Possibility of Monitoring of Movement on Cracks for Solid Rocks

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Abstract. The main goal of this article is to analyze the possibility of measuring on cracks. For measuring the distance between points, e.g. crackmeters are used. When measuring cracks in rock masses, very precise instruments are used, which are referred to as dilatometers. These dilatometers are based on a mechanical or electrical principle and measure directly inside the fracture, as opposed to a crackmeter where we measure on both outer sides of the fracture. Measuring on cracks is one of the methods of evaluating the development of slope deformation on the surface. If cracks appear on the slope, we can use the crackmeter to start more frequent and accurate control of the slippage movement by measuring the relative changes in position using appropriately selected stabilized points on opposite sides of the crack. If we know the direction of movement, we can use only two points to check debonding cracks. If we are measuring marginal cracks, a three-point system is appropriate. Two points are placed outside the landslide and one is placed directly on the landslide. The principle of the measurement consists in evaluating the change in distance of two points (short anchors) firmly connected to the surrounding environment and located in the simplest case on opposite sides of the crack. Crackmeters are also used to measure movements across open tension cracks and scarps delimiting the boundary of the potential slide mass.

1. Introduction
Measuring on cracks is one of the methods of geotechnical monitoring, with which we observe and control slope movements in a certain period of time. Geotechnical monitoring allows us to detect changes in the landslide area. The changes that geotechnical monitoring will allow us to detect include not only physical changes, changes in mechanical properties, changes in slope geometry, but also changes in the rate of movement of the landslide in the landslide area. If the geotechnical monitoring is carried out on a slope where the landslide has already been remediated, then geotechnical monitoring is used here to check the functionality of the remediation measures applied. Geotechnical monitoring normally takes more than ten years to carry out and is therefore a long-term process. [1]

If significant cracks appear on the landslide, more precise and frequent control of the movement of the landslide can be initiated, for example by measuring the relative change in position of suitably stabilised points on opposite sides of the crack. Crack monitoring devices are generally called dilatometers. Dilatometers are generally used to evaluate the change in distance of two points (short...
anchors) that are rigidly connected to the surrounding environment and are located, in the simplest case, on opposite sides of a fracture. The short anchors are specially adapted, for example, to be screwed or slipped on, so that the gauge itself can be easily attached. There are a number of ways of evaluating the change in point spacing. Either a mechanical dilatometer or an electrical dilatometer using string strain gauges is used.

The dilatometer is used to monitor the opening and closing of cracks. There are also special types of dilatometers that are equipped with, for example, a spirit level, which also allows vertical movements to be sensed. Other types include dilatometers that are equipped with a temperature sensor, which allows the effect of thermal expansion to be minimised.

2. Dilatometers
The oldest and relatively frequently used gauges in the Czech Republic are mechanical-optical dilatometers (e.g. TM-71). The method is based on measuring mutual changes in the position of suitably stabilised points on opposite sides of the crack. The gauge is mounted on horizontal steel brackets directly inside the crack, preferably perpendicular to its course. The displacement is recorded in two mutually perpendicular directions. [2]

The principle of measurement with a dilatometer is shown in Figure 1.

![Figure 1. Mechanical-optical dilatometer TM-71, dilatometer scheme](image)

The advantage of the gauge is that it records displacements spatially in the x, y and z axes. The measurement accuracy of this dilatometer is 0.03 mm. [2]

The disadvantages of this gauge are its size (25 x 25 cm) and the steel bracket on either side which is designed to be fixed into the rockwork, this can be a problem as you need to find a suitable place to place it. The width of the crack must therefore be at least 50 cm. [2]

3. Crackmeters
Crackmeters are designed to measure movement across tension cracks in soils, joints in rock and concrete, construction joints in bridges, pipelines, buildings, dams, and more. The method is based on the principle of measuring the change in distance of two points (short anchors) that are firmly connected to the surrounding environment and are located in the simplest case on opposite sides of the crack. The gauge with the measuring unit is placed on the heads of the short anchors. We distinguish two types of evaluation of the change in the distances of the points. The first is the mechanical crackmeter. The second option is an electronic crackmeter using string strain gauges.

