Convergence Measuring Instruments

Levelling measurements of the tunnel roof or other points of the tunnel reveal and convergence measurements of the excavation have developed into the most frequently applied methods of measurement in tunnelling.

To install a convergence measuring section, convergence bolts are positioned as close as possible behind the round in the tunnel reveal (set in concrete or welded on arches). At the tunnel end of the convergence bolts is a thread with a stop for attaching the measuring device (a steel measuring tape or invar wire). A spring pretensions the measuring tape with the convergence gauge, which is also fastened to a convergence bolt on the other side. The change in length between the reference points is read off a mechanical dial gauge on the convergence gauge.

To minimise disruption of the construction work, geodetic measurements have become increasingly popular of late as a means of monitoring convergence. Instead of using convergence bolts, a measuring bolt with luminous diode or reflecting signal is set in concrete and its displacement measured with a theodolite. Measuring accuracies of ± 1 mm are possible and satisfy the stability inspection standards for tunnelling projects. The advantage of this method compared with taking relative measurements between two moving points using a convergence gauge is that it measures the absolute displacements in an excavation. When convergence measurements are taken with a convergence gauge, this is only possible in combination with at least one geodetic measurement.

To carry out continuous convergence measurements we have developed an electro-optical system. In conjunction with a laser it allows you to take convergence measurements automatically at any intervals. This method of convergence measurement is ideal for long-term monitoring of existing, older tunnels.

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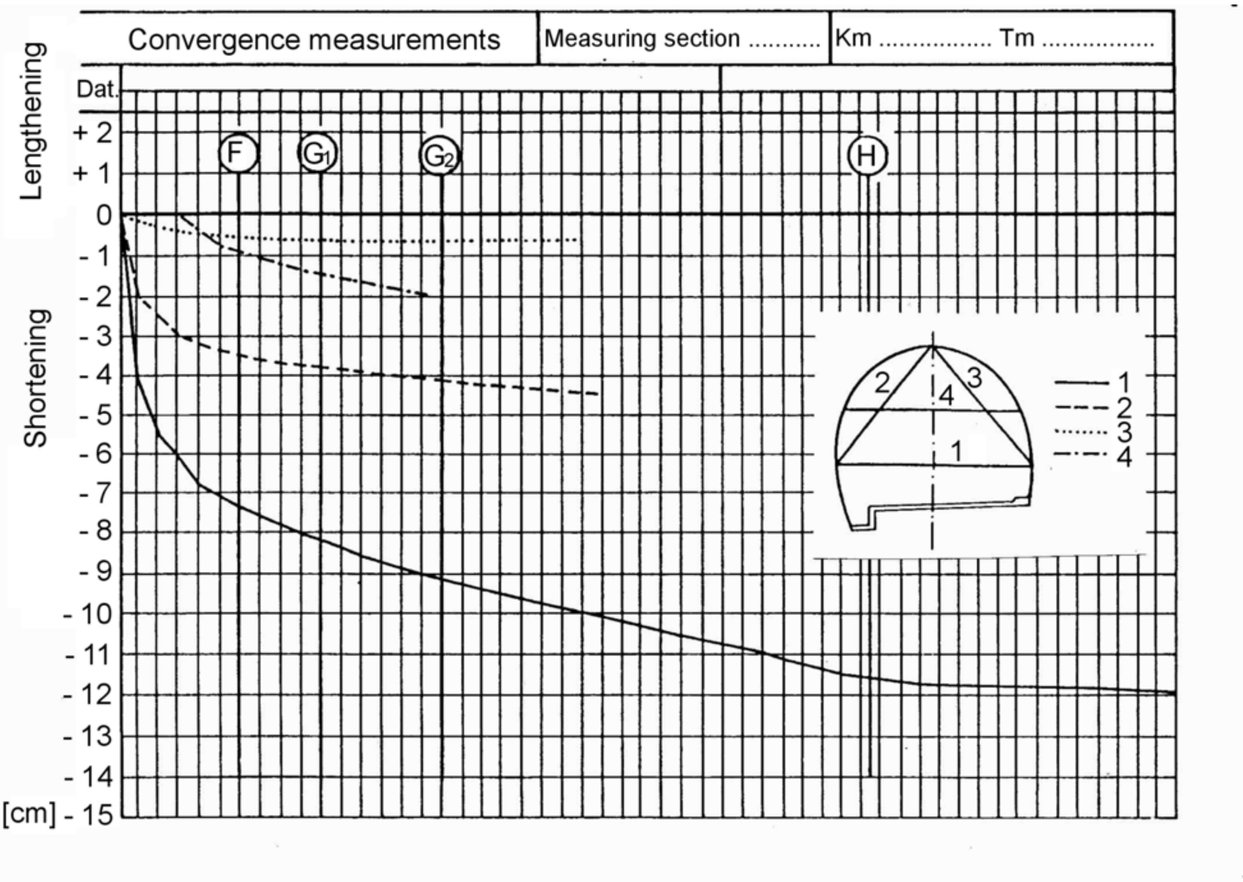

