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Tests on a Bridge Model

Versuche an einem Brückenmodell

Essais sur un modèle de pont

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A new tramway viaduct will be built in the neighbourhood of Stockholm. This viaduct has been designed by the Street Department of the City Stockholm. For traffic reasons, it was proposed that the viaduct should be given a shape shown in Fig. 1. The viaduct had to pass the street at a very acute angle. The flat slab system was chosen for the structure. In order to facilitate the design with regard to the skewness of the viaduct it was proposed to divide the viaduct into two separate parts, that is one viaduct for each direction of the tram traffic.

The deck which forms a circular curve with a radius of 200 m (the total length of the viaduct is 70 m) is supported by roller bearings at its ends and by three intermediate circular columns. As a strict static calculation of such a structure is nevertheless very laborious on account of the curvature, it has been calculated as a straight frame (but the centrifugal forces due to the tramways were of course taken into account). However, partly on account of this approximation, and partly because there are no bridges of this type in Sweden, it was considered desirable to make model tests in order to obtain a more reliable basis for the design. Tests have therefore been made on a model of the viaduct at the Division of Structural Engineering and Bridge Building, the Royal Institute of Technology, Stockholm. The main purpose of these tests was to investigate the accuracy of the method of design. The following description of the tests contains nothing particularly new, but is to be regarded as a contribution to model test practice.

The model was an almost exact copy of the viaduct on the scale of 1 : 62,5 (= 0,016), which was determined by the dimensions of the available materials.

The blocks, which are seen beneath the columns in Fig. 1, have nothing to do with the real viaduct. They are used only for clamping the columns at the lower ends.