Both sides of the crack are fitted with measuring points, the heads of which are adapted for fitting a sliding instrument with readout unit, folding meter, tape extensometer, measuring tape (suitable with force gauge).
The principle of measurement is shown in Figure 2.

![Figure 2. Principle of measurement with a mechanical crackmeter](image)

In the case of the need to use monitoring equipment that ensures accurate and continuous measurement, electrical crackmeters should be used. Their principle is based on the fact that a portable electronic motion path sensor is usually mounted on a bracket on one side of the crack or attached to both anchor points with ball joints (Figure 3). [3]

![Figure 3. Principle of measurement with a electrical crackmeter GEOKON 4420](image)

For indirect measurements, electrical sensors such as vibration, inductive, resistive strain gauge, silicon, magnetic or electromagnetic are used in most cases. The accuracy of these sensors ranges from ± 0,003 to 0,1 mm. [3]

One of the main advantages of the electronic crackmeter is that the device allows a complete continuous recording of the measurement over time (online). For long-term crack monitoring, it is sufficient to store the data on a storage medium over longer periods of time, unless otherwise required. [2]

Electrical inductive crackmeters allow for easier installation, especially in hard-to-reach and large areas such as a cliff or an entire hillside. In this device, the cable sensors are not covered and the measuring points are not anchored deep in the rock, but only a small clamp is sufficient in this case. The electrical inductive crackmeter from GETOOLS (Czech Republic) has a measuring range from 1 to 5 mm with a resolution of 0.001 mm. The principle of measurement with a electrical inductive crackmeter is shown in Figure 4. The whole measuring system works in such a way that the measurements take place at time intervals chosen by us. The measured data is stored on a memory card and therefore the
data is retained even during a power failure. The measured data is forwarded in real time to the server where it is processed. The resulting movement information can be viewed online via a website. The measuring device has a maximum length of 25 cm and due to the way and simplicity of its mounting is popular for use in engineering geology practice. [3][2]

Figure 4. Principle of measurement with a electrical inductive crackmeter 1) cable inductive sensor installed in a stable part of the rock block, 2) thermometer, 3) anchored point A, 4) anchored point B, 5) data cable to the measuring centre

The main disadvantage of the electronic inductive shaking meter is that cable inductive sensors are not covered and therefore may be more susceptible to mechanical damage. The measuring points are not as deeply anchored as in the previous case and could therefore become loose if not handled properly. [2][4]

Another disadvantage is the extensive cabling, especially when using multiple crackmeters at the same time, which goes to the application server. This cabling is susceptible to electrical discharges such as lightning, which can break the electrical circuit and cause data loss. [2][5]

Based on the measurement with dilatometers or crackmeters, we find the result, which is measured displacement. Generally to measure the change in crack size, it is necessary to examine the change in the dimensions of the crack relative to its surroundings. Our result will be for example a graph of the dependence of displacement (mm) and temperature (°C) on date (time). [6]

If the measurements detected changes in crack sizes that were increasing and exceeding established standards, these measurements usually led to a decision to modify the support methods.

4. Conclusions
The methods of measuring on fractures have been designed to reduce risks to human health and also to limit or predict future damage to property, for example due to landslides. In principle, monitoring approaches for crack formation and propagation can be divided into two broad groups. The first group consists of visual inspection using, for example, glass plates. Where visual inspection is not sufficient, instrumented monitoring is used. However, if the instruments are not handled properly or the correct measurement procedures are not followed, inaccurate measurement results may be obtained. There are different ways of evaluating the change in the distance of the points. We can evaluate either mechanically using a mechanical dilatometer or electrically using string strain gauges. Dilatometers can monitor not only crack closure but also crack opening. String (electric) types of dilatometers have greater accuracy compared to mechanical dilatometers and also have the possibility of remote reading. For long-term crack monitoring, the data need only be stored on a storage medium as required, for example over longer periods of time. While there are many advantages to measuring with electrical dilatometers, there are also disadvantages. Some of the disadvantages of an electric inductive crack gauge include, for example, that cable inductive sensors are not covered and therefore may be more susceptible to mechanical damage.
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