Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 67 (1993)

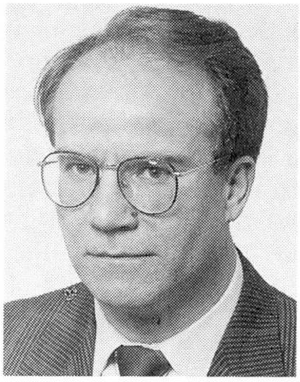
Artikel: Monitoring of trial loadings of bridges using optical fiber sensors
Autor: Wolff, Reinhard
DOI: https://doi.org/10.5169/seals-51404

Monitoring of Trial Loiadings of Bridges using Optical Fiber Sensors

Surveillance des charges d'épreuve des ponts à l'aide de fibres optiques

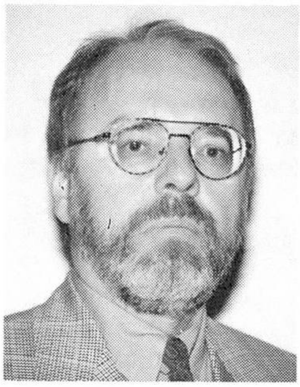
Probelastungen von Brückenbauwerken überwacht mit optischen Sensoren

Reinhard WOLFF
Dr. Eng.
SICOM GmbH
Cologne, Germany



Reinhard Wolff, born 1945. Doctorate at Darmstadt Techn. Univ. Several years in the Central Dep. of Engineering and Design at Strabag Bau-AG's headquarters. Wide experience in the field of bridge construction, construction of tunnels, administration and industrial buildings as well as in environment engineering. Since 1991 managing director of SICOM- Gesellschaft für Sensor- und Vorspanntechnik GmbH (Sensor and Prestressing Techniques Ltd.).

Hans-Joachim MIESSELER
Civil Eng.
SICOM GmbH
Cologne, Germany



Hans-Joachim Miesseler, born 1944, studied constructional engineering in Wuppertal. From 1967 in the design office of Strabag head office in Cologne. From 1987-1990 manager of the department research and development in the central engineering and product management division. Since 1991 Technical Manager of SICOM.

SUMMARY

Monitoring of structures - especially of bridges - is getting more and more important. The reasons for this are the increase of heavy goods traffic, of air pollution and in precipitations, de-icing salts and the fact that prices for traditional maintenance and repairs are going up. In order to guarantee the durability of concrete structures over a long period of time it is necessary to monitor these structures on a permanent basis. In prestressed structures cracks in the concrete and the change in the stress-strain behaviour of the tendons must be observed.

RÉSUMÉ

La surveillance des constructions - surtout des ponts - devient de plus en plus importante. Cela est dû surtout à l'augmentation du trafic des poids lourds, à la pollution atmosphérique et au fait que les coûts de maintenance ou de réparation conventionelles augmentent en permanence. Afin de garantir la durabilité des constructions en béton pendant une longue période, il est nécessaire de surveiller en permanence. Dans le cas des bâtiment précontraints, il faut surveiller les fissures dans la précontrainte ainsi que l'allongement des éléments de précontrainte.

ZUSAMMENFASSUNG

Die Überwachung von Bauwerken - insbesondere von Brückenbauwerken - gewinnt eine immer grössere Bedeutung. Dies ist vor allem auf die Zunahme des Schwerlastverkehrs, Luftverschmutzung, Schmutzpartikel in Niederschlägen und auf Streusalze zurückzuführen sowie auf die Tatsache, dass die Kosten für die konventionellen Instandhaltungs- und Reparaturmassnahmen stetig steigen. Um die Dauerhaftigkeit von Betonbauwerken über einen langen Zeitraum hinweg gewährleisten zu können, ist es erforderlich, die Bauwerke permanent zu überwachen. In vorgespannten Bauwerken müssen Risse im Beton und Veränderungen im Dehnungsverhalten der Spannglieder ständig kontrolliert werden.