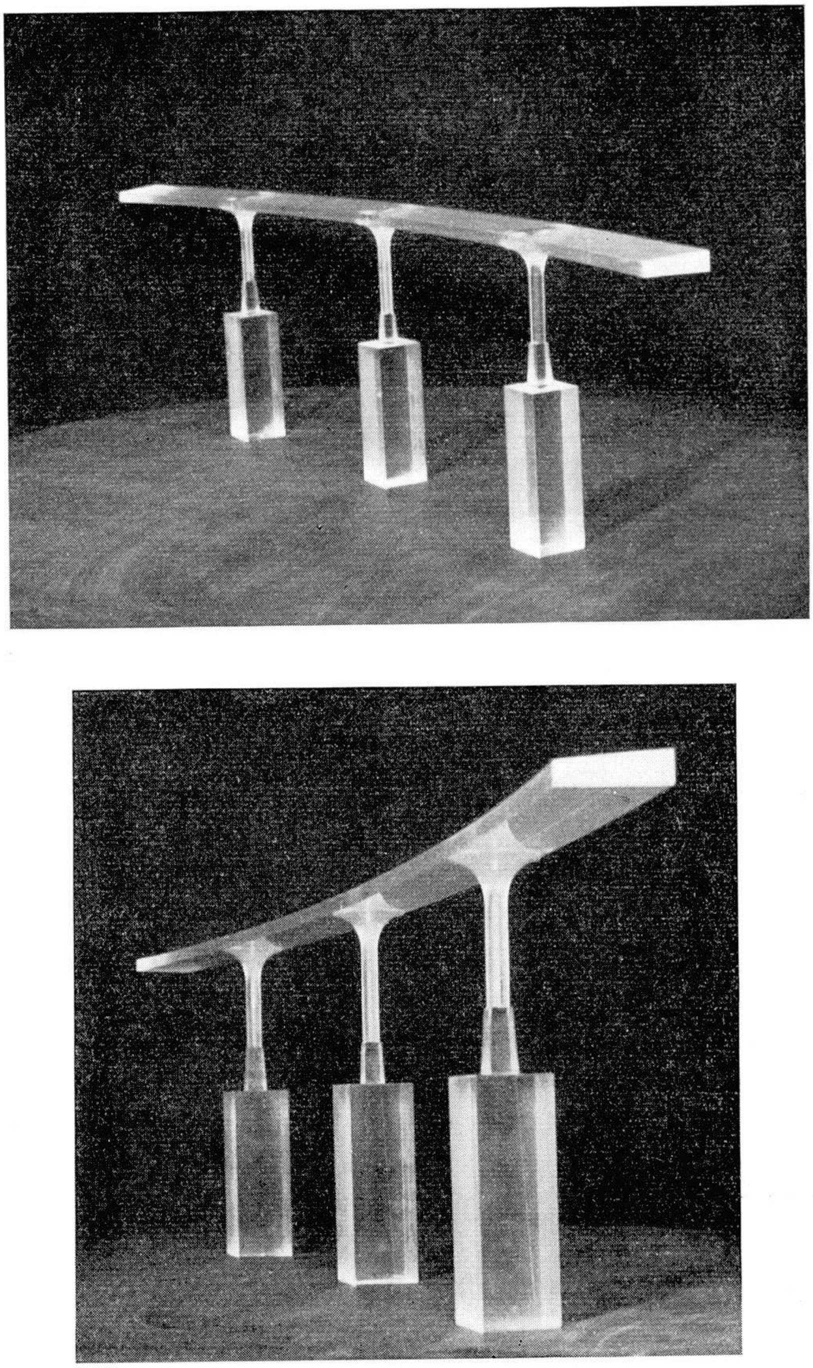

Fig. 1. Model

The model was made of Perspex (or Plexiglass), a material which has many advantages for this purpose. Its modulus of elasticity is low with the result that no great loads are needed to make the strains measurable. Therefore, the fastening and loading devices will be simple. The strain-stress curve is a nearly straight line up to relatively high stresses, but there is a disadvantage that the magnitude of the strains are sligthly variable with time. A further advantage is that the material can easily be machined (e.g. by turning, cutting, boring etc.).

The deck slab was cut out of one piece of the material, and the three columns together with their blocks, were cut from another piece, and were joined by gluing.

As the materials used for the deck and the columns were supplied by different manufacturers, the moduli of elasticity and shear were determined for both materials. Two test bars were cut from each material. The dimensions of each test bar were 300 mm $\times$ 20 mm $\times$ 16 mm.

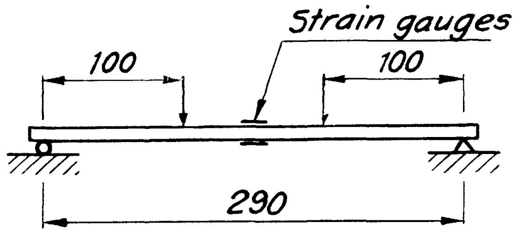

Fig. 2. Bending Tests for Determining Modulus of Elasticity

The modulus of elasticity was determined by bending tests, see Fig. 2. The stresses in the middle section were calculated directly from the load, and the strains were measured with strain-gauges. Two series of loading tests were made on each bar. In the first series, the load was successively increased at intervals of two minutes to the maximum load, which was kept constant for twelve minutes. Then the load was successively removed at intervals of two minutes. In the second series the bar was submitted to the maximum load at once. This load was kept constant for twelve minutes, and then the load was directly reduced to zero. The strains were measured immediately before and after each stage of loading. The results of one of these tests are shown in Fig. 4. It is seen from the diagram that the strains were slightly influenced by time. However, this influence was greatest immediately after the application of load and diminished rather rapidly, so that when the load had been acting for twelve minutes, there was practically no further influence of time. About half of the increase in the strains during the twelve minutes occurred during the first two minutes. Furthermore, the diagram shows that the relation between stress and strain is nearly linear if the rate of loading is constant. (The importance of a constant rate of loading was indicated by Prof. Lardy, Zürich.) For reasons which will be mentioned later, the modulus of elasticity was determined as the ratio of the maximum stress to the maximum strain, i.e. the values obtained immediately before removal of load. When the modulus of elasticity was defined in this way, it was almost equal in both the series of loading tests.

