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Load Tests on Acute-Angled Motorway Bridge

Essai de charge sur un pont d'autoroute biais

Belastungsversuch an einer spitzwinkeligen Autobahnbrücke

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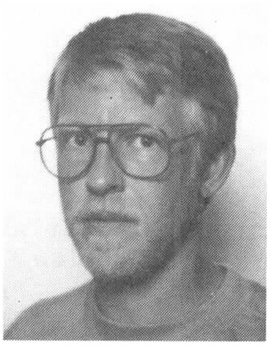

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SUMMARY

A full-scale load test in the serviceability limit state has been carried out on a 6-year-old motorway bridge. The test was made with the purpose of examining the structural behaviour of the bridge under heavy load. The load on the bridge came from two heavy vehicles, and strain and deflection measurements were made on the bridge deck and the edge beam. The test results have been compared with the results from a FEM analysis.

RÉSUMÉ

Un essai de contrainte, grandeur nature, à la limite de charge, a été réalisé sur un pont d'autoroute construit depuis 6 ans. Cet essai a été effectué dans le but d'examiner le comportement structurel du pont sous l'effet d'une lourde charge. Les charges exercées par deux véhicules lourds ont permis de mesurer les augmentations relatives de longueur ainsi que les fléchissements vers le bas du tablier du pont et de la travée latérale. Les résultats des essais ont été comparés avec ceux provenant d'un modèle d'éléments finis.

ZUSAMMENFASSUNG

An einer sechs Jahre alten Autobahnbrücke wurden Belastungsversuche im Bereich der Gebrauchslast einschl. Sicherheitsbelastung durchgeführt. Damit sollte ermittelt werden, wie die Brücke strukturell auf schwere Belastungen reagiert. Nach Plazierung zweier Schwerlastfahrzeuge wurden die Dehnung und die Durchbiegung jeweils an der Deckenplatte und am Randbalken gemessen. Die Ergebnisse des Versuches wurden mit denen aus einem FEM-Modell verglichen.

1. INTRODUCTION

The paper describes a load test performed on a six year old motorway bridge. Originally the bridge was constructed as a part of a large ferry terminal project at the Great Belt which separates the eastern and western part of Denmark. The terminal was a part of a project in which both railway and roadtraffic were to be shipped from the same terminal instead of from two separate terminals several kilometers apart, as was the case until then. However, as a decision was made to establish a fixed link across the Great Belt, the terminal plans were given up during the construction of the bridge, and the bridge therefore never served its real purpose.

As it turned out impossible to re-use the bridge as a part of the on-shore constructions for the Great Belt crossing, the bridge was demolished just after the load testing had ended.

The bridge was constructed using high quality materials, and thus, being practically undeteriorated, it offered a unique opportunity to perform a variety of tests. These could e.g. through a demonstration of the real life behaviour indicate possible needs for alterations in the current design practice and the basic assumptions concerning the concrete properties.

Only tests in the serviceability limit state with live loads were considered, due to limitations on time and budgets.

2. DESCRIPTION OF THE BRIDGE

The bridge consisted of a 2-span post-tensioned plate, simply supported on retaining walls and columns. The angle of intersection was only about 18 degrees, resulting in free edges spanning up to 40 metres. Prior to the load testing, the concrete properties were measured by testing drilled-out cores. The average strength was determined to be 40 MPa and the modulus of elasticity approx. 39.500 MPa.

The bridge is shown in fig 1.