1. INTRODUCTION

For the monitoring of buildings with optical fiber sensors in principle two different types of application can be distinguished. On the one hand the monitoring of concrete structures, e.g. monitoring of crack formation and their further development and on the other hand monitoring of prestressing tendons comprising fiber composite materials. For the monitoring of crack formations in concrete structures the optical fiber sensors especially designed for this case of application are directly embedded in new buildings at critical positions of the load bearing structure known from statics. Their function is to provide information about eventually required maintenance works at a very early stage so that the costs for repair works can be reduced at a minimum. In already existant buildings - especially already damaged buildings - these optical fiber sensors are installed at a later date in the structural elements which shall be monitored in order to monitor cracks and their further development or the repair works which already have been realized with regard to the load bearing capacity of the structural element. In case of fiber composite prestressing tendons the optical fiber sensors are directly embedded in the fiber composite bar in order to indicate its intactness.

2. SENSOR TECHNOLOGY

In order to monitor buildings in a useful way it is necessary to develop appropriate sensors which are able to guarantee reliable measured values during a long period of time. Nowadays the intelligent processing of the high quantity of measured values is no problem due to the available and efficient personal computers.
The sensor technology is - regarding to the monitoring of buildings - only in the beginning of its development. The application of strain gauges on the prestressing steel or the measurement of the prestressing forces with the aid of load cells is not possible in case of prestressing with post-bond. Moreover it is not a durable solution in case of prestressing without bond.
Only the application of fiber composite materials facilitates a permanent control of the prestressing element over its entire length due to the integration of copper wire sensors or optical fiber sensors. Even the monitoring of each individual bar is possible. The sensors are already integrated into the tendon during its fabrication. The sensors indicate the integrity of the tendon or they locate the damage.
Besides the monitoring of the prestressing elements the observation of the stress/strain behaviour of the concrete in the zone subject to tensile forces is very important. Therefor the tensile zone above the piers and the spans are monitored permanently with integrated optical fiber sensors with a measurement exactitude of $\pm$ 0,2 mm.

2.1 The crack detection sensor

In the case of this type of sensor several optical fiber sensors or one optical fiber sensor are stranded with each other with one or several steel wires. If this sensor - which is connected normally to the structural element which shall be monitored in a distance of 1 m through a bearing material - is exposed to tensile load, the sensor effect is created by a loss of light intensity as a result of micro-bending. This light attenuation allows an integral measurement of the changes of the length of the sensor with a long term accuracy of $\pm$ 0,2 mm. The localization of these extensions changes (e.g. cracks) is carried out with an Optical Time Domaine Reflector (OTDR) by reflection measurements and a local dissolution of $\pm$ 0,5 m.

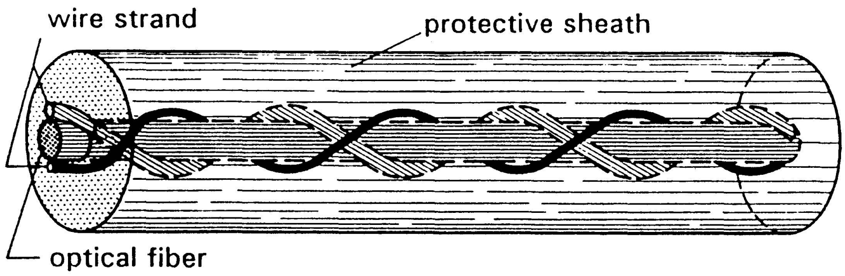


Figure 1:

2.2 The crack width sensor

The crack width sensor is a loop bended optical fiber sensor which is fixed at two bars. These bars are directly connected to the structure on the right and on the left of the joints or cracks which shall be monitored. The sensor monitors and measures permanently changes in the joints or crack width with a measuring sensitivity of 0,02 mm and a measurement range of 0,1 -10 mm.