The modulus of shear was determined by torsion tests, see Fig. 3. The torsional moment was obtained directly from the load, and the changes of angle in the two sections under measurement were determined with dial gauges. The application and the removal of load were carried out in the same

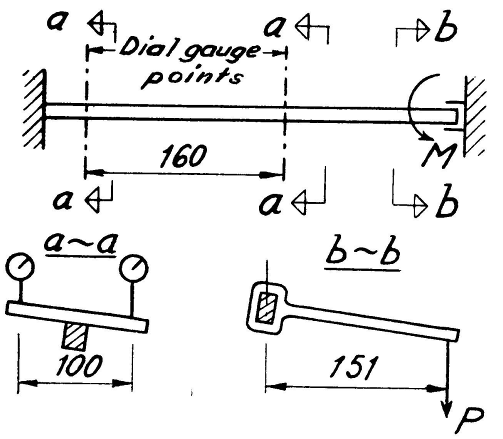

Fig. 3. Torsion Tests for Determining Modulus of Shear

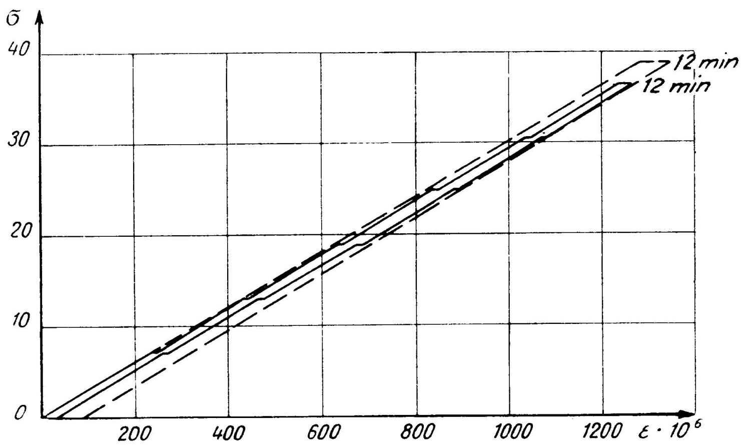

Fig. 4. Strain Stress Curve for Perspex Used in Columns

way as in determining the modulus of elasticity. As a result, we obtained relations between the torsional moment and the change in angle. When plotted in diagrams, these relations were of the type shown in Fig. 4. From these relations the modulus of shear was easily calculated. In these calculations, the test values were used in the same way as in determining the modulus of elasticity.

As a result, we obtained the following values of the moduli of elasticity and shear.

For the material of the columns:

Modulus of elasticity: $E = 28\,900$ kg/cm² for test bar 1
$E = 29\,200$ kg/cm² for test bar 2

average $E = 29\,000$ kg/cm²

Modulus of shear: $G = 11\,700$ kg/cm² for test bar 2

or $G = 0{,}401\ E$

For the material of the deck:

Modulus of elasticity: $E = 25\,700$ kg/cm² for test bar 3
$E = 26\,200$ kg/cm² for test bar 4

average $E = 26\,000$ kg/cm²

Modulus of shear: $G = 10\,300$ kg/cm² for test bar 4

or $G = 0{,}394\ E$

In the main tests the model of the viaduct was fastened in a solid support, and the ends of the deck were fixed so that the real conditions at the roller bearings were imitated as far as possible.

