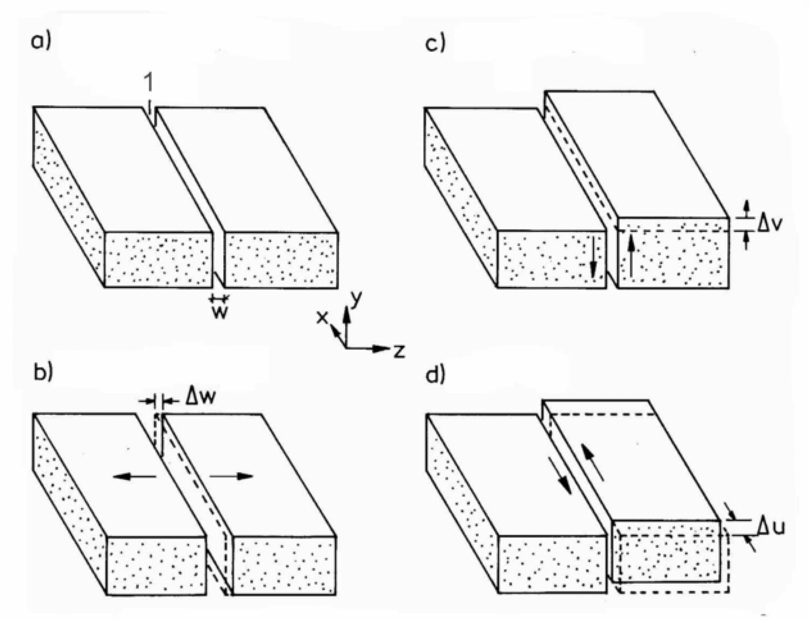
Measurements of substructure displacements at fissures or cracks on structures reveal nothing about the deformation of the rock structure or of a larger structure, but they can provide an insight into the time-related development and current stage of a displacement cycle. The measurement of sub-displacements throws light in particular on disturbances and accelerations of the displacement cycle such as may be triggered, for example, by construction work or the weather.

Sub-displacements at fissures can be measured in terms of crack size (b), vertical height (c) and shift (tangential displacement), as shown in Fig. 1. Ideally measurements should be based on all three components of displacement.

As a rule, the flanks of a fissure change most in their crack width. This explains why the majority of instruments are set to monitor crack width.



a) Initial state
b) Changes of width
c) Vertical offset
d) Shear
1) Crack

Fig. 1 Possible displacements of crack flanks and their coordinates

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The simplest and most frequently used method is to apply plaster markers about 10 mm thick over the crack. To ensure that the hardened plaster marker actually tears above the fissure when the crack opens (rather than shearing off at the point of adhesion to the rock, as is often observed), it is advisable to place a strip of cardboard or polystyrene over the crack. This will weaken the plaster marker at this point and the observation tear will be produced at the weak point when the crack opens.

This more or less reliable method can be replaced by either a mechanical fissurometer type FM 100 or FM 250 (also known as micrometer, deformeter and jointmeter) or an electric fissurometer type FE, where measurement accuracies of up to 0.002 mm are easily possible. The following set ups find application:

1. Displacement measurements across a crack or joint. With a setting gauge, two measuring rods type FB 70 are positioned on either side of the joint at a distance of 100 or 250 mm apart. At fixed intervals the distance is measured by hand with the fissurometer type FM 100 or type FM 250, or electric measurements are taken continuously by a fissurometer type FE that is permanently installed between the measuring rods.

2. Displacement measurements across and parallel to a crack or joint. With a setting gauge, three measuring rods type FB 70 are positioned at the corners of an equilateral triangle so that one side of the triangle is parallel to the joint (see Fig. 2).

3. Displacement measurements in three mutually orthogonal directions in order to determine Δw, Δv and Δu. The displacements can be measured with a jointmeter type F3E parallel to the surface (see Fig. 3).