Fig. 1 Example of a convergence measurement. F: Subsequent anchorage of abutments; G1: Foot anchors; G2: Doubling of foot anchors; H: Bottom end

Levelling and convergence measurements are the most basic measurements in tunnelling. They are normally taken in standard or main measuring sections. Fig. 1 shows a typical measurement result in schematic form.

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The **contactless convergence measurement** method, which is based on the optical trigonometric measurement of target markers such as luminous diodes or reflecting signals, is performed with an electronic tachymeter equipped with an integrated co-axial distance measuring device. The displacements measured with the help of the tachymeter are saved on a data carrier inside the tachymeter and can be transferred to a PC when the measurements are completed. To achieve tunnel convergence measurements with an accuracy of ± 1 mm, the tachymeter must enable direction measurements with an accuracy of at least ± 0.3 mgon and distance measurements with an accuracy of at least ± 0.5 mm.

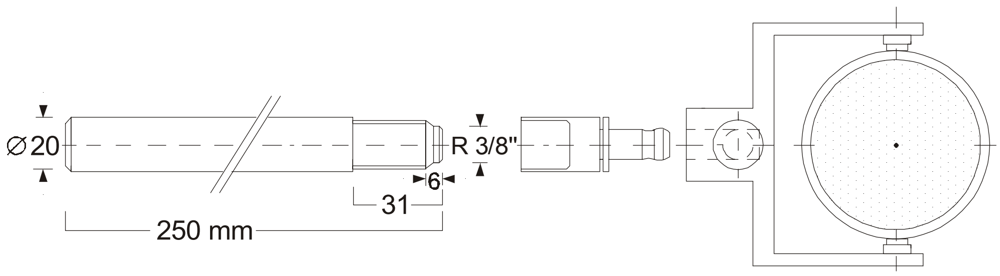

Fig. 1 Contactless convergence measurement signal, consisting of a convergence bolt, rupture joint adapter and bireflex target

To generate signals for the measuring points, a convergence bolt is set in concrete in the tunnel support and a bireflex target is fastened to it by means of a PVC rupture joint adapter that enables the target to rotate (see Fig. 1). This type of signal is used for all measurements taken at a distance of between approximately 15 and 50 m. It is very easy to home in on the target with the tachymeter when a light beam is directed at the reflector. If the measuring point happens to be touched by machinery during tunnelling work, the bireflex target will break off at the rupture joint but normally the convergence bolt will not be bent. The target can be returned to its former position (as it was before the damage occurred) after screwing on a new rupture joint adapter.

Signals for measuring points at a distance of less than 15 m and signals for fixed points are created by triple prisms instead of bireflex targets.

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The distometer ISETH is a precision instrument to take length measurements by means of invar wires. Above all it helps to determine the exact changes in distance and length in case of displacement and deformation measurements. It has been developed from the Institut für Straßen-, Eisenbahn- und Felsbau der Eidgenössischen Technischen Hochschule Zürich (ISETH = institute for road, railway and rock construction of the Technical University of Zurich, Switzerland).

The complete measuring device consists only of mechanical elements. Therefore it is extremely reliable and can be used independent of other equipments. The measurements can be performed very quickly and with a few personnel.

The length of the invar wire is between 1 and 50 m. The measuring range for length changes is 100 mm. The measuring accuracy in case of wire lengths until 10 m is around 0.02 mm, in case of longer wires approximately $\pm 2 \cdot 10^{-6}$ of the distance (average error).

The length measurement device with an invar wire consists of three essential parts: the load transducer, the length transducer, and the invar wire. The distometer ISETH combines load and length transducer in one handy instrument (see Fig. 1).