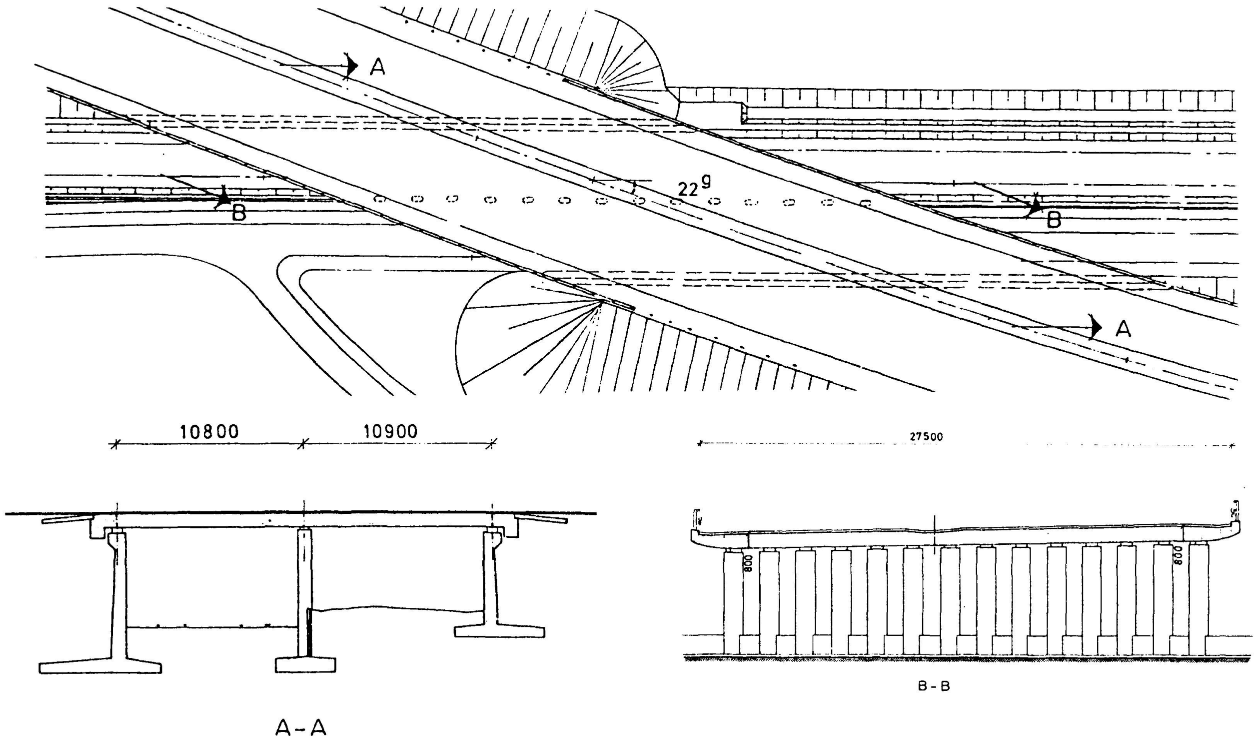


Fig 1 The bridge

3. DESCRIPTION OF THE TESTS

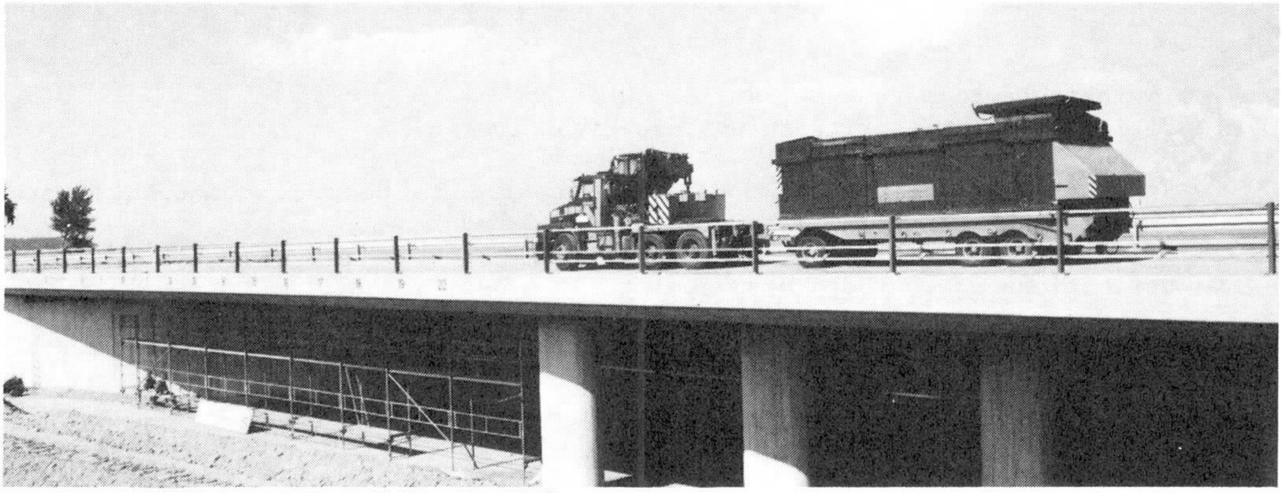
The tests were carried out over two full days at the end of July 1991. The weather was dry and sunny, with temperatures of 20-23°C. The load was provided by two heavy vehicles from the Danish Road Directorate (DRD) and the Royal Danish Army, respectively. The load characteristics of the vehicles are given below, in table 1.