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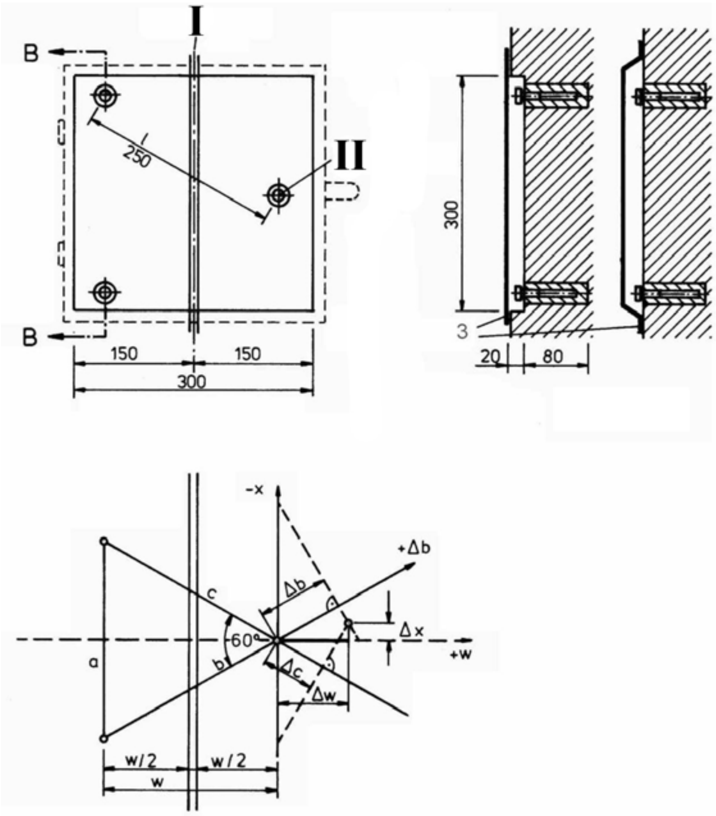


I Joint
II Bolt

Section B-B

1) 3 sides of the triangle are measured (each one twice):

$$\Delta x = \frac{1}{2\Delta a}(\Delta a^2 + \Delta b^2 - \Delta c^2)$$

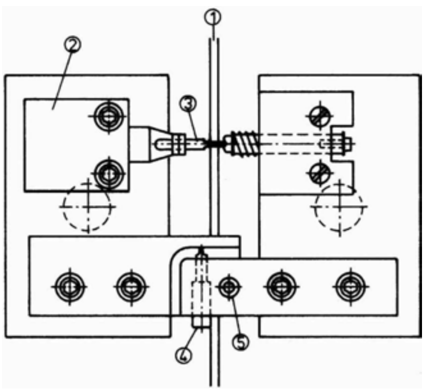
$$\Delta w = \sqrt{\Delta b^2 - \Delta x^2}$$

2) The 2 sides of the triangle which cross the joint are measured:

$$\Delta x = \Delta b - \Delta c$$

$$\Delta w = \frac{1}{\sqrt{3}}(\Delta b + \Delta c)$$

Fig. 2 Displacement measurements with three measurement rods
a) Installation drawing; b) Calculation of relative displacement



1 Joint
2 Limit switch
3 Displacement transducer Δw
4 Displacement transducer Δu
5 Displacement transducer Δv

Fig. 3 Three-dimensional displacement measurement at a joint using a jointmeter type F3E

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The two fissurometers type FM 100 (see Fig. 1) and type FM 250 are mechanical fissurometers for taking distance measurements on measuring rods spaced approx. 100 or 250 mm apart. Using an appropriate setting gauge, two 20 mm diameter boreholes are drilled to a depth of 80 mm. Measuring rods type FB 70 are inserted in the boreholes and secured to the structure by means of fast-hardening cement or plastic mortar.