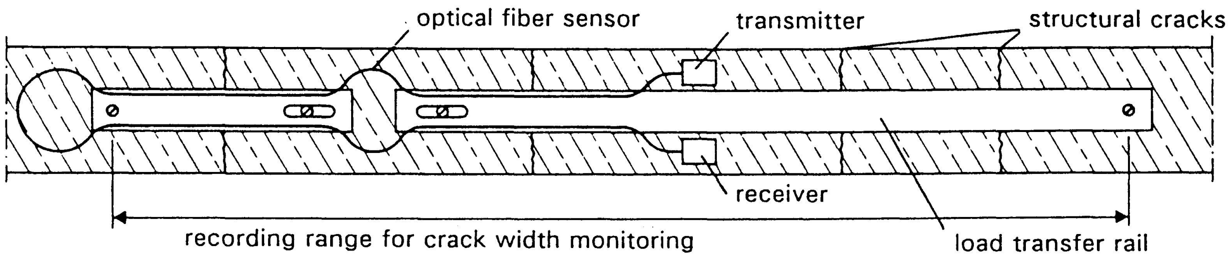


Figure 2:

2.3 The reflector sensor

A light signal is passed through the optical fiber sensor. The reflectors (Fig. 3) reflect part of the light while non-reflected light travels to the next reflector. In this way up to 30 measuring points can be monitored with a single sensor. Velocity measurements provide data on the deformations. An other design is the parallel arrangement of several optical fiber sensors (Fig. 4). In this case a light signal is passed one after the other through each optical fiber sensor with the aid of a multiplexer. With velocity measurements the length of the respective optical fiber sensor is measured and then compared with the sensor length of the parallel arrangement.

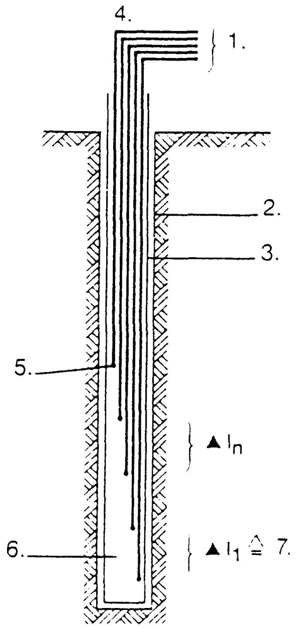


Figure 3:

1. Analysis electronic
2. Bore hole
3. Glass fibre composite pipe
4. n optical fibre sensors
5. Reflective end of sensor
6. Synthetic resin
7. Basic length as required
8. Semi-permeable reflector

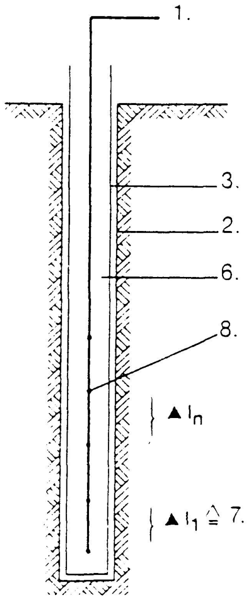


Figure 4:

3. TRIAL LOADINGS

3.1 Marienfelde Bridge, Berlin

The design of the Berlin-Marienfelde pedestrian bridge, a two span TT beam bridge, is an example of the first fully monitored bridge structure. In addition to glass fiber prestressing tendons (partial prestressing as external prestressing) with integrated sensors, a whole series of optical fiber sensors have been embedded directly inside the concrete or been retro-applied. During a trial loading carried out in November 1989 using 250 concrete slabs (weight per slab 1 t), this was able to be monitored with the aid of sensors. By using particularly highly sensitive sensors, evidence was even able to be recorded on the dynamic bahaviour of this bridge.