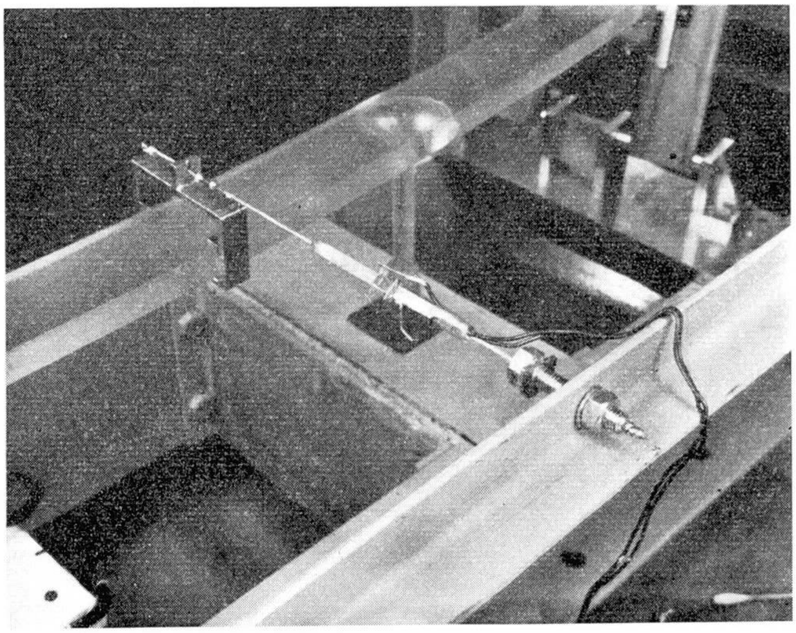

Fig. 5. Loading Devices for Lateral Loads

The tests were made under vertical and lateral loads. The loading devices were in both cases the same, and are shown in Fig. 5 for lateral loads. The principle of loading was as follows. A point of the deck was given a deflection by stretching a thin wire fastened at one end to the deck. The corresponding force in the wire was measured with strain-gauges, which were fastened on a thin steel plate attached at both ends to the wire. Before the test, calibration was made at known loads.

By giving the model a definite deflection, we gained the advantage that there were no appreciable changes in deflections due to the time influence during the tests. On the other hand, the force acting at the model was not constant, and decreased a little with time. However, as the force was measured at a single point, it was easier to keep it under control by repeated measurements during the test.

The measurements of stresses or rather strains at various points of the model were made by means of electric strain-gauges. They were made by AB Hugo Tillquist, Stockholm. Their gauge length was only 6 mm. On small models, it is necessary to use strain gauges with small gauge lengths, as otherwise the results will be doubtful.

The results of the previous measurements on the test bars were taken into account in carrying out the main tests. Therefore, the strains were measured a few minutes after the application of load was made. In this way we largely eliminated the influence of time, which occurs during the first minutes of loading as has been mentioned before. Furthermore, the force was measured three times during each test, viz., at the beginning, in the middle, and at the end of the strain measurements. The difference between the test values were generally small. In view of the fact that the strain measurements were made