	front-axle-load tons	Rear-axle-load tons	Total load tons
The Danish Road Directorate Loaded trailer	22.0	2 x 22.05	66.1
The Danish Road Directorate Volvo truck	6.0	2 x 8.85	23.7
The Royal Danish Army Tank on tank-transporter	-	2 x 31.4 (2x23.7)*	62.8 (47.4)*
The Royal Danish Army MAN Truck	6.6 (7.7)*	2 x 6.0 (2x13.1)*	18.6 (34.0)*

*) With tank in normal driving position

Table 1 Load characteristics of the heavy vehicles.

The vehicle from the Danish Road Directorate, was a heavy Volvo truck with a trailer loaded with steel plates. The vehicle from the Royal Danish Army was a Centurion tank on a Scrammel tank transporter pulled by a MAN truck. The vehicles are shown in fig 2.



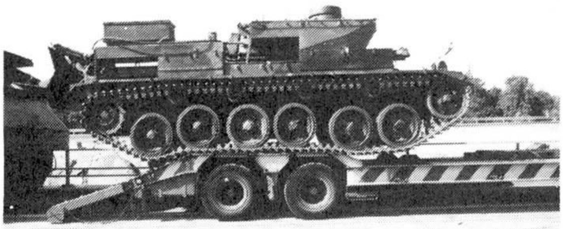


Fig 2 The heavy vehicles. The truck with steel loaded trailer from the Danish Road Directorate (above) and the tank from the Royal Danish Army in position above the rear axles of the transporter (left).

By placing the tank directly above the rear axles of the tank transporter, a load on these two axles of about 63 tons was obtained. Further, a relatively concentrated load of more than 100 tons could be obtained by placing the two vehicles in a back-to-back in-line configuration.

The axle loads were measured with an accuracy of ± 50 kg and the vehicles could be placed on the deck within an accuracy of ± 0.5 m.

13 tests were carried out with different combinations of the loads: 5 tests with the DRD-truck alone, 6 tests with both vehicles positioned in-line next to the edge beam and 2 tests in a side-by-side configuration. Furthermore, 6 reference tests were performed without loading. These reference tests were performed morning, noon and evening, and were performed for calibration purposes, in order to be able to compensate for temperature effects.

