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Autor: Mondrup, Arne Jensen / Frederiksen, Jens Ole / Christensen, Hans Henrik

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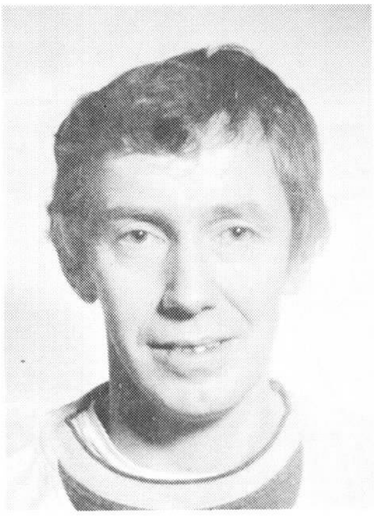
Load Testing as an Assessment Method
Essais de charge comme méthode de jugement
Probebelastung als Beurteilungsmethode

Arne Jensen MONDRUP
Civil Engineer
Danish Road Directorate
Copenhagen, Denmark

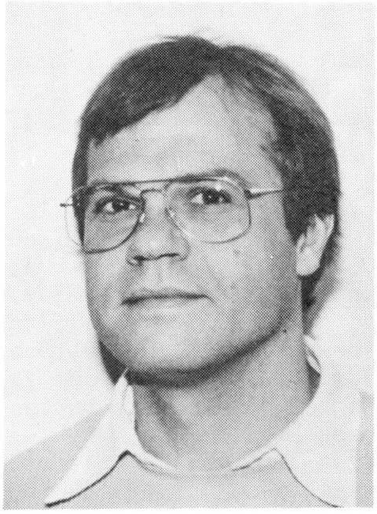
Jens Ole FREDERIKSEN
Civil Engineer
Concrete and Struct.
Hørsholm, Denmark

Hans Henrik CHRISTENSEN
Civil Engineer
B. Højlund Rasmussen
Copenhagen, Denmark

Arne Jensen Mondrup, born 1944, obtained his M. Sc. Degree at the Technical University in Copenhagen. He has specialized in bridge rehabilitation, maintenance and inspections. Arne Jensen Mondrup has diploma from the Danish Concrete Institute and Nitro Nobel, Sweden, in the durability of concrete.



Jens Ole Frederiksen, born 1950, obtained his M. Sc. Degree at the Technical University in Copenhagen. For twelve years he has been involved in experiments on building structures in the laboratory and "in the field".



Hans Henrik Christensen, born 1952, graduated in 1977 in structural and civil engineering at the Technical University in Copenhagen. 11 years of experience in design, repair, rating and load testing of bridges.

SUMMARY

Repeated load testing of a heavily deteriorated structure is an efficient method to evaluate whether the structure still meets the specified requirements with regard to load capacity. Two load tests of a motorway bridge showed that this structure could meet the requirements for load capacity 10 years after the bridge would, according to the traditional method of evaluation, have to be replaced. Generally, a load test is an economically favourable solution compared with the interest paid for a new investment.

RÉSUMÉ

Des essais de charge répétés sur une structure fortement endommagée représentent une méthode efficace pour juger de la capacité portante. Deux essais de charge sur un pont autoroutier ont démontré que sa durée de vie dépasse de dix ans celle donnée par des méthodes d'évaluation traditionelles. En général, un essai de charge est une méthode économique face aux dépenses d'un nouvel investissment.

ZUSAMMENFASSUNG

Die wiederholte Belastung von stark geschädigten Bauwerken ist eine effiziente Methode zur Ueberprüfung der vorhandenen Tragfähigkeit. Zwei Belastungsversuche an einer Autobahnbrücke zeigten, dass diese eine 10 Jahre höhere Lebensdauer aufwies als mit traditionellen Beurteilungsmethoden ermittelt worden wäre. Allgemein sind Belastungsversuche eine wirtschaftliche Methode, verglichen mit den Zinsbelastungen durch verfrühte Neuinvestitionen.

1. INTRODUCTION

Repeated full scale load tests can be used to verify the load carrying capacity of concrete structures, and the replacement of a damaged structure can therefore be postponed for many years. The method is particularly useful when inspections indicate a degree of deterioration that makes it difficult to calculate the load carrying capacity on the basis of material strength or a structural model similar to the deteriorated structure.

The load test of a motorway bridge at Skovdiget north of Copenhagen will be presented as an example of a load test of a deteriorated concrete structure. The twin motorway bridges (Eastern and Western respectively) were constructed in 1965-67 for the Copenhagen Highway Authorities. The bridges now belong under the Danish Road Directorate. The first load test was performed in 1984 and the second in 1988.

