# Extensometers

As the name suggests, the function of an extensometer is to measure extension in the instrument's longitudinal axis (see MÜLLER, 1963, p. 594). The measurement medium is wire or rod, for which the ISRM and DGEG have published size and quality recommendations, or a probe which scans fixed measuring markers in the borehole. According to the measuring medium (Fig. 1) a distinction is drawn between

- wire extensometers
- rod extensometers
- probe extensometers.

Apart from the measuring medium, a wire and rod extensometer consists of a measuring head and an anchor.

The measuring head or measuring stop must be designed to be as safe as possible from damage. Mechanical read-out is desirable (particularly for long-term observations); in order to enable continuous monitoring of displacements electric transducers or rotary potentiometers are also used.

Anchors come in many varieties. The most frequent types are ribbed rods or steel shells that are bonded with the rock by mortar injection. In severely fissured rock it is an advantage to enclose the anchor in packer fleece to prevent the injection medium from seeping away. Mechanical clamping anchors are also used, but care must be taken to ensure their lasting union with the rock.

The extensometer is designed for rock and masonry that is normally affected only by extension. Extensometer measurements are simple and reliable, and they form a major component of most measurement programs for monitoring the behaviour of foundations and structures. For these purposes it is usual to use rod extensometers with a measuring accuracy of $\pm 1 \times 10^{-6}$ (i. e. ± 0.01 mm/10 m).

Often extensometers are also used to monitor settlements at dams or underneath structures. Logically speaking, these instruments should really be called compressometers. Designed to observe soil compression (compressive strain), they were described by TERZAGHI back in 1930 as foundation gauges. Today they are referred to as settlement gauges.

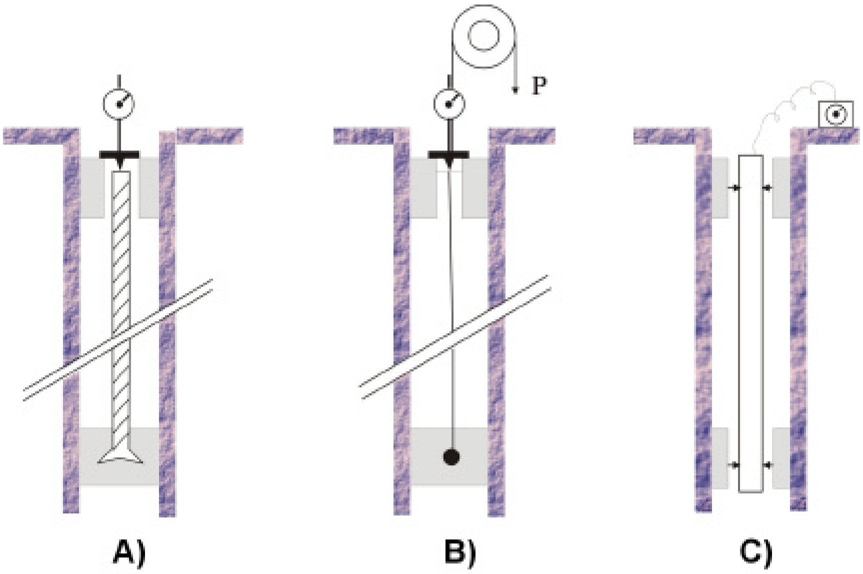


Fig. 1 Extensometer measuring principles (according to PAUL and GARTUNG, 1991)
A) Rod extensometer, B) Wire extensometer, C) Probe extensometer

Considering the field of application, compression is likely to occur in dams and foundations in soil (occasionally accompanied by extension, e. g. in swelling clays or at the foot of a dam), and extension is probable in tunnels, shafts, caverns and slides.

If just a single measuring section is installed in a borehole, we talk of a single-point extensometer. Where several measuring points are arranged along the borehole, we talk of a multiple-point extensometer (Fig. 2). The lengths of the connecting elements (rod, wire) vary. With a probe extensometer, measurements are taken of the changes in distance between neighbouring measuring points set at a practically identical distance apart.

