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Some aspects of contact stress measurements around tunnels

J. Pacovský
Czech Technical University of Prague, Geotechnical Department, Czech Republic

ABSTRACT: Measurement of contact stress between rock mass or soil environment and underground structures ranks among the most difficult tasks of observation measurements. The success and results of this measurement are influenced by each subsequent step of its implementation. Some aspects are discussed.

1 INTRODUCTION

With the development of modern tunnelling technologies in the Czech Republic the significance of „in-situ" geotechnical measurements has increased.

Among the most common observation measurements carried out by the Geotechnical Department in cooperation with the Geotechnika Consortium there are namely the measurements of convergence, extensometric measurements, measurements of development of stress in shotcrete, measurements of surface stress in shotcrete, as well as continuous measurements of stress at the contact between rock mass or soil environment and underground structures.

Within the whole complex of carried out measurements the measurement of contact stress ranks among the most difficult tasks. The success and results of such measurement are influenced by each subsequent step of its implementation - the selection of measuring devices and their gauging in model environment, the process of measuring devices installation, the number of sited measuring profiles, the frequency of measurements, the monitoring of underground processes which may influence stress values etc.

The measurements of contact stress are relatively demanding from the financial point of view. That is why a number of firms in the Czech Republic are trying to provide such measurements by their own means, sometimes even by using their own, hurriedly developed devices. These efforts do not turn out to be very successful in most cases, even in case of using devices developed by foreign renowned firms (such as Glötzl etc.). The presented measurement results, in their turn, are usually rather restrained, without any special contribution to the studied problems.

The actual concern of firms ordering measurements therefore should not be confined to their results stated in the final report only, but prior to the beginning of measurements they should ask for a demonstration of measuring devices following the process of measurements as well.

2 MEASURING DEVICE

The Geotechnical Department started dealing with the problems of measuring contact stress as early as in 1976. At that time, mainly due to financial reasons, the only possible way which could be taken was that of developing our own measuring apparatus, as well as the entire measurement technology. The results of many years' development include, apart from a perfect supply of apparatus and measuring devices of our own development, also a great number of practical experience and knowledge.

The instruments used for measuring contact stress are hydraulic pressure cells (HPC) with a tensometric transducer of hydraulic pressure into an electric signal. This is a hydraulic measuring device in which the pressure of liquid medium is converted into another measurable parameter whose relation to the measured pressure is known. The meter consists of a flat liquid cell. Cells are produced by using a specially developed technology. There exists a series of constructional modifications allowing to select transducers for various pressure ranges (0 - 100 kPa to 0 - 10 MPa).

The measurements are carried out by using a central measuring unit. The central unit is a device which serves for automatic measurements of a greater amount of HPC cells over longer time periods . The results of such measurements are recorded in its memory from where they are transferred to a computer of IBM PC class by means of a serial line (e.g. by using a notebook or hand-held PSION computer). The central unit contains, among other components, a real time circuit which guarantees precise timing of measurements and reliable recording of measurement times. The real time circuit is equipped with its own reserve power supply and therefore it operates even in case that the device is switched off. The whole central measuring unit feeds on 220 V electrical network by means of an adapter. In case of powercuts it contains a built-in battery which is able to provide its operation without network feeding during a time of over 20 hours. For long-term operation in a location without a possibility of network feeding a car battery may be applied.

The number of measurement channels is adjustable within a range of 1 - 48, the time interval between individual series of measurements is 10 - 96 hours. The overall memory capacity amounts to 8192 bytes. If, for example, 10 HPC cells are connected and the reading interval is set at 1 hour, the capacity of the central unit will be exhausted after 12 days of measurements; by then 2920 measured values will be recorded in the memory. This means that the transfer of measured data into a computer will be necessary after 292 hours of measurements (i.e. approximately after 12 days) at the latest, making thus the central unit's memory free again.

The recorded data may be viewed or printed out in the form of a text editor directly on site, or it may be graphically processed by converting the text file into a spreadsheet MS Excel.

The central measuring unit is mounted inside a massive water-proof case which is, among other things, fitted with a panel for a potential manual reading of values in case of a failure of the central unit. For the manual reading of values a modified digital multimeter is used supplied with additional devices.

3 SOME EXPERIENCES

During a period of nearly 20 years a number of successful, as well as less successful measurements have been carried out. The results of several measurements have brought interesting knowledge, which has not always been in a full accordance with the results of mathematical modelling.