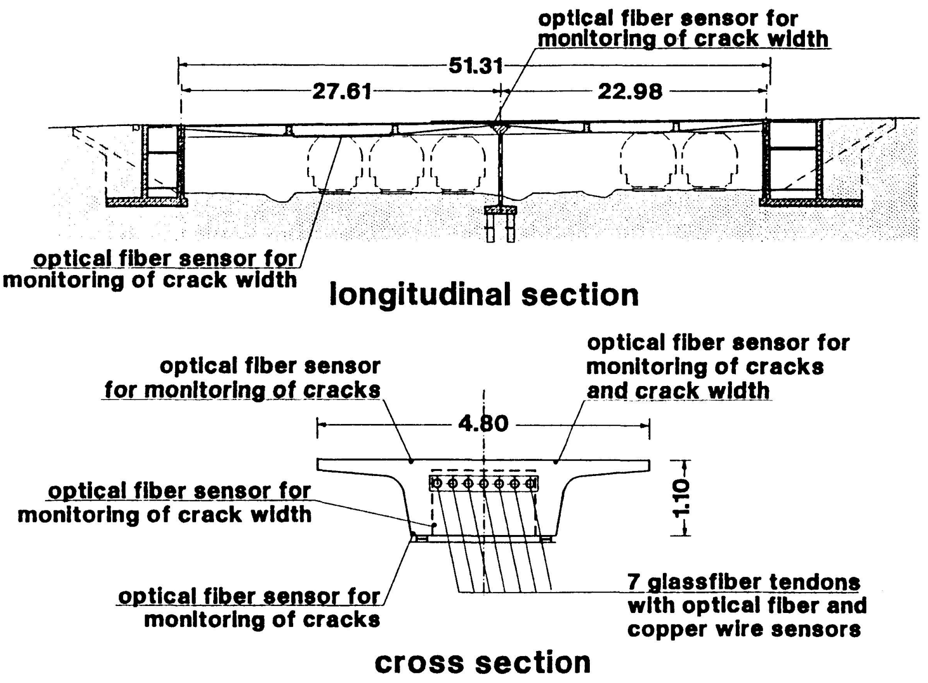


Figure 5: Measurement layout

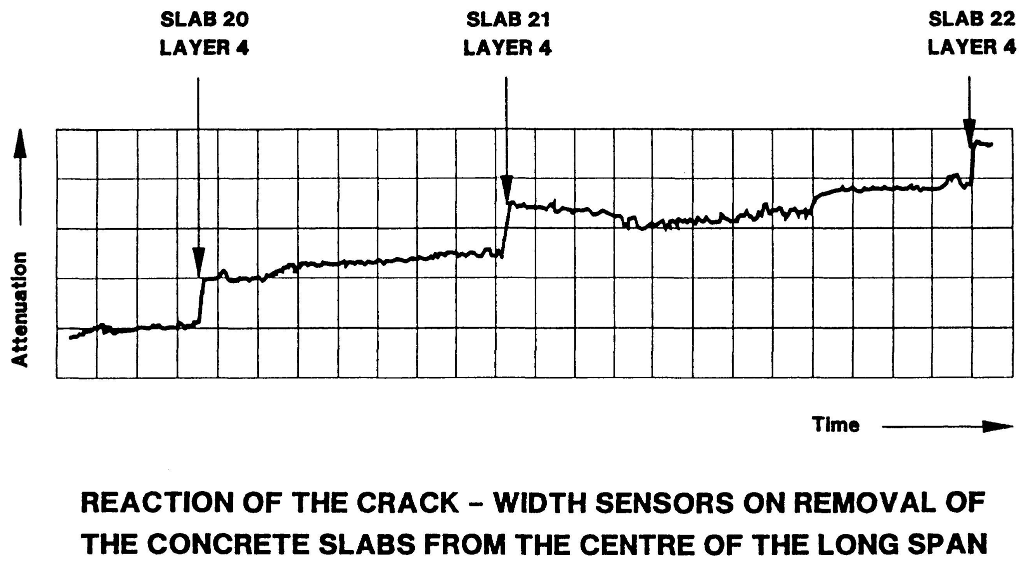


Figure 6: Monitoring of the test load by means of the optical fiber sensors embedded in the concrete

3.2 Schiessbergstrasse Bridge, Leverkusen

This three span, solid concrete slab bridge (bridge classification 60/30), is designed with limited prestressing comprising 27 glass fiber prestressing tendons (working load 600 kN) and post-bonding. Three glass fiber bars per tendon are provided with sensors and there are to be four additional optical fiber sensors integrated directly into the concrete on the upper and four on the lower side of the slab. The trial loading of the Schiessbergstrasse Bridge which has been realized on 31st of March 1992 showed in an impressive way the efficiency of the optical fiber sensors embedded in the concrete construction. By means of the loading of the bridge with a truck of a total load of 27,5 t it was possible to measure additional extensions of the bridge in the μ-range.