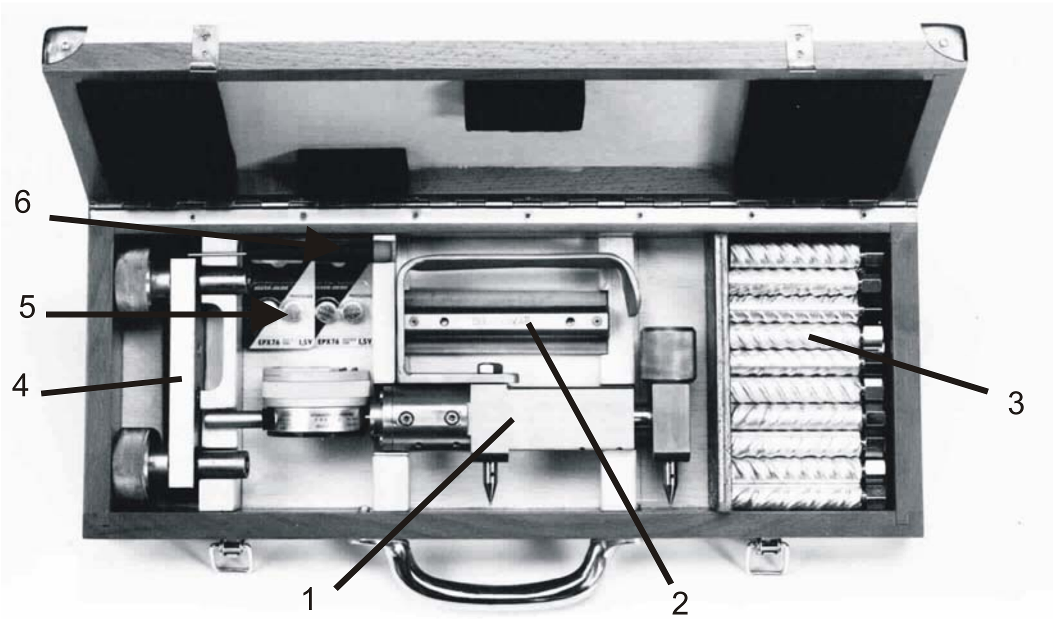

Fig. 1 Mechanical fissurometer type FM 100 with accessories. 1 Fissurometer, 2 Measuring rod type FB 70, 3 Calibration device made of INVAR steel, 4 Setting gauge, 5 Spare batteries for electric dial gauge, 6 Screwdriver for changing the battery

To take measurements, the spherical probe tips of the fissurometer are inserted in the conical measurement marks of the rods and gently pressed into position. The distance between the rods can then be read off the electric dial gauge with a reading accuracy of ± 0.001 mm; a measuring accuracy of ± 0.002 mm is possible. The fissurometer has a measurement range of 12 mm. Before and after each measurement cycle the instrument must be calibrated on a calibration device made of INVAR steel, and the temperature must be measured to allow for temperature compensation if required.

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The electric fissurometer type FE can be used to take continuous measurements of the distance between two measuring rods type FB 70 positioned a minimum of 100 mm and a maximum of 3000 mm apart (Fig. 1).

To install the measurement setup, two measuring rods are positioned the correct distance apart and the fissurometer is screwed into position. The instrument is connected with the measuring rods via ball bearings, ruling out secondary bending stresses due to relative displacements of the crack flanks.

Fig. 1 Electric fissurometer type FE with the measuring rods set 250 mm apart

The user can select a measurement range of ± 1 mm, ± 10 mm, ± 20 mm or ± 50 mm to suit his particular needs.

The measurement signals are transmitted by cable to a measured-value logger for processing on-site or in the office.

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The setting devices type F3M or F3E allow displacement measurements at fissures and cracks in three mutually orthogonal directions. The displacements can be read either off a dial gauge or off three permanently installed electric displacement transducers. The first device is measured by hand at fixed intervals, the second allows a continuous remote measurement with an automatic measured-value logger.

Measurement accuracies of around ± 1/20 mm are easily possible with the mechanical models, improving to ± 1/100 mm with electrical measurements. Parallel to this we recommend a temperature measurement at the flanks of the fissure, as the daily and yearly temperature course can cause strains at the structure which the setting device registers together with the foundation-related displacements. Not before a reliable interpretation of the displacements, especially very small ones, is possible.