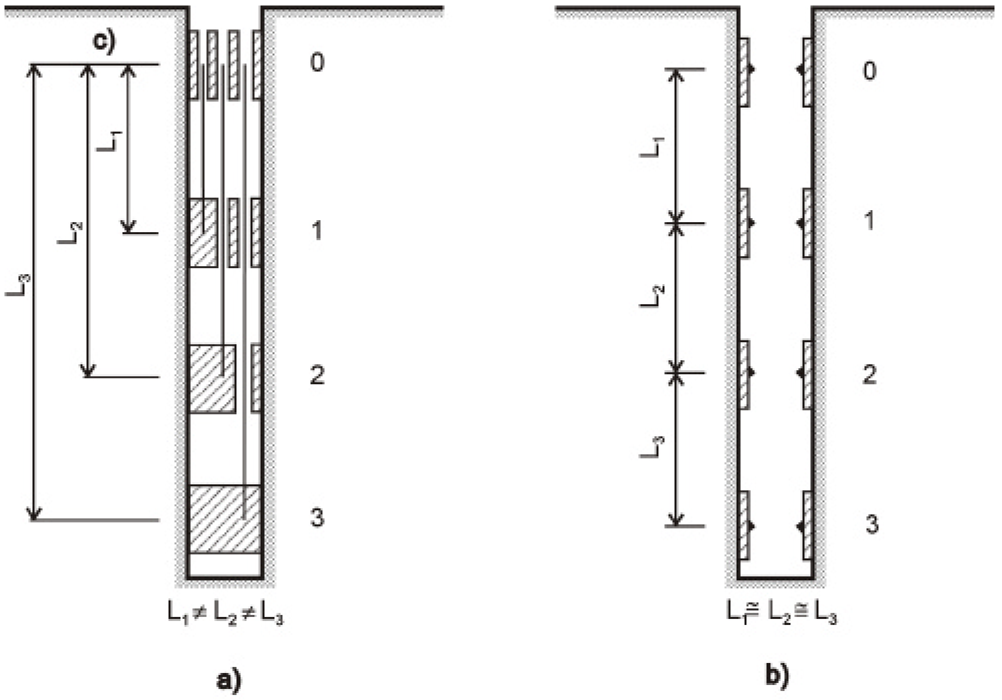


Fig. 2 Schematic examples of multiple-point extensometers (according to PAUL and GARTUNG, 1991)
a), b) 3-point rod extensometer, c) Extensometer head
0, 1, 2, 3 = Measuring points

The extensometer's field of application places special demands on the equipment's design. Extensometers used in tunnelling should be designed to fit in a maximum borehole size of 46 mm (mini-extensometer). It is also important for these instruments to be delivered to the construction site in a more or less ready-to-use condition, and they should be anchored mechanically because this is the only way to meet tunnelling requirements (drilling with the heading equipment, no overhead injection, measurement possible at the very next round).

The overall length of this multiple-extensometer may be limited to one tunnel diameter (i. e. 10 - 12 m; this depth can just about be drilled using the heading equipment).

In mining applications, and particularly in coal mines, allowance must be made for the possibility of explosive atmosphere. This must be taken into account when selecting the materials used to manufacture the extensometer (no plastic, no aluminium).

When extensometers are used in areas other than those just described, their complete prefabrication is not absolutely essential. There is a strong temptation to have the installation work carried out by non-specialists, with a great risk of the instruments being wrongly installed.

ISRM guidelines have been published for the measuring accuracy and measuring range. They can be tested in a trial run like that proposed by PEKKART and STILLBORG (1982).

### Frost-proof foundation of the extensometer head

If an extensometer head is exposed to frost, it is often desirable to be able to distinguish the lifting and lowering of the head caused by freezing-thawing cycles from displacements caused by the structure. Two model variants are available for this purpose:

1. The simpler and cheaper solution is to install an additional extensometer rod that extends 1.25 m into the foundation and whose movements are subtracted from those displacements reaching further down. Should this not be desirable because there are low-depth structure-related displacements, the following procedure is adopted:

2. Before sinking the extensometer borehole, a shaft is dug at the measuring location in accordance with Fig. 3a, a plastic tube inserted and the annular space filled with concrete. The borehole is then sunk and the extensometer installed.

The extensometer head can be covered as shown in Fig. 3b. First, two drainage pipes are laid. An oval surface box made of cast iron is then placed on top, a gravel packing formed so that the ends of the drainage pipes end in it, and the rest of the excavation is refilled with concrete. The surface box must comply with the test guidelines laid down in DIN 3580 and must be fitted with a riveted cover. Instead of the surface cap it is possible to install a concrete shaft ring in accordance with DIN 4052 - 5b (inner diameter 450 mm) and a cast iron manhole cover that should comply with the guidelines laid down in DIN 1229.