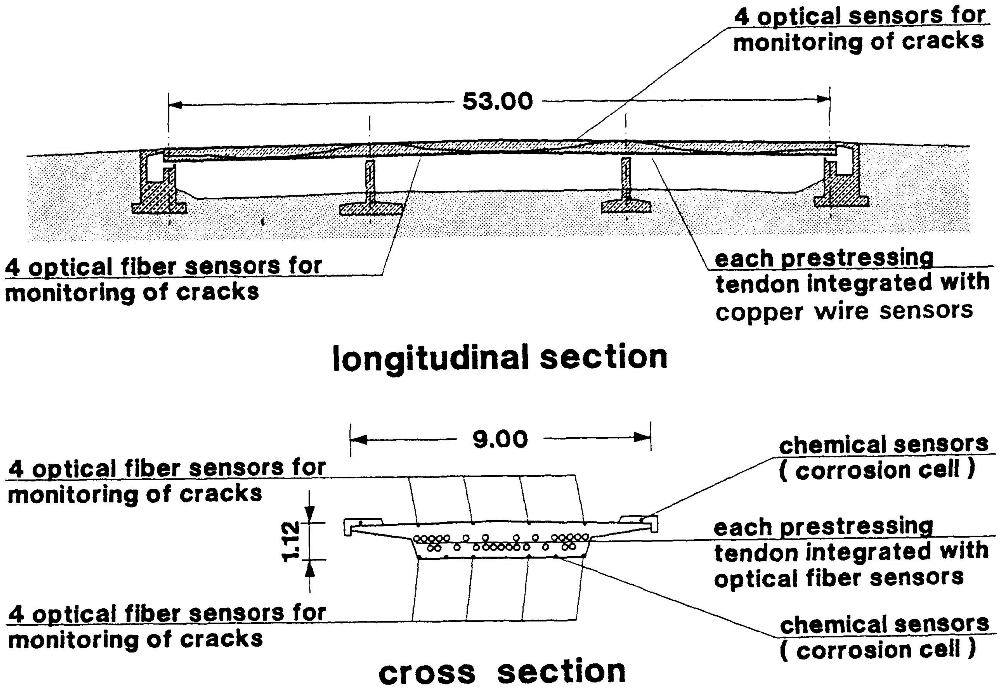


Figure 7: Sensor layout

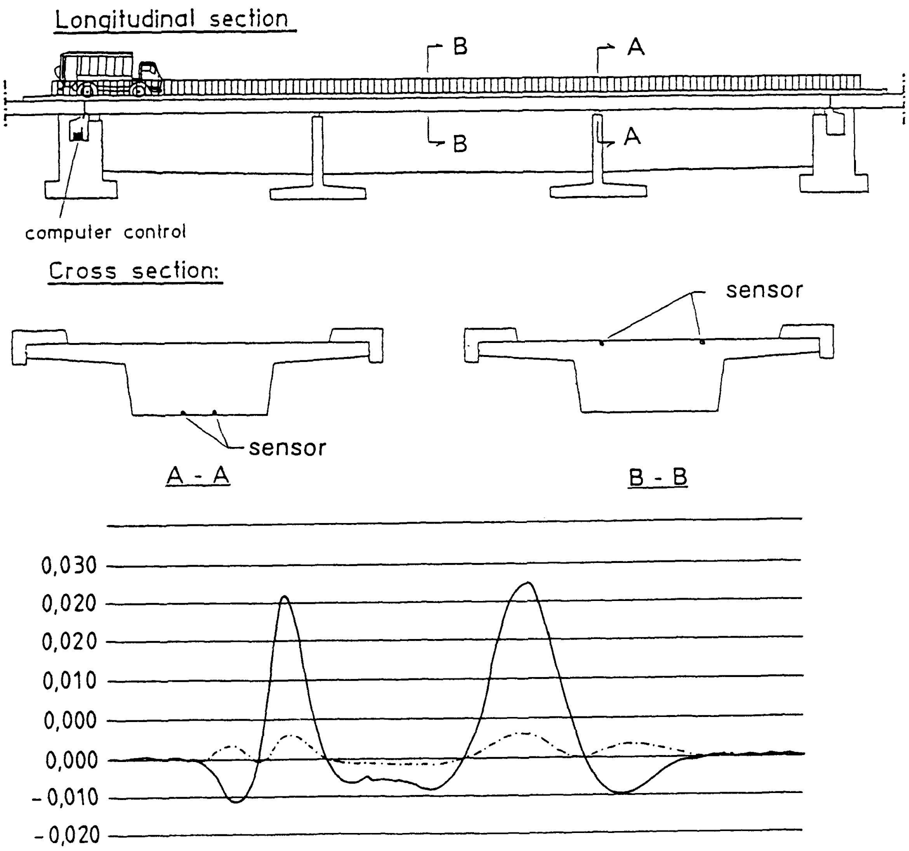


Figure 8: Trial loading

3.3 Nötsch Bridge, Kärnten, Austria

The Nötsch Bridge is the first bridge in Austria with glass fiber composite prestressing tendons, and is designed with limited prestressing comprising 41 glass fiber prestressing