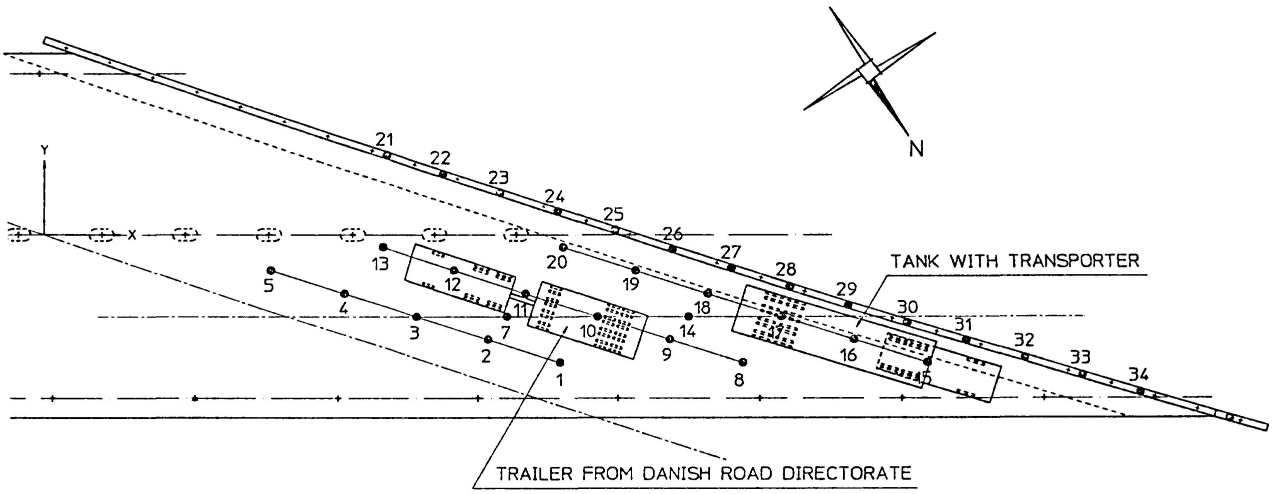


Fig 3 Typical set-up of the heavy vehicles (Test no 18).

The following measurements were carried out:
(The position of the measuring points are given in fig 3)

- Strains at 19 points at the lower side of the deck. 3 components were measured at each point. (points 1 - 19)
- Deflections of the edge beam (points 21 - 34), and at the points 15 - 20
- Strains at 14 points at the upper side of the edge beam. 1 component (the longitudinal one) was measured at each point. (points 21 - 34)
- Strains of unloaded parts of the construction (for reference purposes).

The strains were measured by DEMEC mechanical strain-gauges with an acurracy of 10^{-5}. The deflections were measured using a GEODIMETER theodolite.

Besides for calibration purposes, the unloaded tests served for the detection and quantification of temperature effects. During testing the upper side of the bridge-deck was subject to a temperature rise of about 10°, which represented potential temperature induced stains of the same order of magnitude as the maximum load-induced strains. The temperature rise underneath the deck, on the other hand, was only about 2°. By comparing morning and evening reference tests, it could be concluded that the bridge deck was subject to a slight compression in the x-direction, and a corresponding slight expansion in the y-direction. The magnitude of these strains was only 10 - 15 x 10^{-6}, which is considerably smaller than the maximun bending strains, thus leading to the conclusion, that the temperature rise leads to an increase in the internal stress level, rather than to stains. Consequently, considering the procedure of calibrating against unloaded tests, scattered througout the day, the temperature effects were neglected.

The reproduceability of the strain measurements was determined by means of a special test bar. Fluctuations within ± 5 x 10^{-6} were observed. The accuracy of the deflection-measurements was measured to ± 0.75 mm.