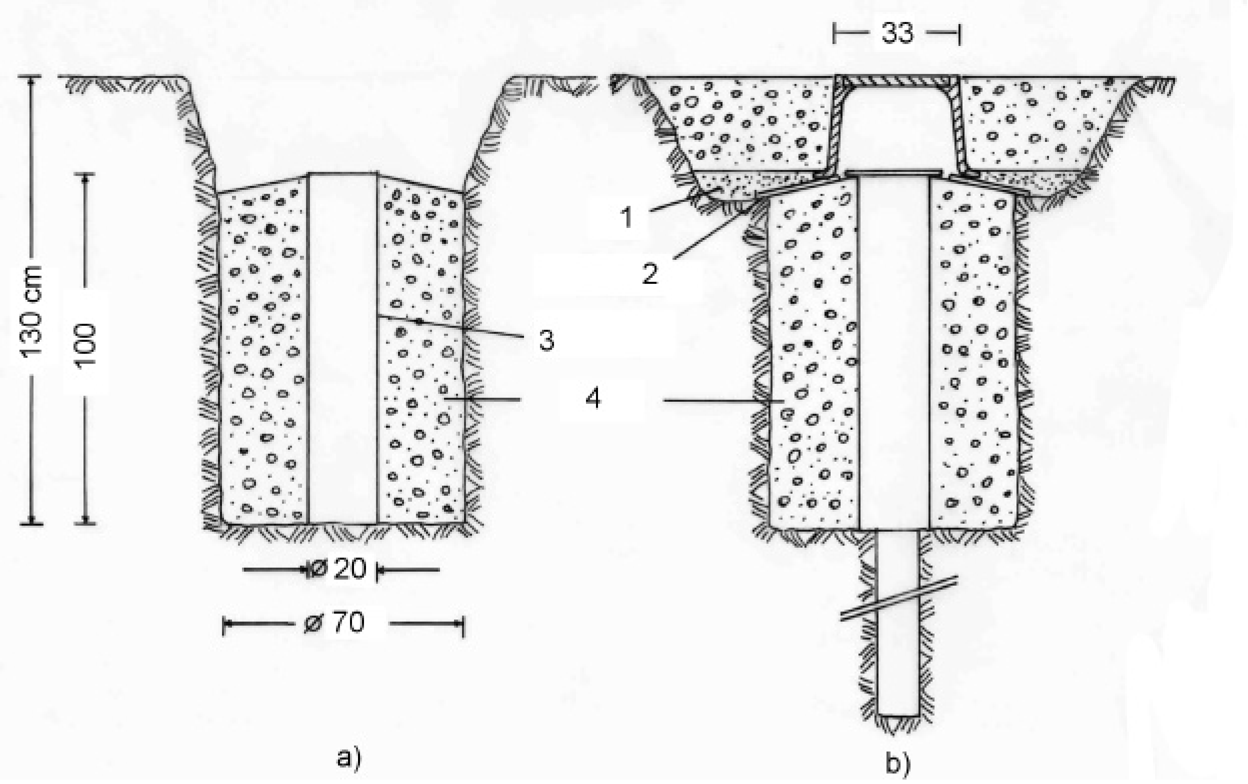


Fig. 3 Providing an extensometer head with a frost-proof foundation
a) Preparing the drilling point
b) Making the head cover and drainage
1 Gravel, 2 Drainage pipe, 3 Empty pipe, 4 Concrete

# Probe Extensometers

## Sliding Micrometer ISETH

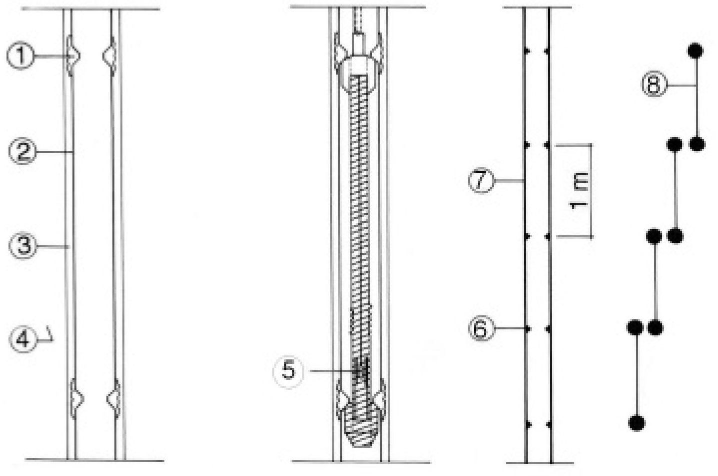
The sliding micrometer, developed at the institute for road, railway and rock construction of the Technical University of Zurich, Switzerland, is a probe extensometer of high precision. The instrument is used to continuously determine the axial displacement components along bore holes in rock, concrete or soil. High precision measurements are achieved by using the cone-sphere principle for tensioning the portable sliding micrometer in the measuring marks.

