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. $\pm$ 0.01 mm/10 m).

Geotechnisches Ingenieurbüro
Prof. Fecker & Partner GmbH
Am Reutgraben 9 Fon: ++7243/5983-7
D-76275 Ettlingen Fax: ++7243/5983-97

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.

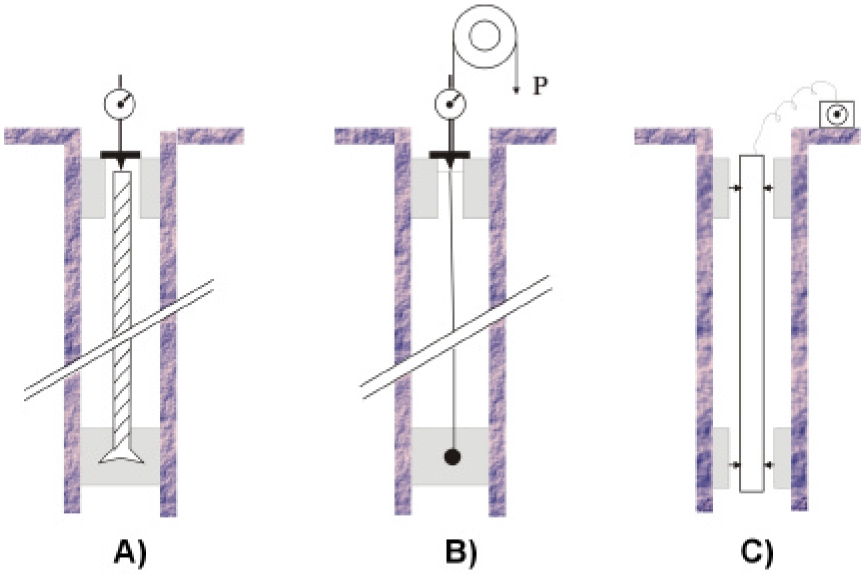

Fig. 1 Extensometer measuring principles (according to PAUL and GARTUNG, 1991)
A) Rod extensometer, B) Wire extensometer, C) Probe extensometer

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.

Geotechnisches Ingenieurbüro
Prof. Fecker & Partner GmbH
Am Reutgraben 9 Fon: ++7243/5983-7
D-76275 Ettlingen Fax: ++7243/5983-97

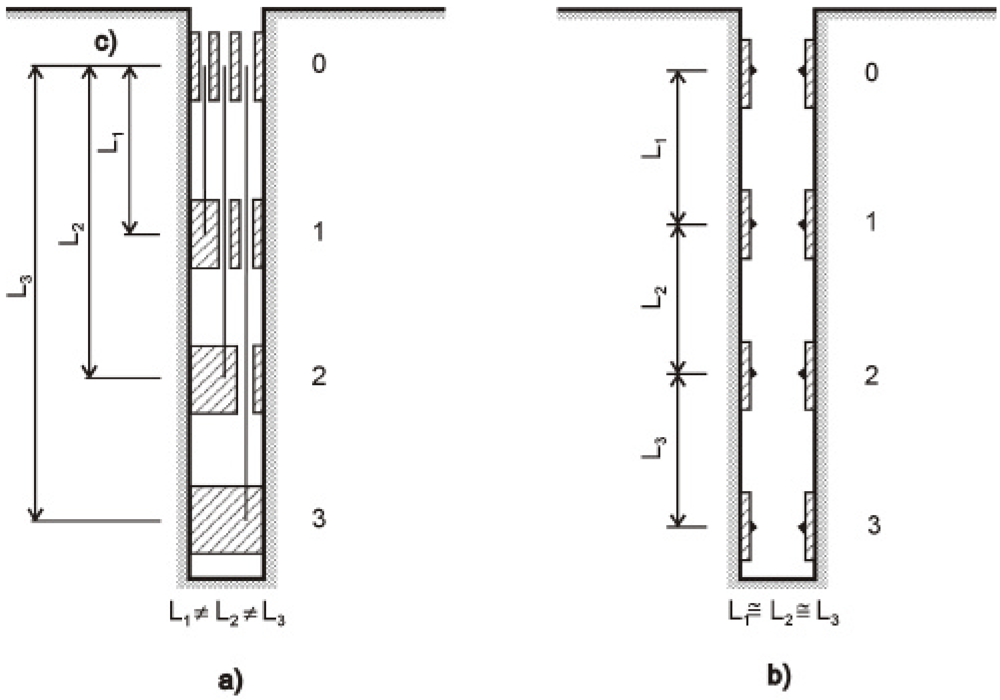

Fig. 2 Schematic examples of multiple-point extensometers (according to PAUL and GARTUNG, 1991)
a), b) 3-point rod extensometer, c) Extensometer head
0, 1, 2, 3 = Measuring points

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).