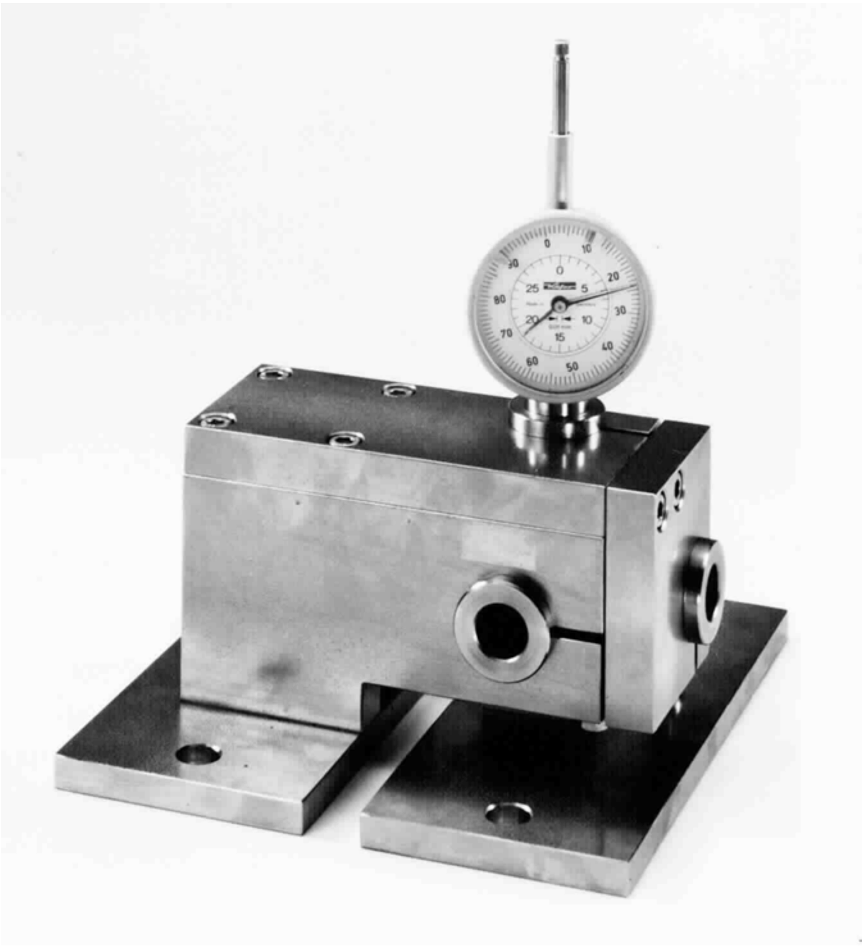

Fig. 1 Setting device type F3M with mechanical reading

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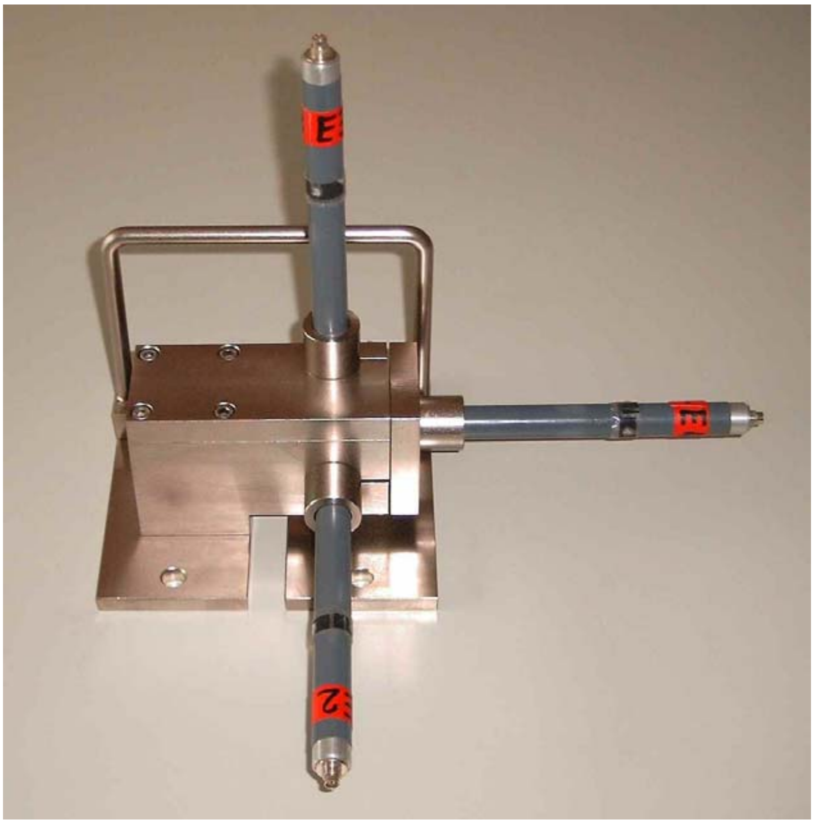

Fig. 2 Setting device type F3E with electrical reading

To install the setting device four 12 mm diameter dowel holes are drilled to a depth of 75 mm with a drilling pattern. After having pressed in the dowels (S12) the instrument is positioned at the measuring point in arrested condition; irregularities are to be compensated by a cement layer or by washers. Then the instrument is fixed with four 10 mm diameter screws. When the cement layer has hardened the arresting mechanism is removed and the instrument is ready for measuring.

For the mechanical measurement device dial gauges with a measuring range of 10 or 30 mm can be selected, the measuring range of the electric displacement transducers is 25 mm.

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For monitoring movement across cracks in buildings or in rock the crack spy is used as a cost-effective instrument. It consists of two plastic plates which overlap for part of their length. One plate is calibrated in millimetres and the overlapping plate has an hairline cursor (see Fig. 1).

As the crack width opens or closes, one plate moves relative to the other. The relationship of the cursor to the scale represents the amount of movement occurring. The measuring range is ± 20 mm, the measuring accuracy ± 0,5 mm.

