Evaluation of the load-carrying capacity of structural members in existing buildings by proof load testing

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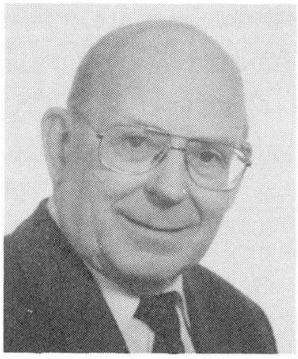

Gerhard Spaethe, born in 1932 received his civil engineering degree from the Technical University Dresden in 1958. He was at last head of the department of structures and deputy director in the Institute of Rehabilitation and Modernisation of Buildings in Berlin. In October 1997 he retired.

Summary

The first part of the paper reports about experimental work testing prestressed concrete slabs by a self-securing system consisting of a hydraulic device and the measuring-equipment plotting deflections and strains on-line on the computer screen. Tests of connections in multilayer external walls are mentioned. The verification of structural safety after proof load testing is considered. Applying the Bayesian procedure for the determination of the characteristic value (5 %-fractile) of the resistance, taking into account prior informations before the test and additional information by test results, the verification of the structural safety can be carried out by the limit state method.

1. Experimental Method

If great uncertainty in the theoretically calculated load-carrying capacity (resistance) exist and if safety reserves are expected in structural elements of existing structures an experimental test in situ can be very useful.

Modern developments in hydraulic loading devices and in computer based on-line measurement technology have improved the experimental possibilities for proof load testing.

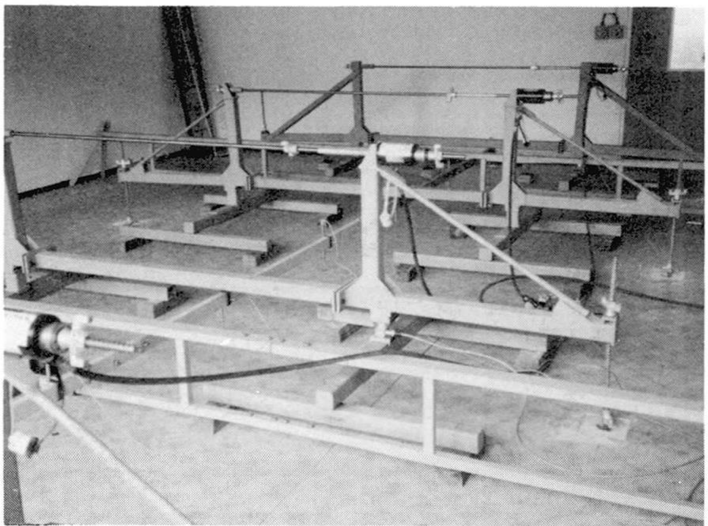

Fig.1 Set up for proof load testing of slabs

Fig. 1 shows a set up for tests of slabs built as a component system in existing buildings. Tensile forces are induced in the upper chord of a truss. The compressive forces at the bottom are distributed by a leverage system to get quasi-equally distributed loads. The reactive forces are induced into neighbouring walls or into the support of the slabs in the floor below.

The results of the measurement of the forces, the deflections and the strains in steel and concrete are shown on line at the computer-screen . The experimenter can so directly control the state of the structure during the proof load test and guarantee, that the linear, elastic area is not exceeded. So a self-securing system is available which avoids damage to the tested structure entirely or almost entirely.

2. The determination of the characteristic value of the load carrying capacity with the Bayesian procedure

The practical verification of the structural safety by the limit state method with partial safety factors is based on the characteristic value, which is defined as 5 %-fractile of the load-carrying capacity of the structural element. If a reliable value of the characteristic value is available by the proof load test than the safety check can be carried out by the principals of limit state design in a well know manner.

The Bayesian method is applied to determine the characteristic value as 5 %-fractile of the load carrying capacity by a proof load test, taking into account prior information by calculation or engineering judgement before the test.

It is shown that in the case of a transformation from a tested element to a not tested one from the same population the posterior distribution function of the resistance R is

$$F_R''(r) = \int_{-\infty}^{+\infty} F_R(r|\vartheta) f_\Theta''(\vartheta) d\vartheta = \frac{1}{c} \int_{-\infty}^{+\infty} F_R(r|\vartheta) \prod_i (1 - F_R(s_{pi}|\vartheta)) f_\Theta'(\vartheta) d\vartheta$$

and in the case of a direct testing

$$F_R''(r) = \begin{cases} \frac{1}{c} \int_{-\infty}^{+\infty} \frac{\left(F_R(r|\vartheta) - F_R(s_{pj}|\vartheta)\right)}{1 - F_R(s_{pj}|\vartheta)} \prod_i (1 - F_R(s_{pi}|\vartheta)) f_\Theta'(\vartheta) d\vartheta & if \quad r > s_{pj} \\ 0 & if \quad r \le s_{pj} \end{cases}$$

4. Conclusions

From the results of an example the following conclusion can be drawn:

- The higher the proof load is in a successful test, the higher is the characteristic value of $R_{0,05}$.
- The characteristic value $R_{0,05}$ increases with increasing number n of tests.
- The characteristic value is greater if the structural member is directly tested than in the case of conclusions from tests of other elements from the same population.
- The more diffuse the prior information is, the more effective is the experiment.
- In the case of an exact prior information only the direct testing gives an effect.
- If the structural element is tested directly and successfully with high load-levels the prior information becomes irrelevant.

These results are in good agreement with the engineering-experience. Bayesian procedure gives the possibility to combine information about the load carrying capacity R by calculation before the test with new information by testing and gives a rational basis for the verification of structural safety by the limit state method. With these experimental and theoretical methods existing structures often can be saved and used for a longer residual service life.