} = m \cdot 10^{(0,167+0,3 \cdot I \pm 0,43)} \quad (8)$$

The relationship between the seismic acceleration and the forces G_m , F_{mp} , and P_{un} was studied for earthquake intensities ranging from 3 to 7 on the MSK-64 scale. The mass of the non-structural mountain rocks varied from 200 to 8000 kg, and the angle of the slopes they are located on ranged from 0 to 40 degrees (with earthquake frequencies between 2 and 6 Hz). In the calculations based on the formulas, the internal friction coefficient, moisture content, and fractional composition of the mountain rocks were taken into account.

Table 1. The data calculated using the formulas

Earthquake intensity,	P(in.max) (N)	P(ин.маx) (N)	P(in.min) (N)	P(ин.мин) (N)	P(0*), (N)	P(20*), (N)	P(40*), (N)
-----------------------	---------------	---------------	---------------	---------------	------------	-------------	-------------

(points) I							
3	1104,31	2512,41	241,596	346,809	46188	43416,72	35564,76
4	2415,96	5012,91	528,555	691,974	46188	43416,72	35564,76
5	5285,55	10002,1	1156,35	1380,67	46188	43416,72	35564,76
6	11563,5	19956,8	2529,82	2754,8	46188	43416,72	35564,76
7	25298,2	39819	5534,65	5496,55	46188	43416,72	35564,76
8	55346,5	79449,3	12108,5	10967,1	46188	43416,72	35564,76

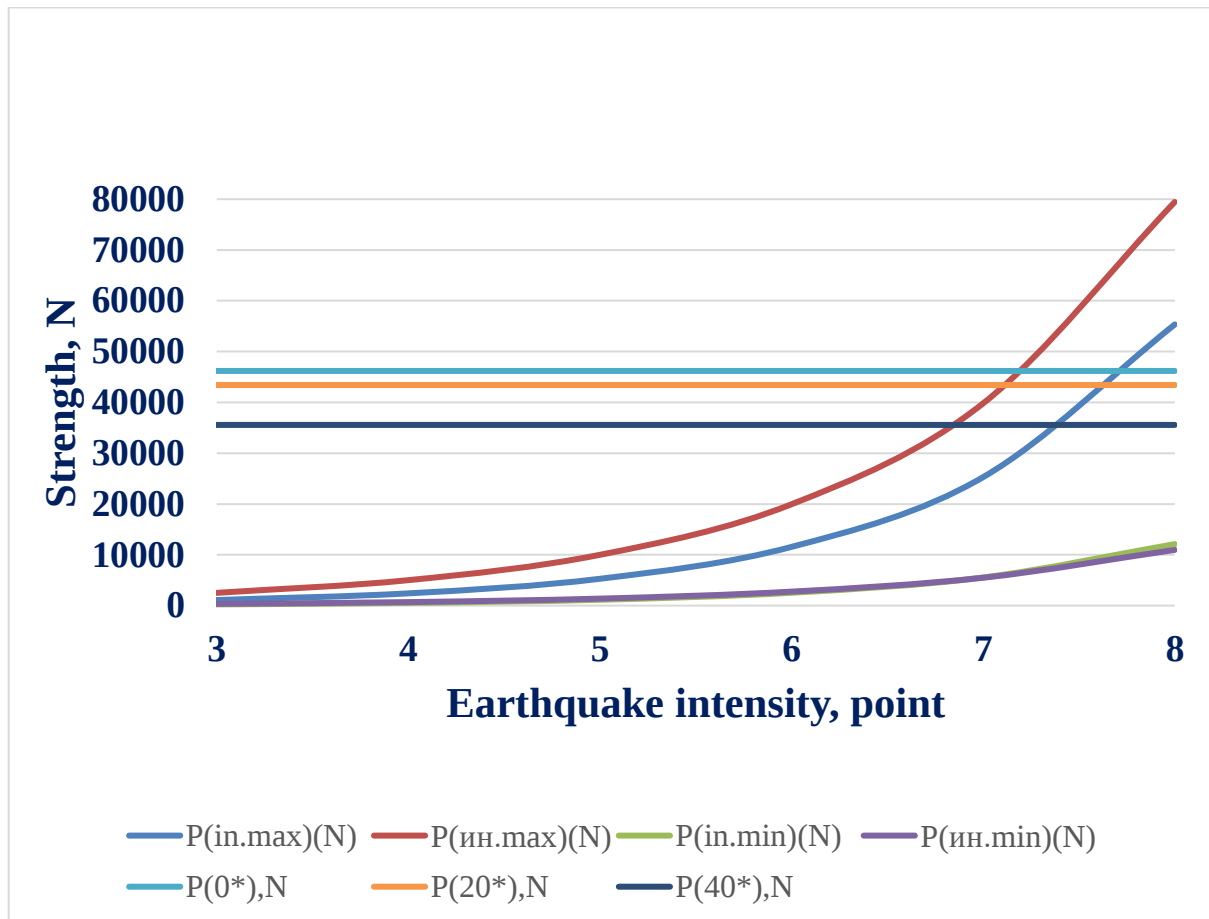


Figure 2. Dependence of forces acting on rock elements on earthquake intensity

To analyze the stability of the mountain rock elements on slopes, a graph was constructed based on the calculated data obtained from formulas (7) and (8), showing the relationship between the forces acting on the non-structural element and the magnitude of earthquake intensity (Figure 2). The graph clearly indicates that the mountain rocks on the slope begin to shift during earthquakes with an intensity of 6-7 on the scale.