2. STRUCTURE

Each bridge is approx. 220 m long and approx. 22 m wide. The concrete superstructures consist of two main girders joined with transverse ribs at intervals of approx. 2 m, with cantilever wings on the outsides. The average length of the spans is approx. 20 m and at the ends approx. 10 m. The span across the S-train tracks is approx. 24 m. Each main girder, continuous over 12 spans, is supported by 11 Franki-pile founded columns.

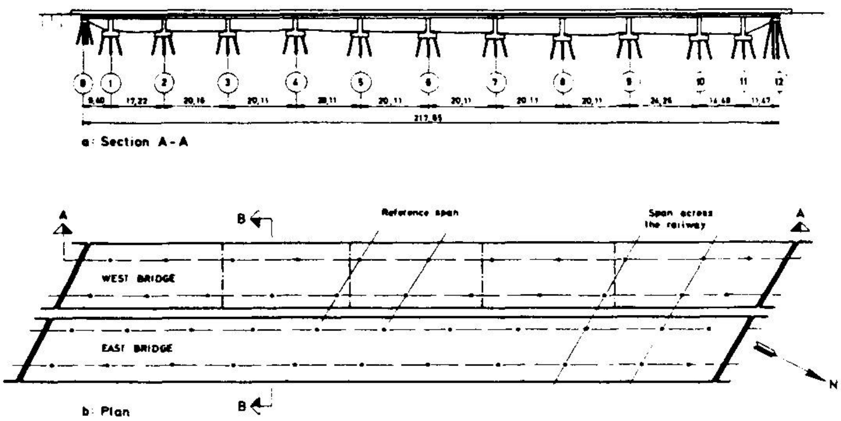


Fig. 1 Elevation and plan view

Each bridge was cast in five sections and prestressed and posttensioned longitudinally and transversely using the BBRV system.

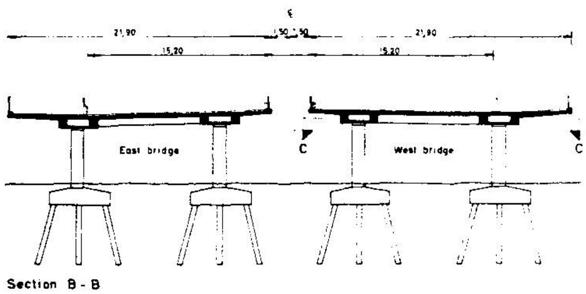


Fig. 2 Cross section

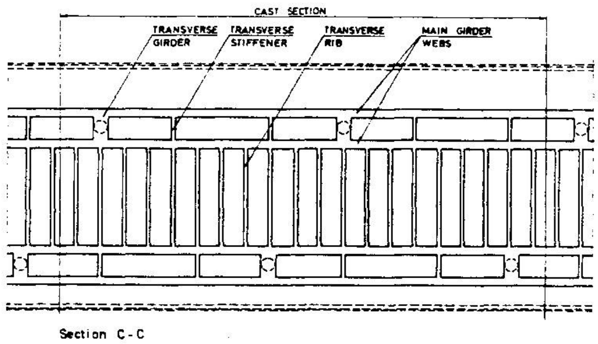


Fig. 3 Sectional plan view

The main girders are constructed as box sections with a cross sectional height of approx. 1 m. Transverse stiffeners 1.4 m wide are cast in the main girders over the columns as transverse girders with short cables arranged as a reversed U. The structure of the bridges is shown in figures 1-3.

3. HISTORICAL BACKGROUND

3.1 The Eastern Bridge

In 1976, the normal repair work at the Eastern bridge began. The main elements of the repair work were replacement of the old insulation and surfacing, including a new concrete surface, and an overall improvement of the dewatering system.

As the repairs progressed, however, a number of other damages were discovered that had to be remedied. Surface water, which had penetrated the insulation and was retained in cavities, had percolated into the concrete. Further, the concrete proved liable to alkali-siliceous reaction, and in many parts on the top side of the bridge deck, especially near drains, had deteriorated to a degree that necessitated replacement.

The prestressing cables were heavily corroded and sometimes uninjected. Consequently, the work was extended to include a relatively extensive examination and repair of the prestressing cables by reinjection. Other damages were discovered, and the complete repair work on the Eastern bridge lasted until 1984 and cost approx. DKK 25 million.

3.2 The Western Bridge

Preliminary studies had indicated that the same deficiencies would be found in the Western bridge. Consequently, the Danish Road Directorate initiated a study in 1982 to find alternatives to a costly overall repair. The outcome was among other things that the construction of a new bridge would cost approx. DKK 50 million, including the demolition of the old one.

4. DECISION ON LOAD TEST

On the basis of the above it was decided that the Western bridge should remain for the time being, provided the load capacity was sufficient to meet a given minimum load requirement. Only strictly necessary repairs will be carried out, such as securing a tight, even surface with sufficient friction to maintain reasonable road comfort and security.

