Anchoring devices for mounting reticulate catchers on rocky sections of roads

Georgy Lelikov and Dmitry Prostakishin
Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, Russia
E-mail: mgsu_promalp@mail.ru

Abstract. This paper discusses an important aspect of ensuring safety during construction work at height, as well as when installing protective elements that catch possible falling parts of the terrain, when it is adjacent to the roadway and other communication routes. The purpose of the field tests was to verify the stability of products on the terrain with the application of static and dynamic loads. The stability test was carried out during installation on different rocks and also different regions of the CIS countries. Dynamic tests simulating cargo stall at various factors, followed by researching the ways to stop the falls. Static tests were carried out using manual tension systems - tackles. Tests in the laboratory were carried out in order to determine the destructive load on the product. For this, a special test mold was made that simulated the natural conditions. All tests were carried out using anchoring devices of various sizes, as well as with different options for the installation depth and support of the anchor. During the tests, a number of features based on the design form were discovered. The results of laboratory tests are displayed in the table with data for all test samples. A comparison was made of the bearing characteristics. As a result of this work, both the positive and the negative aspects were identified, it was especially important that the question arose of the need to possess the necessary competencies for installing this type of device.

1. Introduction
Improving the remote settlements requires the laying of roads and communication networks, which often have to be carried out in mountainous areas. It is necessary to ensure safety in multiple potentially hazardous areas, while doing this economically, due to the increased numbers of such local areas. Safety from falling elements of soil and rock, as well as talus ground, when driving along sections of roads adjacent to rocky sections, is ensured by the presence of special catcher nets made of metal wire of at least 3 mm in diameter. In turn, the catcher element is attached to the rock with spacer threaded anchors, ensuring its reliable positioning. Areas in which it is necessary to provide the necessary measures for the application of protective elements are mostly inaccessible and remote from district centers of settlements and other infrastructure, and work in such areas is difficult due to the complexity of the terrain, the lack of centralized access to electricity and the inability to use construction equipment, and potential hazard, which requires the availability of skilled labor, the deployment of additional infrastructure with power points and etc.

The main reason for the increased volume of areas where it is necessary to apply protective nets and other protective elements is the significant deterioration of the equipment that has been used for these purposes to date. In view of this, a number of tests of special anchoring devices were carried out,
which are used for simple and quick fixation on natural rocky areas for the possibility of installing protective elements on them. Another use of simple anchoring devices is shown in [1].

During tests, attention was paid to the design of such anchors and their maximum bearing capacity. As the test samples stamping elements from a steel sheet having the shape of a “unit” with an elongated “leg” and a pointed beak were used (figure 1). Anchors were manufactured at the FSUE “Krasnoyarsk Machine-Building Plant”. The choice of this form was dictated by the fact that with a greater load on the given anchor element with a vertical load, it is able to go deeper into the ground and does not have the possibility of spontaneous release from it. Material for the samples was determined by the following criteria: durability, strength and lack of toxicity. At the same time, this material should have sufficient softness for a better location in the ground and increase the friction force.

![Figure 1. Form of the anchoring device.](image)

2. Methods

The tests were carried out in two stages: field and laboratory.

The shape of the anchor gave good results in both laboratory and field tests: on the granite rock masses near Vyborg city, the shell rock of the Elbrus region, granite massifs of the Krasnoyarsk “pillars”, and calcareous deposits of the Polushkinsky quarries in the Moscow Region.

The first stage was a field test. Field tests were carried out in two types: static and dynamic. Static - determining the maximum load on the anchor, before losing its main bearing properties. Dynamic - determining and monitoring the stability of the position of the anchor on the relief under loading. Additionally, you can familiarize yourself with the load distribution during dynamic tests [2]. Static - were carried out by loading the anchor device with a 4-fold pulley system with an efficiency of ~ 95% [3, 4] when loading by two test participants weighing ~ 80 kgf. Dynamic - by dropping a control load of 50 kg with a drop factor of 1 and 1.5 [5, 6]. For both types of such tests, the anchor device was installed at all possible depths in the natural relief. The anchor was loaded through the lower eye with a slight deviation from the vertical from 5 to 10 degrees. In all tested cases, spontaneous release of the device from the installation site on the terrain was not recorded.

The second stage of testing anchoring devices was a laboratory test on a static stand and the determination of the breaking load on this element. To do this, at the test stand for personal protective equipment (PPE) against falling from a height, which is part of the test laboratory of the Institute for
Integrated Safety in the Construction of the National Research University of Moscow State University of Civil Engineering, the laboratory staff conducted a series of tests for the loss of the main load-bearing properties of the anchor device. A detailed description of the stand is presented in [7].

The stand consists of two test blocks: for static tests and for dynamic tests (figure 2). For our tasks, only the unit for static tests was involved.

![Test stand for PPE against falling from a height.](image)

Figure 2. Test stand for PPE against falling from a height.

Samples were mounted on a specially designed mold for these purposes (figure 3), simulating the position of the anchor on the ground. Due to the fact that it is not always possible to install such an anchor to the full depth on the relief, the tests were carried out as follows. Test samples of each size were installed on the bench in three fixed positions of the depth of support: to a depth of 1 cm, to half its possible size and to full depth.
The loading of the samples was carried out with a fixed speed of 50 mm/min in the direction of the expected loading. Measurement of effort was carried out by a strain gauge mounted on a device for tension. The measuring equipment made it possible to take readings in a wide range from 0 to 50 kN with an accuracy of ± 1%.