In mountainous regions, the seismic risk (threat and damage) level for railway infrastructure is high, and the duration of repair work depends on the extent, type, structure, and degree of damage to the affected facilities. Typically, damage to the road surface and the soil layer (pavement) at level *d1* is addressed within the first two days following the earthquake. Restoration at level *d2*, which requires appropriate forces and equipment, is completed within three days. Damage at level *d3* is resolved within seven days, while damage at level *d4* is repaired within one month, and damage at level *d5* may take more than a month to be addressed.

During an earthquake, railway infrastructure, including its non-structural elements, and mountain rocks, will inevitably begin to experience mechanical vibrations. The amplitude, velocity,

acceleration, and direction of these vibrations depend on the nature of the seismic waves. As the vibration process occurs, the stability (or equilibrium) conditions of the elements involved (such as mountain rocks and boulders) change, because, on sloped surfaces, the inertia forces of stationary mountain rock masses arise under the influence of internal and external friction forces. The balance of the overall forces maintaining the stability of the rocks is altered, causing the mountain rocks on the slope to begin to shift during earthquakes with an intensity of 6-7 on the scale.

In mountainous areas, rockfall and debris sliding occur, with rocks, coarse sand, gravel, and large stone fragments falling from the slopes and blocking the railway tracks, thereby complicating the operation of the railway and making its maintenance more difficult.

References

1. Сулайманов С.С., Нурматов Х.М. (ТДТрУ). TRANSPORTDA RESURS TEJAMKOR TEXNOLOGIYALAR. Xorijiy olimlari ishtirokidagi respublika ilmiy – texnika anjumani maqolalari to‘plami 2023 yil 20-21 dekabr), Toshkent, O‘zbekiston. Тоғли худуддан ўтган темир йўл объектларида сейсмик риск даражасини баҳолаш)
2. Сулайманов С.С., Нурматов Х.М. (ТДТрУ). TRANSPORTDA RESURS TEJAMKOR TEXNOLOGIYALAR. Xorijiy olimlari ishtirokidagi respublika ilmiy – texnika anjumani maqolalari to‘plami (2021 yil 18-19 dekabr), Toshkent, O‘zbekiston. Зилзила оқибатида Ангрен-поп темир йўл линиясига етказиладиган зарар, йўқотишлар турлари ва унга қарши кураш чораларининг зарурий босқичлари.)
3. Сулаймонов С.С., Нурматов Х.М. Сейсмик рискни камайтириш бўйича ангрен-поп темир йўл линияси салоҳиятини баҳолаш муаммолари, проблемы архитектуры и строительства problems of architecture and construction (научно-технический журнал) (Scientific and technical magazine) 2021 й.
4. Нурматов Х.М. Зилзила рўй берганида йўлларнинг зарарланишини масофадан туриб прогнозлаш.
5. Плотникова Л.Т. О соотношении сейсмических параметров грунтов, определяемых по записям слабых и сильных землетрясений (на примере землетрясений Ташкентской эпицентральной зоны)// Сейсмическое микрорайонирование. – М.: Наука, 1977. – С.181 – 189.
6. Абдурахманов С.А. Валиев Т.С, Касымов С.М. и др. Сейсмическое микрорайонирование территорий г. Ташкента и прилегающих зон. // Ташкентское землетрясение 26 апреля 1966 года. – Ташкент: Фан, 1971. – С. 450–462.
7. Плотникова Л. М. Спектральные и спектрально-временные особенности землетрясений потенциально –опасных зон района Чарвакского водохранилища// Районирование сейсмических аспектов. – Ташкент: Фан, 1990.- С.154-168.
8. Плотникова Л. М., Тер-Карпетова К. С., Рустанович Д.Н. Расчетные сейсмограммы сильных землетрясений для сооружений с учетом частотных особенностей очаговых зон района// Сейсмические воздействия на гидротехнические и энергетические сооружения. – М.: Наука, 1980. –С. 132- 144.
9. Narziev S., Asqarov J., Khokimyatov A. Methodology Of Organization Of The Labor Process And Preservation Of Employees’ Health //The American Journal of Engineering and Technology. – 2021. – Т. 3. – №. 04. – С. 79-84.
10. Lazarenkov A. et al. IMPACT OF PRODUCTION ENVIRONMENT AND LABOR PROCESS FACTORS ON THE BODY OF FOUNDRY WORKERS //Science and innovation. – 2024. – Т. 3. – №. A4. – С. 285-292.

11. Mamashaev B., Narziev S. BASIC CONDITIONS OF LABOR PROTECTION IN LANDSCAPING WORKS //Science and innovation. – 2023. – T. 2. – №. A2. – C. 191-195.
12. Murodov V., Narziev S. THEORETICAL ANALYSIS OF FIRE SAFETY //Science and innovation. – 2023. – T. 2. – №. A3. – C. 103-108.
13. Narziev S., Latibov S. PROSPECTS OF PROMOTION OF SPORT AND BREWING IN THE POPULATION //Science and innovation. – 2023. – T. 2. – №. B1. – C. 392-395.