At the beginning of 1995 a continuous measurement of contact stress during the driving of a service tunnel going through the historic centre of Prague was carried out. The achieved results of this measurement may very well present the importance of an appropriate selection of measurement frequency.

The service tunnel is driven by using a WESTFALIA ALPINE shield at a depth of about 12 m below the land surface, the height of rock cover being 7 to 8 m. The geological environment is formed by sands and gravel sands. The profile of the tunnel stope is 15 m^2, the inner section being 9.5 m^2. The tunnel's lining is made of reinforced concrete, concreted into adjustable forms. The minimum thickness of lining is 30 cm.

The shield works in two-metre steps, the last 8 m of concreted lining resting on telescopic formwork (Fig.1).

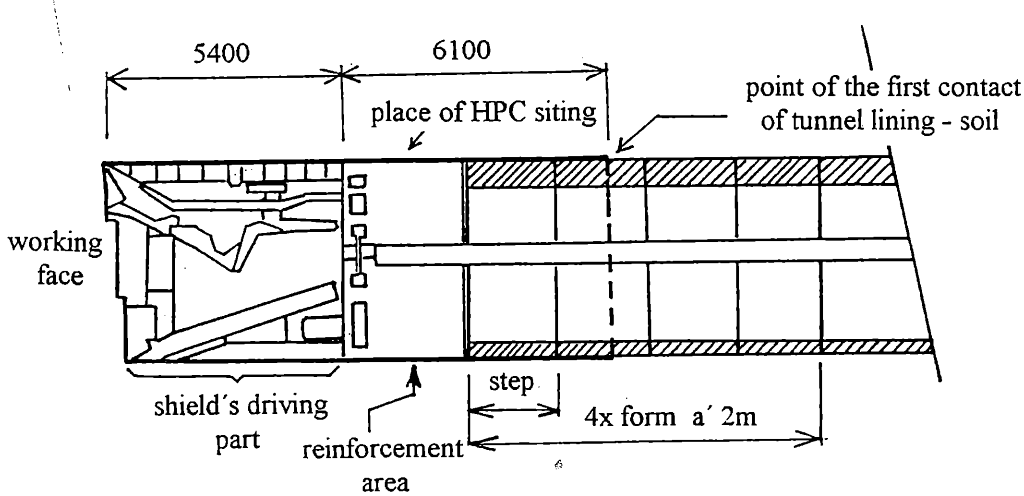


FIG.1 SCHEME OF „WESTFALIA ALPINE“ TUNNELLING SHIELD

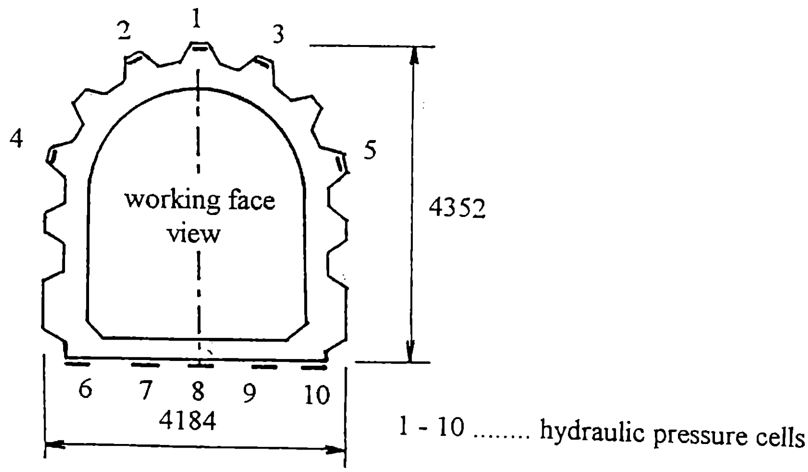
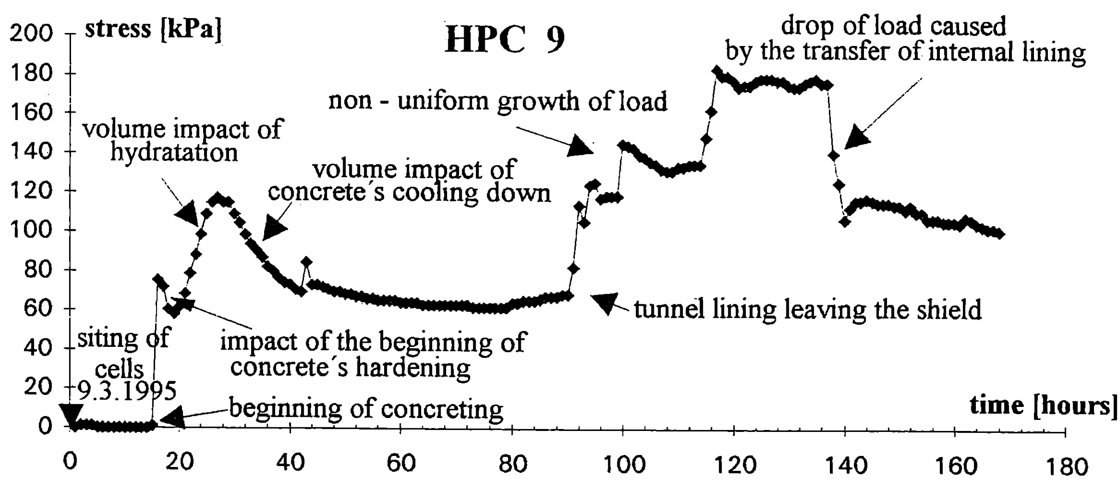
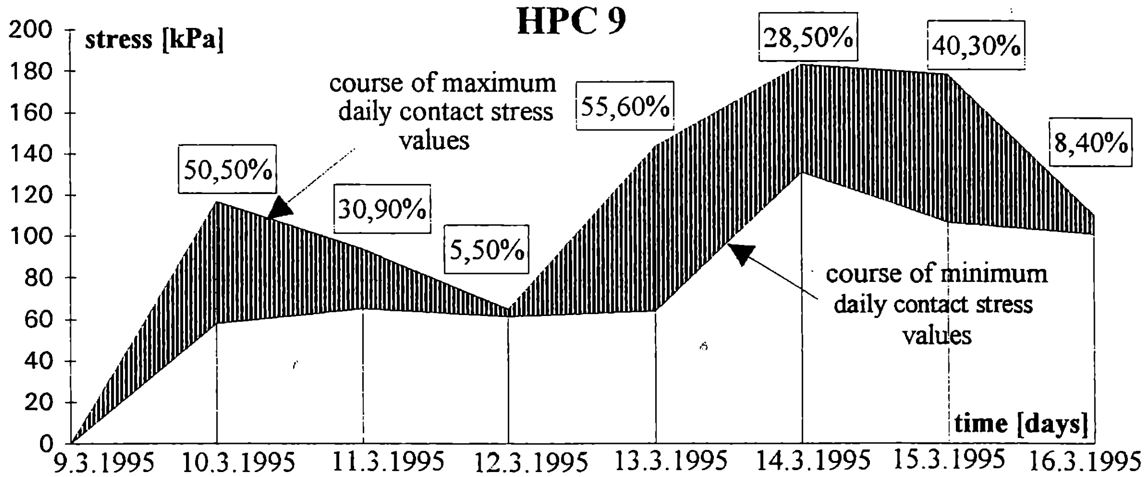


FIG.2 SCHEME OF HYDRAULIC PRESSURE CELLS (HPC) SITING

GRAPH 1 : CONTACT STRESS MEASUREMENT HPC 9 (measurement interval of 1 hour)



GRAPH 2 : POTENTIAL DISPERSION OF ACQUIRED VALUES AT MEASUREMENT INTERVAL OF 1x PER DAY



Measuring cells had been sited before the form under the shield's protection was concreted. The central measuring unit described above was used for the registration of measured values. 10 HPC cells were connected to the central unit, the reading interval being set at 1 hour. The scheme of hydraulic pressure cells siting is seen in Fig. 2. The results of contact stress measurement, i.e. the determination of the tunnel's actual load, served as a basis for the modification of reinforced concrete support of the tunnel's lining.

Graph n. 1 shows a typical graphic output (0 - 180 hours of measurement) with a supplementary commentary based on the knowledge of the processes running in time. In graph n. 2 maximum, as well as minimum daily values of the measured contact stress have been displayed. With a frequency of measurements 1x per day the measured values could theoretically move anywhere inside the highlighted area. The potential value dispersion is expressed in percentage. The comparison shows how different values of load could be achieved on the basis of individual graphic records, despite the fact that they all come from identical measurement.

The selection of a suitable reading interval presents the only problem which has to be solved during the implementation of contact stress measurement. By getting the most detailed course of the measured values as possible, identification of other effects participating in the obtained results may be facilitated.

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