tendons (working load 600 kN) and post-bonding. Similar to the Bridge Schiessbergstrasse the suitability of the sensors has been proved by a trial loading. Two trucks with a total load of 2 x 22 t did produce additional extensions in the middle field of approx. 50 μm.

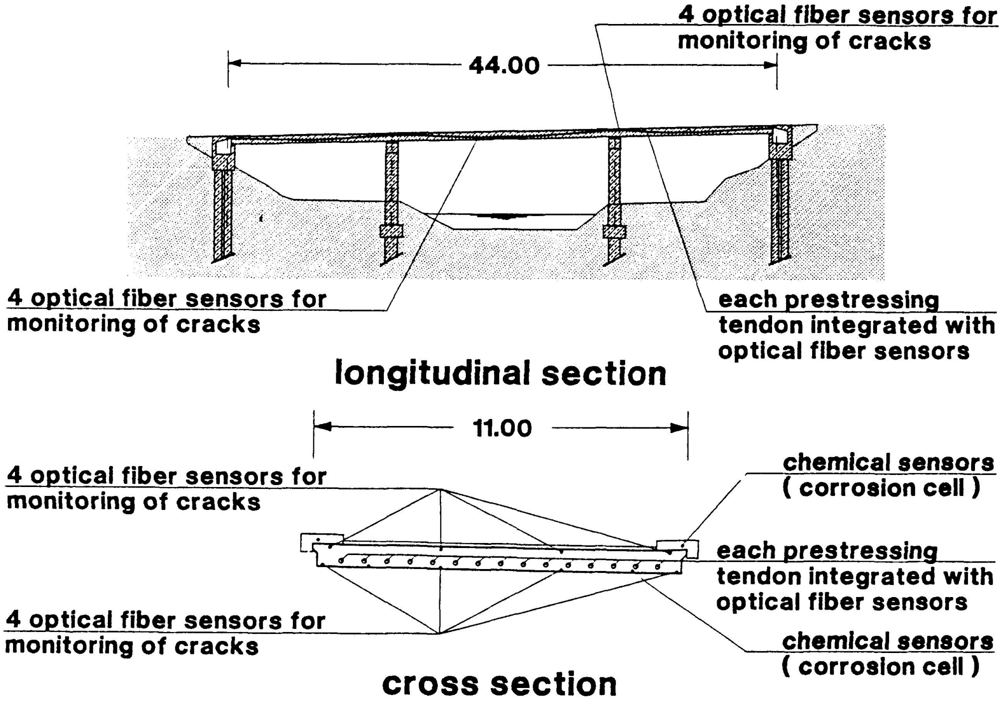
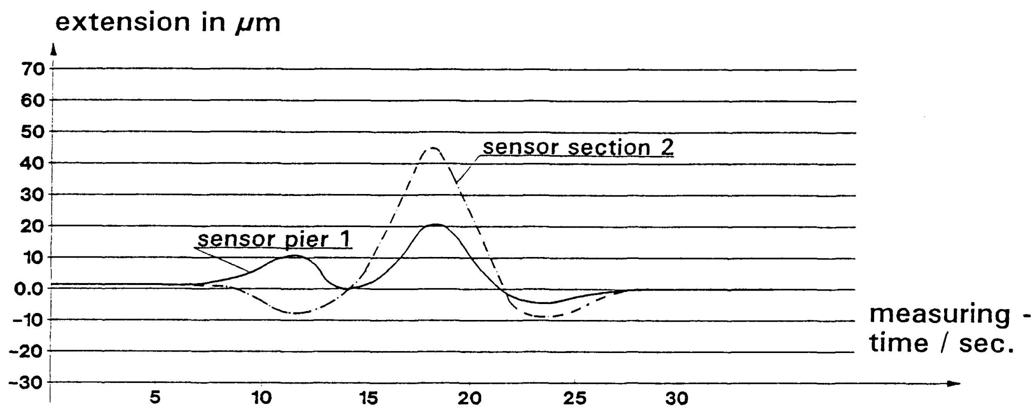