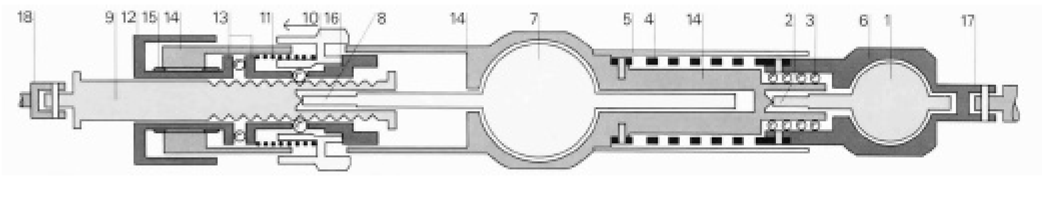

Fig. 1 Scheme of a distometer: **1** Dial gauge to measure the spring extension; **2** Transducer; **3** Axial ball bearing; **4** Precision steel spring; **5** Protective tube; **6** Connection between dial gauge and precision steel spring; **7** Dial gauge for length measurement; **8** Transducer; **9** Drag-bar with notches for coarse movements; **10** Ring to release the notch; **11** Pressure spring to press the ring 10 at the notch 16; **12** Turning ring for fine adjustment of drag-bar; **13** Ball bearing; **14** Instrument body; **15** Clamping nut; **16** Notch; **17, 18** Couplings

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The load transducer keeps the required tension stress of the invar wire during the measurement. It consists essentially of a precision steel spring, whose extension is the degree for the tension working on the invar wire. The extension of the spring can be adjusted to a desired value by means of a dial gauge.

A second dial gauge serves as length transducer which delivers the measured value. It measures the distance between distometer and the end of the invar wire that is fixed there.

In case of a constant pretension the invar wire has a constant and largely temperature independent length. The wire is equipped with precision couplings that allow the perfect connection between the distometer at one end and the measuring point at the other end.

The equipment is completed by measuring rods at the object to be measured and by two articulated connections which are inserted between rod and invar wire and between rod and distometer (Fig. 2).

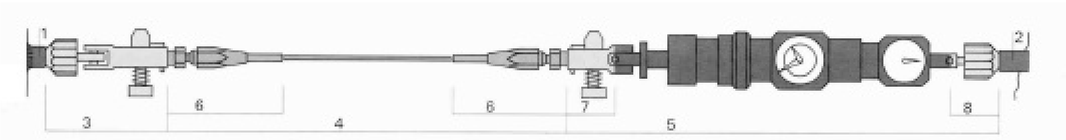

Fig. 2 Distometer equipment ready for measurement: **1** Measuring rod, welded; **2** Measuring rod, concreted; **3** Articulated connection with clamp for wire couplings; **4** Invar wire; **5** Distometer ISETH; **6** Wire coupling; **7** Clamp for wire-coupling at distometer; **8** Articulated connection at distometer

For each distance to be measured the invar wire is cut to the necessary length on-site and equipped with a coupling at both ends.

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For subsequent measurements the single wires are reeled on a thimble. A compensator fixes the free end of the measuring wire at the thimble. In a wooden transportation box you can store up to fifteen thimbles.

The quality of the measuring values depends on the indication of the dial gauges in the load transducer and in the length transducer of the distometer. For control, calibration and adjustment the calibration gauge is used. It consists of two end boards which are connected by three invar rods. These rods give them the constant distance, necessary for the length calibration.

To calibrate the load transducer a standard weight is used, which is fixed at the distometer that hangs vertically in the calibration gauge. An indication deviating from zero can be corrected by turning the face of the dial gauge. Thus the ageing of the spring can be controlled at any time and a usual zero point derivation can be corrected.

To calibrate the length transducer the distometer is attached between the two end boards of the calibration gauge by means of the articulated connections. After having adjusted the necessary load at the load transducer the length transducer indicates the calibration value of the distometer. Mathematically or by turning the face an eventual change can be taken into consideration.

The comparability of the measuring values depends on the constant length of the invar wires as well as on the calibration of the distometer. Thus it is necessary to calibrate before and after each measurement.

We are realising distometer measurements, delivery and installation of the measuring rods and we are producing invar wires to customer's order. If desired we're also evaluating the measuring results and we're formulating geotechnical statements.

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Sales Information

2.2.2.1 Invar wire, d = 1.0 mm

2.2.2.2 Invar wire, d = 1.65 mm

2.2.2.3 Wire compensator

2.2.2.4 Thimble, d = 330 mm

2.2.2.5 Precision coupling for invar wire, d = 1 mm

2.2.2.6 Precision coupling for invar wire, d = 1.65 mm

2.2.2.7 Measuring rod, brass, l = 75 mm, to set in cement

2.2.2.8 Transportation box for 15 thimbles

2.2.2.9 Distometer with calibration device and transportation box

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