Metallic measuring marks, connected with each other by a plastic protective casing, are firmly grouted in bore holes with a diameter of approx. 100 mm or any pre-cast tube-like opening in concrete. Before injecting we recommend to control the proper installation of the protective casings by a sliding micrometer measurement.

The probe, weighing about 3 kg, is inserted into the casing and moved in a step-by-step fashion between the measuring marks which are at 1.0 m intervals. Both the spherically shaped probe heads and the measuring marks are provided with recesses which enable the probe to slide along the casing from one measuring mark to the next (sliding position). By rotating the probe 45 and pulling back on the guide rods, the probe’s two heads are tensioned between two adjacent measuring marks (measuring position).

A linear displacement transducer inside the sensor head is activated, and the measured values are transmitted by a cable to the digital readout unit with internal data memory.

In vertical or strongly inclined measurement casings (with depths up to approx. 30 m) the probe can be brought into measuring position and tensioned with only the aid of guide rods. For depths greater than 30 m, the movement and tensioning of the probe is accomplished by a winch and the reinforced electric cable. The probe is still positioned by guide rods. If horizontal or slightly inclined measuring casings are used, it is possible to measure straight lines up to a length of 100 m without a winch.



a b c

Fig. 1 Sliding micrometer ISETH (according to THUT, 1985)

a) Measuring tube cemented in the borehole
1 Conic measuring marks, 2 HPVC casing, 3 Injection medium, 4 Rock, concrete or soil

b) Sliding micrometer in measuring position
5 electric displacement transducer

c) Measuring method for sliding micrometer and Trivec
6 Measuring marks, 7 Measuring casing, 8 Step-by-step setting of the probe

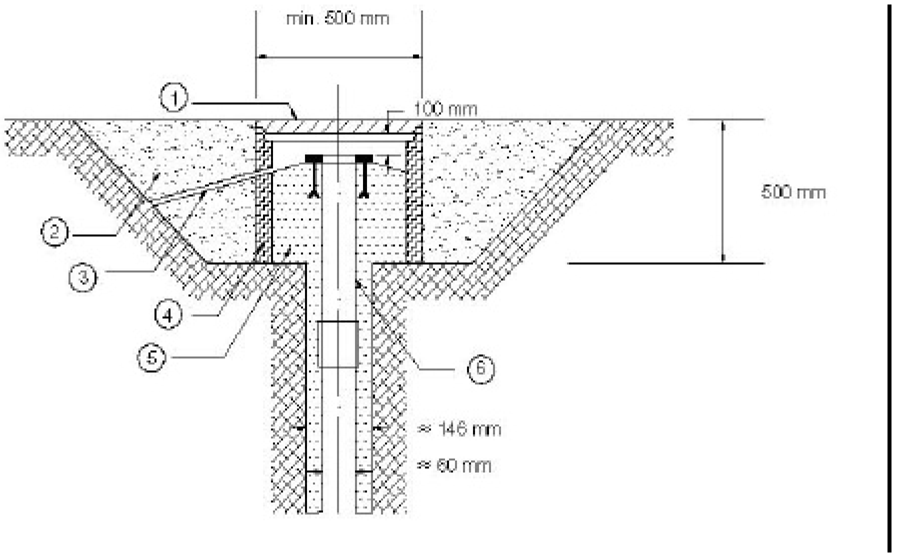


Fig. 2 End shaft for sliding micrometer and Trivec

1 Cover
2 Backfill
3 Drainage
4 Cement shaft
5 Mortar
6 Sliding micrometer or Trivec measuring tube

High precision measurements can be achieved due to the excellent reproducibility of placing the probe. In the calibration frame an accuracy of $\pm 1 \mu m$ and under field conditions $\pm 2 \mu m$ are attained. The high precision is due to the cone-sphere principle which defines the exact position of the sensor heads with respect to the measuring marks. The sensitivity of the instrument in terms of strain amounts to $1 \cdot 10^{-6}$, the measuring range is 10 mm. Probe and the calibration device are provided with a temperature sensor to compensate length changes of the measured distance influenced by temperature.