The following procedure was decided upon to find out whether the bridge was sufficiently safe against collapse:

- Verification that the minimum load capacity existed all over the bridge by load test.
- Periodical inspections of the bridge until such a time when the bridge had to be demolished.

The periodical inspections include visual inspection of the bridge and measuring of deflections and deformations (gradient of column etc.). Further, the loading test has to be repeated at regular intervals.

5. PLANNING OF THE LOAD TEST

5.1 The Critical Regions of the Bridge

Based on the experience gained from the Eastern Bridge, the potentially damaged areas, which would affect the safety of the bridge, were pointed out:

- The transverse girders over columns where the short U-cables might be heavily corroded.
- The construction joints in the main girders where the longitudinal cables often were damaged by corrosion in the couplings.
- The cantilever wing on account of corrosion of the transverse prestressing cables.

- The span across the railway tracks where the concrete appeared heavily deteriorated.
- The foundation of the abutments.

The loading test procedure was organized to take all critical regions into account, both with regard to the application of the load and the positioning of the measuring equipment.

5.2 Loads

The size of the test load was determined in order to meet the requirement that, in the two traffic lanes and the service lane of the overpass, the bridge had to conform with the specification Civil Class 45 (in accordance with the Road Traffic Act), and in one lane, while the bridge was closed to traffic, Civil Class 100.

The load test was applied to the bridge using two drays, one with a constant load of 600 kN and the other with loads varying from 300 to 900 kN, using combinations of 12 concrete blocks of 50 kN each. The main girders were loaded in five stages up to the maximum of 1500 kN: 900, 1100, 1300, 1400 and 1500 kN. The drays were brought to a standstill at the various load points while the relevant measurements were made.

5.3 Measurements

The following measurements were made with regard to the main girders:

- With the load on mid-span, levellings were made to the centre of the span in question.
- With the load at a construction joint, levellings were made to the centre of the span in question and strain measurements were made at the joint.

Supplementary strain measurements were made for the two main girders of the span across the railway tracks which were placed in the section that had deteriorated most, and for a second span chosen for reference:

- With the load placed at mid-span, strain measurements were made at the centre of these two spans and at the cross sections above the nearest column.
- With the loads on the transverse girders close to these two spans, strain measurements were made across the bridge at the top and at the bottom of the girder and furthermore along the bridge at the underside of the girder in question.

6. ELECTRONIC EQUIPMENT

6.1 Equipments for Measuring Strain

Pin gauges with built-in displacement transducers (with linear variable differential transformer) were used for the strain measurements. The length of the pin gauge was chosen sufficiently big (1000 mm at mid-span, above columns and at transverse girders, 500 mm at construction joints) to facilitate the measuring of minor strains and to record beginning cracks, if any. The sensitivity of the transducer was better than 10^{-3} mm/m. Because of the variations in the air temperature during the relatively long loading test cycle, the pin gauges were protected by a jacket of insulating material.

6.2 Mobile Data Centre

The recording system attached to the pin gauges was installed in a mobile data centre. The system consisted of one data logger, one computer, two terminals with graphic screens, one printer and one plotter. This equipment ensured that the result was continuously recorded, processed and plotted out as load/deformation curves.

Each measurement of strain included measurement of the temperature of the pin gauge. Furthermore, the temperature of the air was recorded in addition to the temperature of the concrete at the centre of the top and bottom of the main girder cross section.

7. THE RESULTS OF THE FIRST LOAD TEST IN 1984

The deflection measurements at mid-span, with the load applied at mid-span, showed fine linear relations between the load and deflection. At main girder No. 3, a maximum deflection of approx. 7.5 mm was measured for normal spans and of 12.0 mm for the span across the railway tracks. The measurements indicate that a cracking stage had not yet been reached in the main girders, probably because the tensile strength of the concrete was higher than anticipated. Further, it may by interpreted as a sign that existing prestressing is sufficient.

The strain measurements, made at the transverse girders over the columns supporting the span across the railway tracks and the reference span, generally showed minor strains, which meant that temperature variations had affected the results considerably. After adjustment for the effect of the temperature variations, fairly linear relations between load and strain were established. The measurements made at transverse girders showed no sign of cracks, and there was no significant difference between the measurements made at the span across the railway tracks and the reference span, respectively.

The strain measurements at construction joints showed only minor strains, which again means that temperature variations have affected the measurements. As the strains measured were very small, it was difficult to interpret the results. It was, however, possible to conclude that no cracking had occurred at the construction joints during the loading test.

8. THE RESULTS OF THE SECOND LOAD TEST IN 1988

The load test in 1988 was performed with exactly the same equipment as the load test in 1984, both with regard to measuring system and applied drays with concrete blocks. Even the pin gauge was used in the same position.