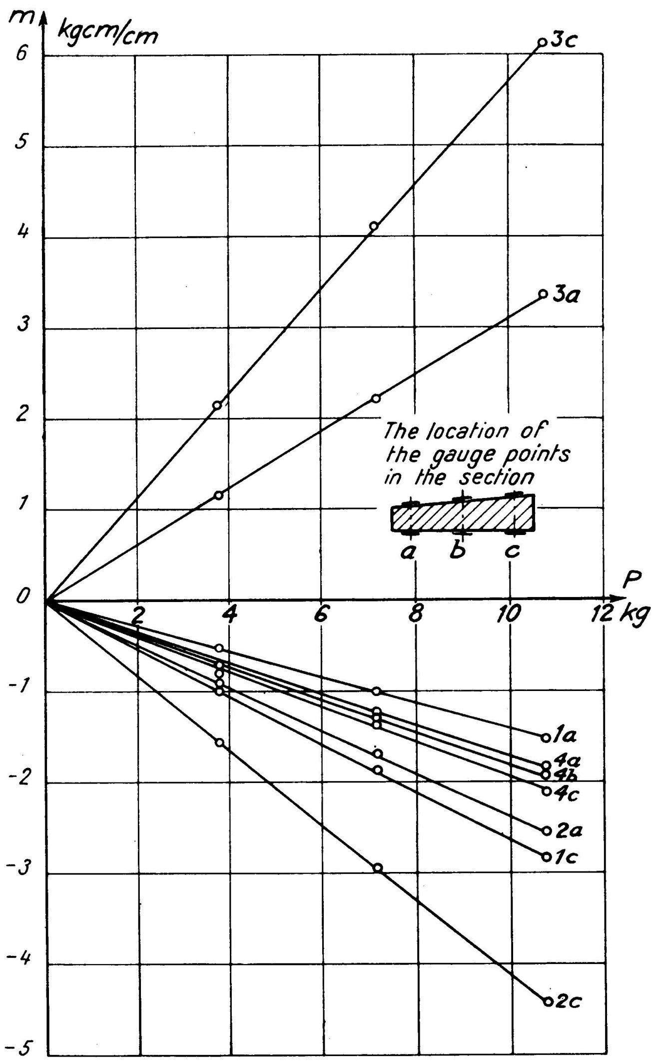

Fig. 6. Moments in Various Points of Deck as Functions of Load

after the time influence had mostly been eliminated, the moduli of elasticity and shear were defined as before.

All results of the tests cannot be described here, but we shall give an example. We choose a test in which a vertical load acted on one of the middle spans, see inset in Fig. 8. The moments in the columns and the deck at various points and at various loads are calculated from the primary results of measurements. In Fig. 6 the moments at the various points of the deck are shown as functions of the load. From this diagram we see that the plotted test values are very close to straight lines. The deviations are in general of the same magnitude as the accuracy of gauge readings. Hence we can write the moments

$$M = \alpha \frac{Pl}{100}$$

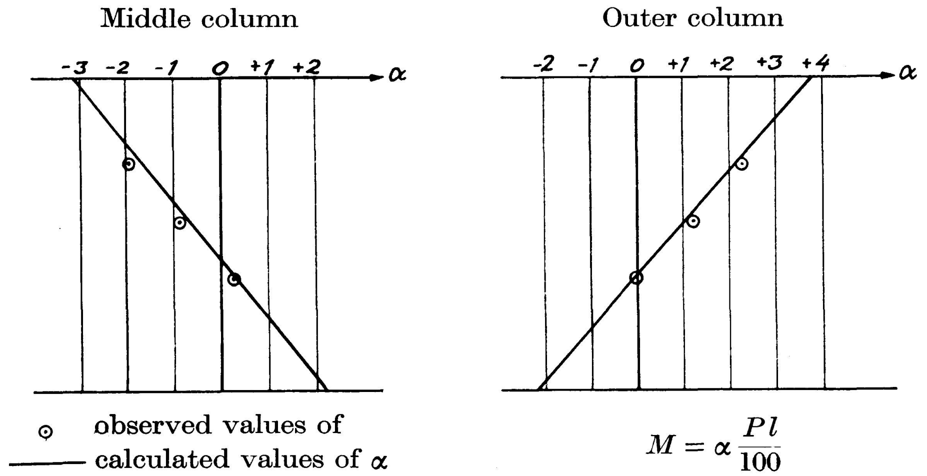

Fig. 7. Moments in Middle Column and an Outer Column Compared with Theoretical Values