We realise sliding micrometer measurements and installation of the protective casing to customer's order. If desired we evaluate the measuring results, also in diagrams, and we formulate geotechnical statements.

## Sales Information

2.4.1.1 Sliding micrometer measuring tubes
base length 1.0 m made of HPVC
outer diameter 60 mm, inner diameter 50 mm
with telescopic coupling and conic
accurate stop

2.4.1.2 Cover made of HPVC for measuring tube, below,
with telescopic coupling and 0.5 m measuring tube

2.4.1.3 Cover made of HPVC for measuring tube, above,
with flange d = 150 mm to fix the cable winch
and 0.5 m measuring tube

The sliding deformeter is a probe extensometer with mechanical measuring stops which are attached at distances of 1 m in the measuring tube. According to Fig. 1 the distance $M_o$ between the measuring head above and the measuring mark above is measured. The value $M_o$ is measured with an electric deformation transducer inside the probe and transferred per cable to a readout unit. A later analogic measurement gives the changed measuring value $M_1$ if a deformation has come off. The change of the distance $\Delta L$ can be calculated from the difference of the measuring values $M_1$ - $M_0$. The particular values inform about the deformation distribution meter by meter and the summation about the total deformation along the measuring axis.

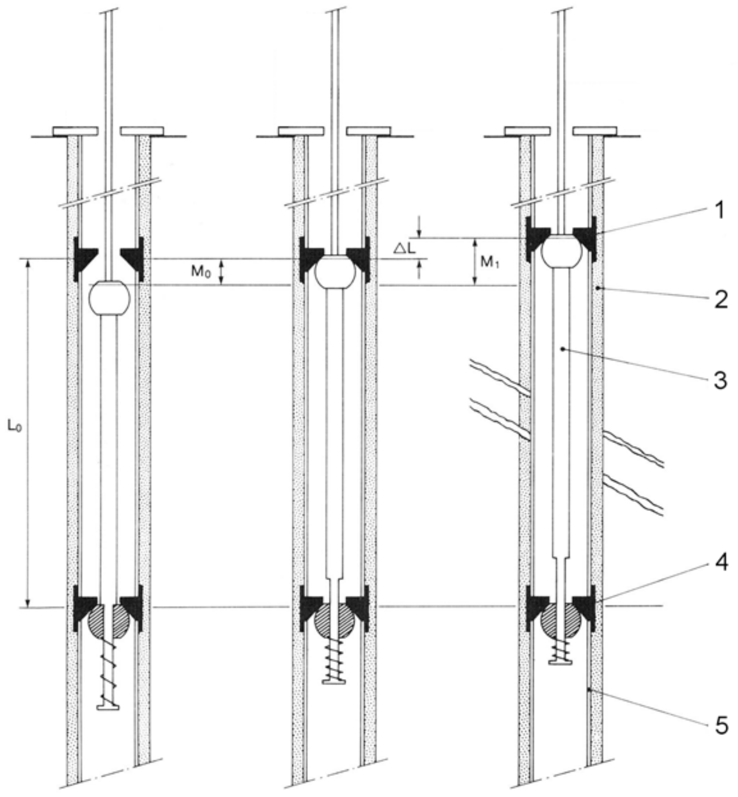


Fig. 1 Principal of the measuring process with the sliding deformeter
1 Measuring mark (cone-sphere principal), 2 Argil, cement, 3 Probe,
4 Measuring mark, 5 Plastic tube

The measuring range of the probe is around 22.5 mm in case of a base length of 1000 mm. The resolution of the displacement measuring system is 0.01 mm, the measuring accuracy of the total system is better than ± 0.03 mm per meter.

In boreholes assigned for the probe extensometer different sorts of measuring tubes can be installed and connected with the rock by cementing:

2.4.2.1 Sliding deformeter measuring tube, base length 1.0 m, made of HPVC, outer diameter 60 mm, inner diameter 50 mm, with telescopic coupling made of ABS (acrylen-butadien-styrole), outer diameter 67 mm, and installation material (socket hexagon head cup screws type M4 x 8 with point and adhesive tape), weight of mounted tube 1.02 kg/pc.