A comparison shows that the results of the load test in 1988 are almost identical with the results of the load test in 1984. Only few examples of the measured result can be shown here, but measurements were made on a total of about 100 different spots.

8.1 Measurements of the deflection at mid-span across the railway tracks

In 1984, the deflection at the main girder No. 3 was measured at 12 mm and in 1988 at 12.5 mm. The curves show fine linear relation between load and deflection. It should be noted that the deflection of failure will be in the magnitude of 150 mm.

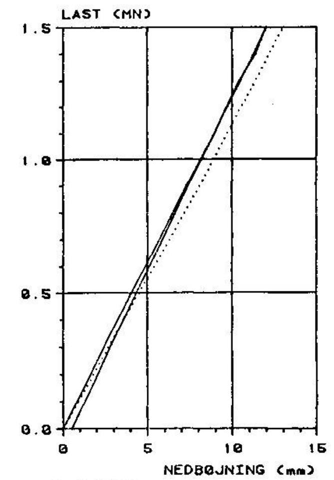


Fig. 4 1984

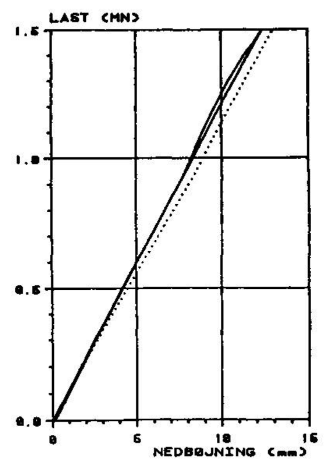


Fig. 5 1988

8.2 Measurements at the top of the transverse girder over columns

The results of the two load tests are very close to each other. Compared with the results from 1984, the deformation measured in 1988 is minor.

8.3 Measurements at the construction joint in the main girder

At the load test in 1984, the maximum deformation at the eastern side of main girder No. 3 was measured at 15/1000 over a length of 500 mm. In 1988, the deformation was measured at 14.5/1000 at the southern side of the joint. At the northern side the measurement was in 1984 11.5/1000 and in 1988 13/1000.

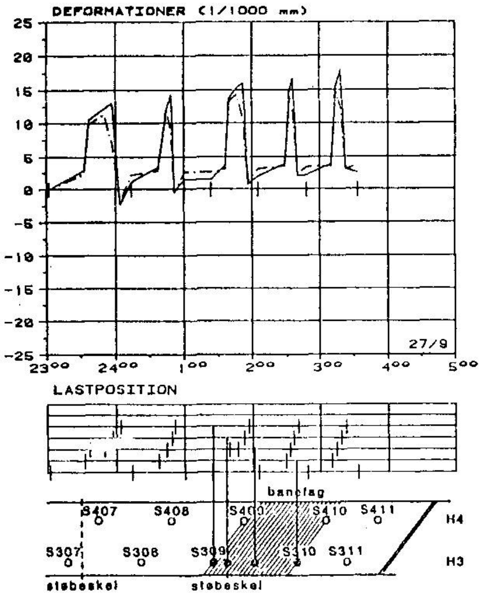


Fig. 6 1984

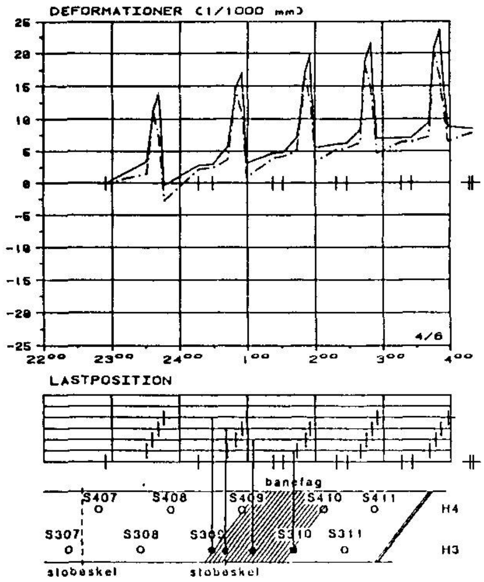


Fig. 7 1988

9. CONCLUSION

There are no signs of failure of any kind, neither in the substructure nor in the superstructure. It may thus be taken as verified that under the existing conditions, the bridge could meet the specified requirements with regard to load capacity.

However, the loading test provided no definite answer with regard to the safety factor against future collapse, nor of the expected service life of the bridge.

On the other hand, the construction has shown such a small increase in the measured deformation (measured on about 100 spots) that it has been decided to use the bridge for the next 4-6 years. Till that time, load tests will be carried out, but it is presently being expected that the remaining lifetime will be more than 10 years.

It should be noted that the bridge is carefully inspected four times a year in order to observe any increase in deterioration.

It has been possible to perform the load test during periods of slack traffic with a minimum of obstruction to the traffic.