Figure 9: Sensor layout



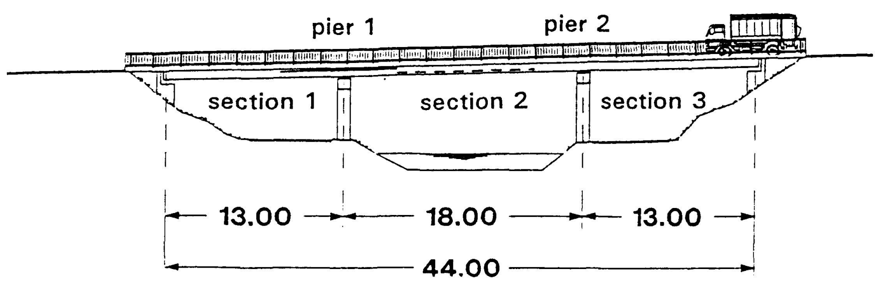


Figure 10: Trial loading

4. CONCLUSIONS

The current constantly increasing requirements and demands on heavy building structures make the question of the utilised materials' durability and the useful life of such structures in general to be of ever greater and wider interest. Compared with essentially new construction, investment for the preservation of building structures claims a not inconsiderable proportion of the funds available.
The possibility of integrating sensors, on the one hand directly into the bar materials during production, and on the other the embedding of such sensors in the concrete, opens completely new horizons for the permanent monitoring of building structures.

5. REFERENCES

1. Miesseler, H.-J.; Lessing, R.: Experiences in monitoring of load bearing structures with optical fiber sensors. IABSE-Congress, Lisbon 1989.

2. Miesseler, H.-J.; Preis, L.: High performace glass fiber composite bars as reinforcement in concrete and foundation structures. Bauen mit Kunststoffen, Issue 2/1988, Pages 4-14.

3. Miesseler, H.-J.; Wolff, R.: Experience with the monitoring of structures using optical fiber sensors. FIP XIth International Congress on Prestressed Concrete, Hamburg, 4-9 June 1990.

4. Wolff, R.; Miesseler, H.-J.: Application and experience with intelligent prestressing systems based on fiber composite materials. FIP XIth International Congress on Prestressed Concrete, Hamburg, 4-9 June 1990.

5. Wolff, R.; Miesseler, H.-J.: New Materials for Prestressing and Monitoring Heavy Structures. Concrete International, 9.1989, Vol. 11, No. 9.