2.4.2.2 Measuring tube for combined measurement with sliding deformeter and inclinometer, base length 1.0 m, made of HPVC, outer diameter 63 mm, inner diameter 51 mm, with 4 grooves in the inner casing to take up inclinometer probe and telescopic coupling made of ABS (acrylen-butadien-styrole), outer diameter 67 mm, and installation material (socket hexagon head cup screws type M4 x 8 with cylindrical seat and adhesive tape), weight of mounted tube 1.34 kg/pc.

At the bottom of the borehole the measuring tubes have to be completed with an HPVC measuring tube l = 0.5 m:

2.4.2.3 suitable for HPVC measuring tube, diameter 60/50 mm,
with telescopic coupling
(2.4.2.1)

2.4.2.4 suitable for HPVC measuring tube, diameter 63/51 mm,
with 4 grooves in longitudinal direction
for combined measurements with borehole inclinometer
(2.4.2.2)

At the borehole opening the measuring tubes are closed with an HPVC cover (diameter 150 mm). The cover acts at the same time as fixture to screw on the cable trolley:

2.4.2.5 suitable for HPVC measuring tube, diameter 60/50 mm
(2.4.2.1)

2.4.2.6 suitable for HPVC measuring tube, diameter 63/51 mm,
with 4 grooves in longitudinal direction
for combined measurements with borehole inclinometer
(2.4.2.2)

# Plastic Rod Extensometer

# Type Glötzl GKSE 16

The plastic rod extensometer type Glötzl GKSE 16 is a further development of conventional rod extensometers.

**Design:** The plastic rod extensometer consists essentially of:

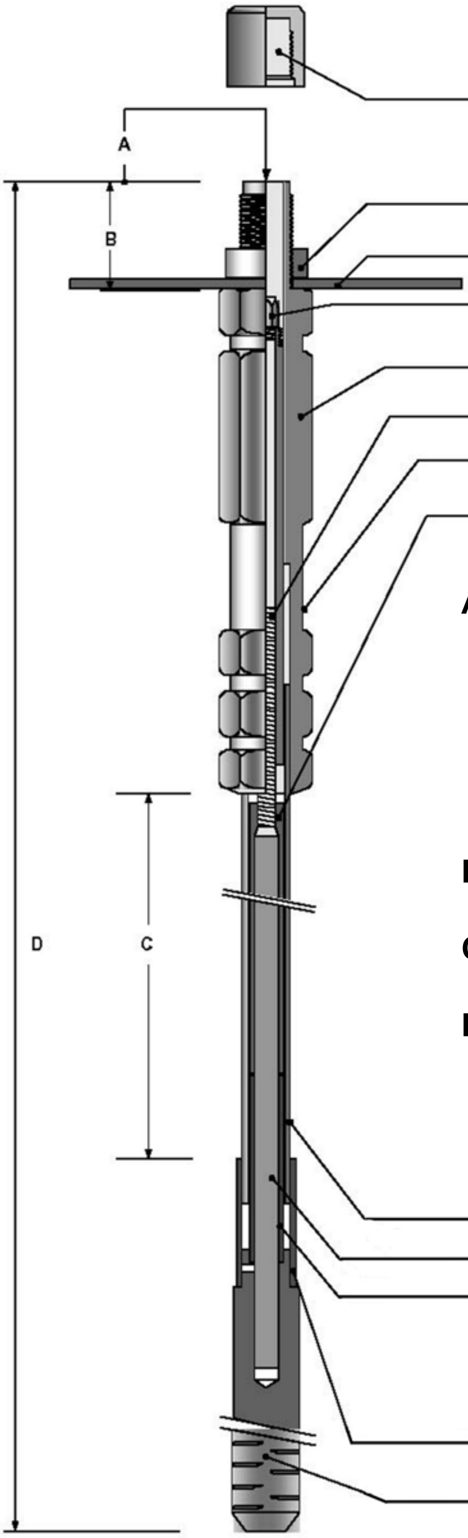
- A measuring head with an adjustable measuring stop
- Measuring rod consisting of a glass fibre rod with plastic sheathing, a protective PVC tube
- Anchor point made of ribbed Torsteel