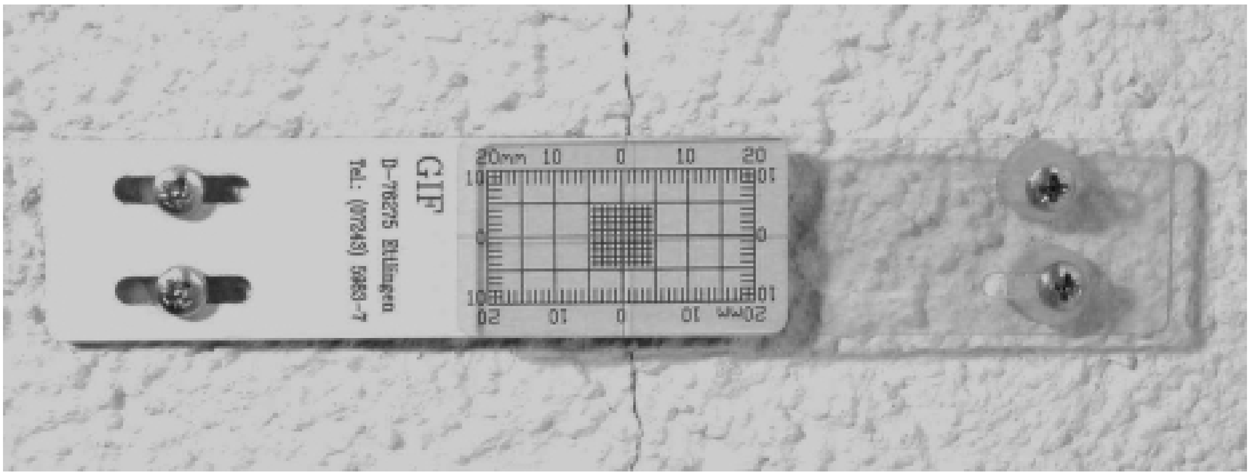

Fig. 1 Crack spy in its standard version

The two plates can be fixed at the monitoring point either using a two-package system or dowels, if the situation allows it.

Besides the standard crack spy different variants are available: One for monitoring movement across cracks in corners, one for monitoring settlement of floors relative to wall, column, etc., and another for monitoring movement across cracks when one surface moves out of plane with the other, particularly at retaining walls.

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Sales Information

2.1.1.1	Fissurometer type FM 100, base length 100 mm
2.1.1.2	Fissurometer type FM 250, base length 250 mm
2.1.1.3	Measuring rod type FB 70, d = 15 mm, l = 70 mm
2.1.1.4	Setting device 100 mm
2.1.1.5	Setting device 250 mm
2.1.1.6	Calibration device made of INVAR-steel 100 mm
2.1.1.7	Calibration device made of INVAR-steel 250 mm
2.1.1.8	2 pcs spare batteries for fissurometer
2.1.1.9	Screwdriver
2.1.1.10	Instrument box for complete measuring device with fissurometer type FM 100
2.1.1.11	Instrument box for complete measuring device with fissurometer type FM 250
2.1.2.1	Fissurometer type FE, base length 250 mm
2.1.3.1	Fissurometer setting device F3M mechanical
2.1.3.2	Fissurometer setting device F3E electrical with three displacement transducers
2.1.3.3	Adjustment gauge for dial gauge
2.1.3.4	Mounting device

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2.1.4.1 Crack spy standard made of PVC
Dimensions: length 171 mm, width 30 mm, depth 4 mm
Linear coefficient of thermal expansion: 7.3 cm/cm°C x 10^{-5}
Measuring range: ± 20 mm
Measuring accuracy: ± 0,5 mm

2.1.4.2 Crack spy made of PVC for monitoring movement across cracks in corners
Dimensions: length 141/82 mm, width 30 mm, depth 4 mm
Linear coefficient of thermal expansion: 7.3 cm/cm°C x 10^{-5}
Measuring range: ± 20 mm
Measuring accuracy: ± 0,5 mm

2.1.4.3 Crack spy made of PVC for monitoring settlement of floors relative to a wall, column, etc
Dimensions: length 33/50 mm, width 30 mm, depth 4 mm
Linear coefficient of thermal expansion: 7.3 cm/cm°C x 10^{-5}
Measuring range: + 3 to - 23 mm
Measuring accuracy: ± 0.5 mm

2.1.4.4 Crack spy made of PVC for monitoring out of plane movement
Dimensions: length 187/65 mm, width 34 mm, depth 4 mm
Linear coefficient of thermal expansion: 7.3 cm/cm°C x 10^{-5}
Measuring range: + 25 to - 25 mm
Measuring accuracy: ± 0.5 mm

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