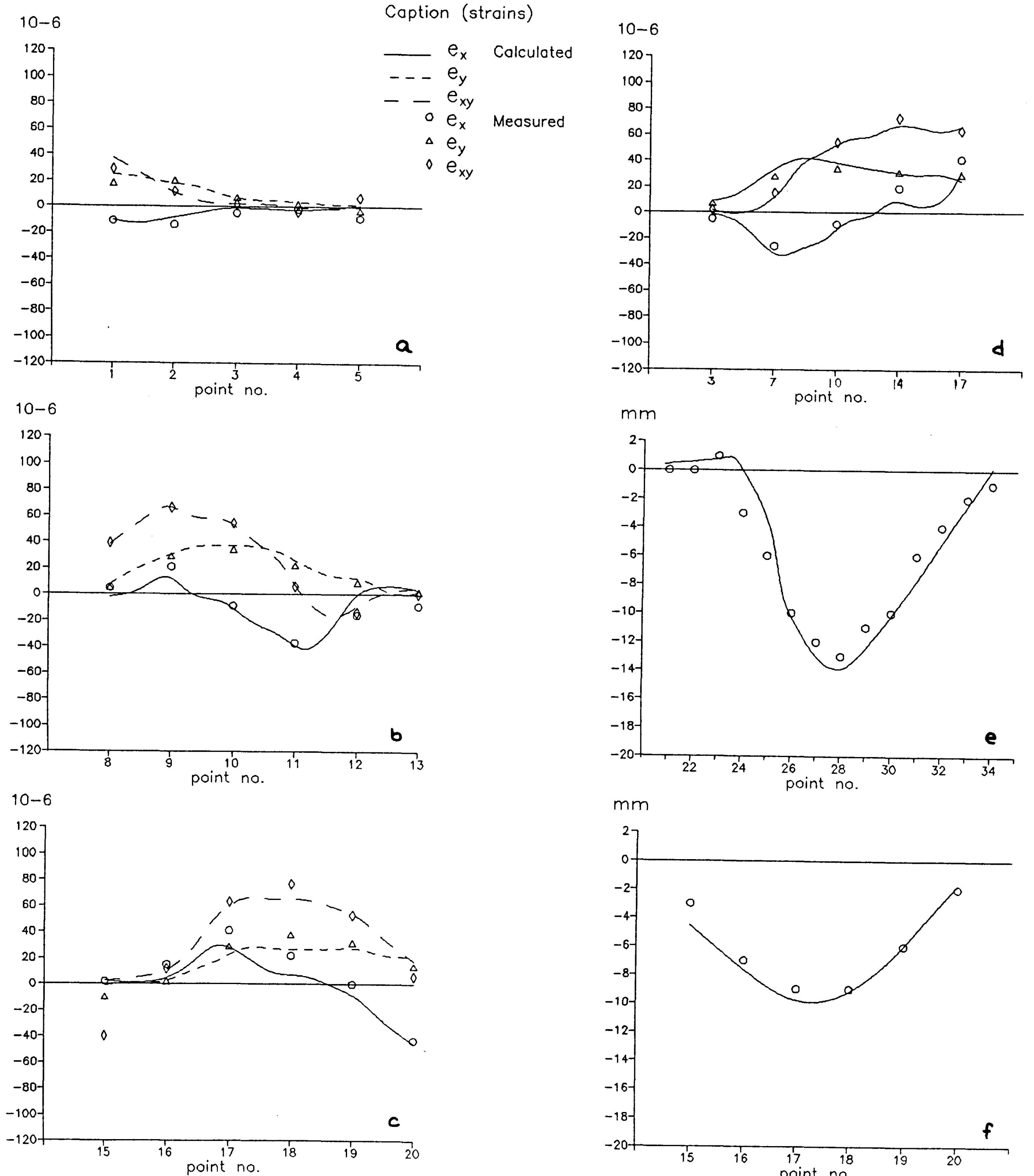


Fig 4: Test Results. Measured (markers) and calculated (lines) results. The x-axis indicates the number of the measuring point (see fig. 3). (a - d: strains, e and f: deflections).

4. RESULTS

The maximum edge beam deflection was measured to approx. 10 mm with the load consisting of the the steel plate loaded DRD-truck only, and to approx. 17 mm when both vehicles were present.

The corresponding strains were in the range of -50×10^{-6} to 60×10^{-6} and -60×10^{-6} to 130×10^{-6}, respectively.

The longitudinal strains measured at the upper side of the edge beam were in the range of -100×10^{-6} to 80×10^{-6}.

No cracks were detected, even though the loads by far exeeded the level of the serviceability limit state, and actually were close to the ULS design loads.

The results obtained from a selected test are shown in fig 4. Note that all strains are 'true' strains, measured in three directions: e_x parallel to the retaining walls (= the x-direction), e_y shifted an angle of -90 degrees with respect to the x-direction and e_{xy} shifted -45 degrees.

The test results have been compared to theoretical results provided through an FEM-analysis, in which the bridge was represented by 300 triangular plate elements in each of the unloaded quadrants of the bridge, and by 600 elements in the loaded section. The plate edges, i.e. the edge beam and the load distributing beam at the bearing line, were modelled by additional beam elements. The curved shape of the plate at the free edge was modelled using wedge shaped plate elements.

5. CONCLUSIONS

Fig 4 shows an exellent agreement between the measured and the calculated results, thus indicating that the behaviour of bridges, even with very acute intersection angles, may be successfully predicted by the use of standard FEM modelling. The good agreement also confirms, that the bridge was fully intact, without sign of cracking.

Finally, the tests demonstrate that the mechanical strain gauge technique, which was used, is a well suited tool, and provides a sufficient degree of accuracy, for the kind of load testing described in this paper.

6. AKNOWLEDGEMENTS

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