With the hard inclusion method, stress sensors of generally high rigidity are inserted in a borehole in order to record changes of stress. This method uses transducers whose modulus of elasticity is higher than that of the rock at the measuring point. The procedure is based on the following theoretical relationships:

If a transducer with modulus of elasticity E_G is friction-locked in an elastically loaded rock body with modulus of elasticity $E_M > E_G$, the stress in the transducer will differ from that in the surrounding rock; stress concentrations will arise in the transducer. If the modulus ratio E_M/E_G is known, the stresses measured in the transducer can be corrected.

It is possible to distinguish between a number of methods according to their principle of measured value conversion or measured value transmission:

- Hydraulic measuring principle
- Electrical measuring principle
- Mechanical measuring principles
- Optical measuring principle

Flat pressure pads of standard rigidity have proven particularly successful as stress sensors. The pressure transducers (Fig. 1) are installed properly orientated in measurement boreholes. Stress components are measured in orthogonal direction to the pressure pads.

To produce the friction-locked connection between the pressure pads and the rock, the boreholes are filled with a mortar that matches the rock's characteristics. Prestressing by high-pressure injection of epoxy resins can take place once the mortar has hardened.

This method is also suitable for measuring small changes of stress. In viscous or plastically strained rock areas the transducer can be expected to "grow into place" through rock flowage, i. e. the stresses inside the rock gradually build up in the transducer, too. Under such rock conditions and with the right choice of mortar it is also possible to determine the actual magnitudes of the orthogonal stress components in addition to stress changes.

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

The standard rock stress sensor consists of:

Three directionally orientated, flat steel pressure pads with three valve transducers type BB 10/20 KF 50 each turned through 120 °. Load capacity 0 - 50 bar (higher possible if necessary). Injection line around the pressure pads and square rod connection. Connection lines for measurement of the valve transducers and injection lines for subsequent injections.

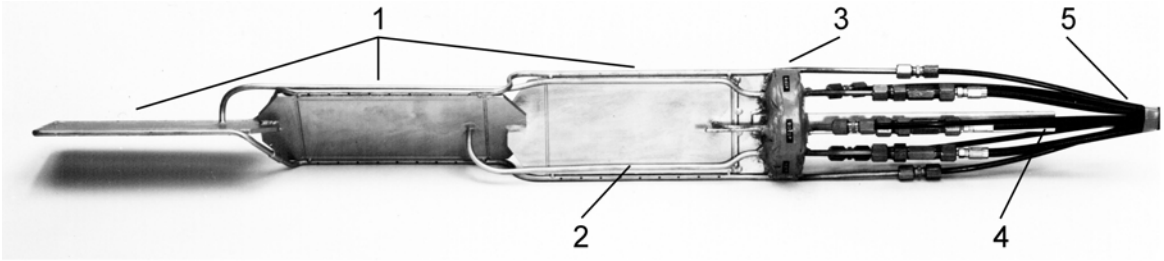

Fig. 1 Pressure transducer with three hydraulic pressure pads

1 Pressure pads
2 Injection line
3 Valve transducers
4 Square rod connection
5 Connection lines

Pressure in the pressure pads is measured either hydraulically by means of valve transducers system Glötzl or electrically by pressure sensors. The stress inside the pressure pads can be read off the instrument directly in bar.

The perforated high-pressure injection lines arranged around the edge of the pressure pads are closed with adhesive tape in order to prevent mortar getting in during installation. Once the filler mortar has hardened, artificial resins or similar can be pressed through these injection lines to prestress the filler and the embedded stress sensors.

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