Fig. 1 Single-point extensometer GKSE 16

**Advantages:**

- Delivered in preassembled form (see Fig. 2)
- No on-site assembly work on the extensometer itself
- Low installation costs
- No transportation problems
- High measuring accuracy
- Measuring head can be sunk in the borehole
- Lengthening and shortening possible
- Low weight

Fig. 2 Extensometer in packed condition, ready for installation, rolled up in a coil of approximately 1.2 m diameter



Protective cap dia. 26 mm

**Measuring head**

1. Locknut
2. Base plate for single/multiple heads
3. Measuring stop, adjustable ± 60 mm, with adjustable sleeve
4. Extensometer head, hexagonal SW 27 mm
5. Measuring rod
6. Turned groove for securing in concrete

7. Connection sleeve

**A. Measuring point manual reading**

1. Depth gauge with vernier ± 1/10 mm
2. Mechanical dial gauge ± 1/100 mm
3. Electrical transducer with digital readout unit

**Remote reading**

4. Electrical remote reading with transducer

**B. Measuring range** Adjustable with threaded rod ± 60 mm

| | |
|---|---|
| **C. Measuring rod** | Glass fibre rod and protective PVC tube, wound diameter 1 m |
| **D. Dimensions** | Overall length = Measuring length<br>Minimum length 1 m,<br>maximum length 100 m |

**Measuring rod**

| | |
|---|---|
| 1. Protective PVC tube | dia. 16 mm |
| 2. Glass fibre rod | dia. 9 mm |
| 3. Protective coating | dia. 11 mm |

**Anchor point**

1. Elastic connection of the protective tube to the anchor
2. Anchor rod dia. 22 mm, length 500 mm, made of ribbed Torsteel

Multiple-point extensometers are formed by fixing several single-point extensometers to a base plate with a locknut. For the most part the measuring heads are sunk in the borehole; thus damage in the course of construction work is largely ruled out.

Fig. 3 6-point extensometer with base plate and plastic bracket. Transducers are screwed directly on the measuring head for remote reading.

Base plates designed specially for sinking in the borehole are available for installing the extensometers in boreholes. It is thus possible to sink single-point and multiple-point heads fully in the borehole. Damage during construction work, e. g. during blasting, is ruled out.

Fig. 4 6-point extensometer type GKSE 6/16 B, consisting of single-point extensometers with base plate for installation in boreholes

**Technical data**

Extensometer rod: Glass fibre core dia. 11 mm with plastic sheathing
Protective tube: PVC 16 x 2 mm

Standard measuring range: min. 1 m
max. 100 m

Adjustment range for the measuring stop: ± 60 mm
Transmission accuracy: 1 - 20 m ± 0.02 mm
up to 50 m ± 0.10 mm
up to 100 m ± 0.30 mm
Extensometer head: hexagonal SW 27 mm
Base plates: 1 - 13 point, designed for sinking or surface mounting

Required borehole diameter (inside installation diameter) without allowance for injection and venting lines:

| 1 | 2-3 | 4 | 5-7 | 8-13 points |
|---|---|---|---|---|
| 35 | 60 | 76 | 86 | 131 mm dia. |

Weight: Extensometer rod, protective PVC tube and glass fibre core 1 m = 0.3 kg

Mechanical gauge: Measuring range 30 mm
Resolution ± 0.01 mm

Accessories: Calibration standard, locknut spanner, measurement stop adjustment tool, transport case

Digital readout unit: Measuring range 50 mm
Resolution ± 0.01 mm

Accessories: Calibration standard, locknut spanner, measurement stop adjustment tool, transport case

## Sales Information

2.4.3.1 Extensometer rod d = 16 mm,
consisting of protective tube and glass fibre core

2.4.3.2 Extensometer head to 2.4.3.1 with measuring stop
(140 mm) and anchor point l = 0.5 m

2.4.3.3 Extensometer rod d = 12 mm,
consisting of protective tube and glass fibre core

2.4.3.4 Extensometer head to 2.4.3.3 with measuring stop
(140 mm) and anchor point l = 0.5 m

Base plate for

2.4.3.5.1 1 - 3 points extensometer

2.4.3.5.2 dito for 4 - 6 points extensometer

2.4.3.5.3 dito for 7 - 9 points extensometer

2.4.3.6 Measuring set consisting of mechanical gauge
resolution 1/100 mm, measuring range ± 15 mm,
calibration device, adjustment tool, transport case