3. Results
Anchor characteristics are shown in table 1.

Table 1. Anchor characteristics.

| Anchor type   | Weight, gr | Length, mm | Thickness, mm | Maximum depth of support, mm | Steel grade |
|---------------|------------|------------|---------------|-----------------------------|-------------|
| Small anchor  | 60         | 105        | 3             | 35                          | 30HGSA      |
| Medium anchor | 80         | 128        | 3             | 45                          | 30HGSA      |
| Big anchor    | 110        | 150        | 3             | 55                          | 30HGSA      |

The results are shown in table 2.

Table 2. The results of tests on a static stand.

| Anchor type   | Test results, kgf |
|---------------|-------------------|
|               | Depth of support 1 cm | Half depth of support | Full depth of support |
| Small anchor  | 720               | 1210                 | 1770                  |
| Medium anchor | 850               | 1140                 | 1880                  |
| Big anchor    | 630               | 910                  | 1270                  |
4. Discussion
An analysis of field tests revealed the following recommendations for the use of such anchoring devices. Small anchor are suitable for shallow cracks, the rather rigid and durable. Medium Anchor is the most versatile anchor. It is suitable in most situations, with different types of terrain. A large anchor is convenient in narrowing deep cracks, it has shown itself giving great results with a large number of unstable relief.

The main advantages of such anchors are as follows:
- ease of installation, the installation of such an anchor does not require a power tool, just one hammer for tight clogging, which greatly simplifies the task;
- ease and low cost of production of such an anchor;
- the ability to install on unstable terrain where it is impossible to install conventional anchor bolts;
- reusable, easily dismantled from rock;
- maintainability, due to the softness of the metal is easily repairable;
- environmental friendliness, does not damage the terrain and is not an unnecessary element in the natural environment, does not leave any traces when dismantled.

5. Conclusions
The capacity characteristics of anchor devices largely depend on the type of steel, hardening technology and the thoroughness of the inspection control cycle [8]. These anchor devices are widespread and used in mountaineering in the organization of rock insurance [9]. The results obtained during the tests have previously shown the possibility of using such anchor devices on a solid relief for fastening catching networks, provided that the number of anchor points per square meter of barrage elements is calculated for the correct load distribution [10]. But for a more accurate analysis of the results, additional tests with a large number of test samples are needed. At the same time, for more critical areas, it is recommended to use more sophisticated methods of fastening anchors to keep from talus ground and using traditional drilling methods [11].

References
[1] Pease David, 2015, Quick and Easy Anchor System, Carolina Fire Rescue EMS Journal 29(3):14;
[2] Semmel Von Chris, Hellberg Florian, 2009, Stand in der Wand, Panorama 2009(2):74-767;
[3] Kulaev V.E., Yakovleva L.I., Kulaev E.V., Voshchevoz D.S. Theoretical study of the efficiency of hoisting hoists. In the collection: Actual problems of scientific and technological progress in the agro-industrial complex VII International scientific and practical conference in the framework of the XIX international agro-industrial exhibition "AgroUniversal - 2013". 2013.S. 172-176;
[4] Gibbs Mike, 2012, Tying it all Together: Considerations for equalizing multi-point anchor systems, Proceedings of the International Technical Rescue Symposium 2012;
[5] Lionel Manin, Jarir Mahfoudh, Matthieu Richard, David Jauffres, Modeling the climber fall arrest dynamics, ASME 2005 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. DOI: 10.1115/DETC2005-84131;
[6] Krzysztof Baszczyński, The Influence of Anchor Devices on the Performance of Retractable Type Fall Arresters Protecting Against Falls From a Height, International Journal of Occupational Safety and Ergonomics, (2006) 12:3, 307-318, DOI: 10.1080/10803548.2006.11076692;
[7] Stupakov A.A., Kapyrin P.D., Lelikov G.D., Semenov P.A., Vasilenko V.V. Stands for researching personal protective equipment against a person falling from a height. Bulletin of MGSU. 2015. No. 8. S. 130-139;
[8] Vasily Vasilenko, Dmitry Korolchenko, Pham Nam Thanh. Definition of the inspection criteria for personal protective equipment (for work at heights) on example of full body harnesses. MATEC Web Conf. 251 02042 (2018) DOI: 10.1051/matecconf/201825102042;
[9] Schad R. Analysis of climbing accidents — Accident Analysis & Prevention. — 2000. — Vol. 32, Issue 3. —P. 391–396. DOI: 10.1016/S0001-4575(99)00026-3.
[10] McKently John, Parker Bruce, Smith Cedric, 2007, A Look at Load-Distributing and Load-Sharing Anchor Systems, Proceedings of the International Technical Rescue Symposium 2007;
[11] Karaban D.T., Lutovich E.A., Mistnikov V.A., Gubanov V.A., Kharitonov I.I. Test results of anchor support of increased bearing capacity in the mine workings of Soligorsk potash mines. Research and innovation. 2011.Vol. 5. No. 1. P. 129-131.