Geotechnisches Ingenieurbüro
Prof. Fecker & Partner GmbH
Am Reutgraben 9 Fon: ++7243/5983-7
D-76275 Ettlingen Fax: ++7243/5983-97

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:

Geotechnisches Ingenieurbüro
Prof. Fecker & Partner GmbH
Am Reutgraben 9 Fon: ++7243/5983-7
D-76275 Ettlingen Fax: ++7243/5983-97

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.

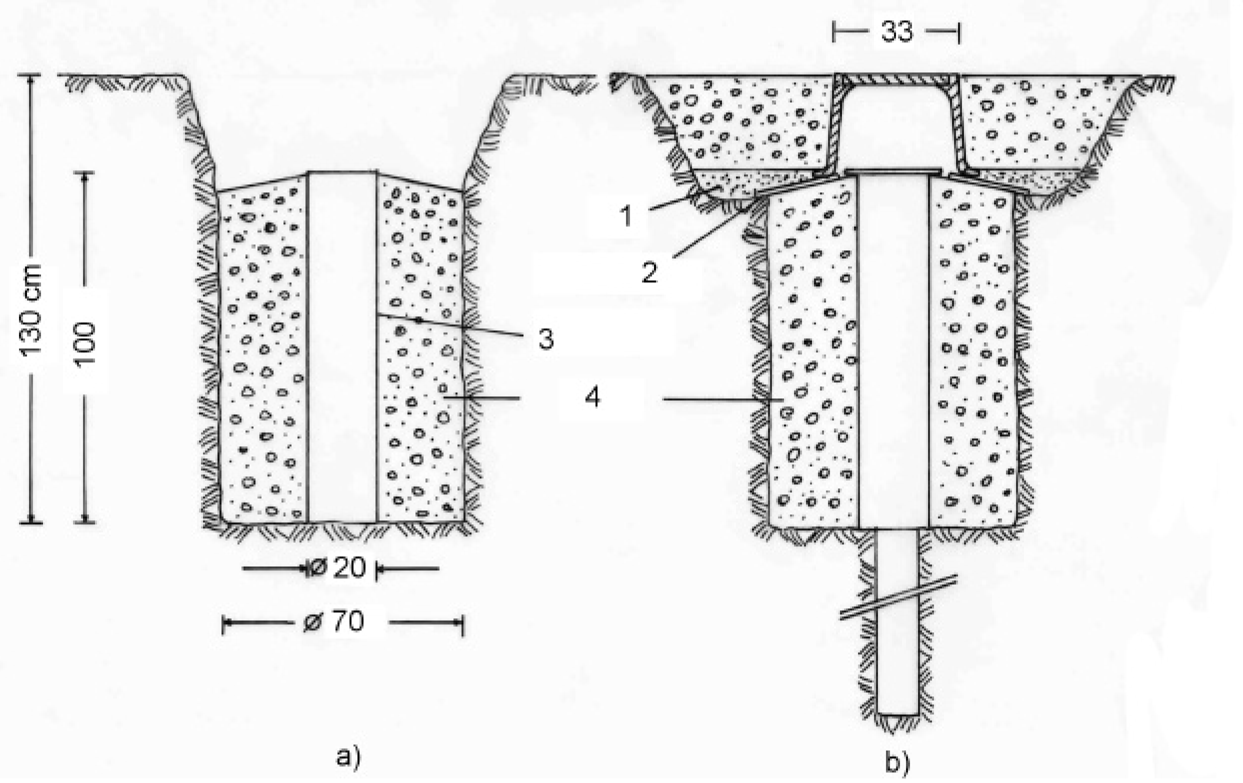

Fig. 3 Providing an extensometer head with a frost-proof foundation
a) Preparing the drilling point
b) Making the head cover and drainage
1 Gravel, 2 Drainage pipe, 3 Empty pipe, 4 Concrete

Geotechnisches Ingenieurbüro
Prof. Fecker & Partner GmbH
Am Reutgraben 9 Fon: ++7243/5983-7
D-76275 Ettlingen Fax: ++7243/5983-97