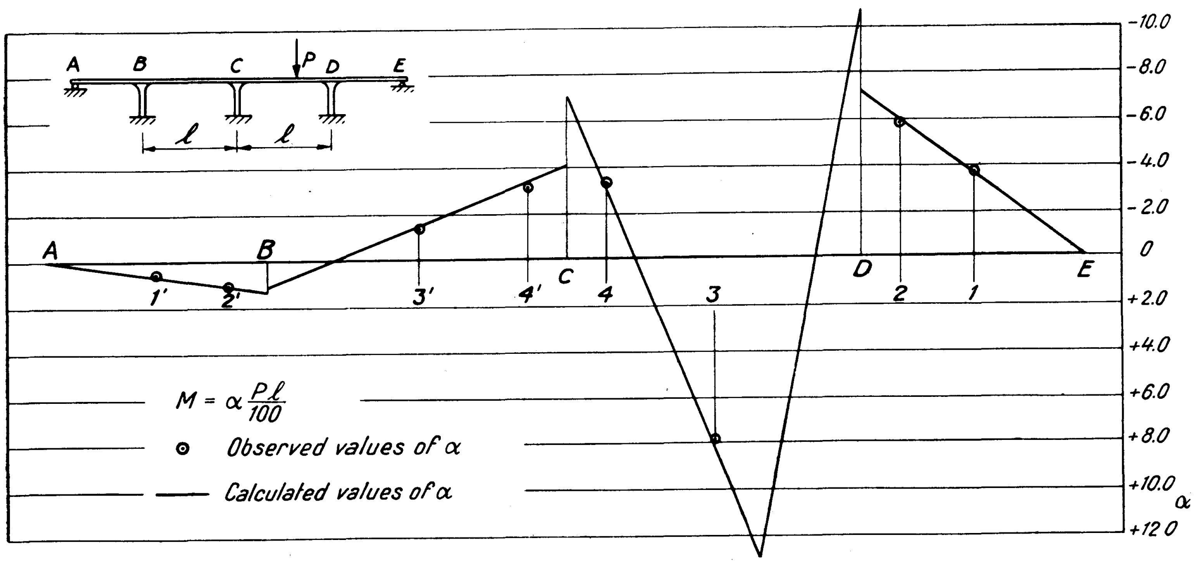

Fig. 8. Moments in Deck Compared with Theoretical Values

where P is the load and l is the length of one of the middle spans. Consequently, α will be a dimensionless constant representing the moment. Figs. 7 and 8 show the observed values of the moments in the middle column, one of the outer columns, and the deck. For comparison, the same diagram shows the moments calculated on the approximate assumption that the viaduct is straight. The agreement between the observed and the calculated values is fairly good, especially for the deck.

The results of these model tests are very encouraging. They show that it is possible to make tests even with rather complicated models on a small scale. When the set-up was ready, the tests were carried out very rapidly and easily, and the agreement between the results was very good.

Summary

Tests on a model of a viaduct have been made at the Division of Structural Engineering and Bridge Building, the Royal Institute of Technology, Stockholm.

The model was made of Perspex. This material has an almost straight strain-stress curve, but the strains are sligthly influenced by time, and this influence must be considered in carrying out the tests. The stresses in the model were measured with strain-gauges.

An example of the results is given, and is compared with calculated theoretical values. The agreement proved to be very good.

Zusammenfassung

Der Bericht behandelt die Versuche am Modell eines Viadukts, die in der Abteilung für Brückenbau der Kgl. Technischen Hochschule Stockholm ausgeführt wurden. Das Modell war aus Perspex hergestellt. Dieser Werkstoff ist durch ein annähernd lineares Verhältnis zwischen Dehnung und Beanspruchung gekennzeichnet. Die Dehnung wird aber etwas von der Zeit beeinflußt, und dieser Einfluß muß bei der Ausführung der Versuche berücksichtigt werden. Die Spannungen im Modell wurden durch Dehnungsmesser bestimmt. Ein Beispiel der Versuchsergebnisse wird angeführt und mit berechneten theoretischen Werten verglichen. Dabei wurde eine gute Übereinstimmung festgestellt.

Résumé

Des essais sur un modèle d'un viaduc ont été effectués dans la Section des Ponts et Charpentes à l'Ecole Royale Polytechnique Supérieure à Stockholm. Le modèle était construit en Perspex. Cette matière est caractérisée par un rapport presque linéaire entre l'allongement et l'effort, mais les allongements sont légèrement influencés par le temps, et il faut tenir compte de cette influence dans l'exécution des essais. Les efforts dans le modèle ont été mesurés par des indicateurs d'allongement. Les résultats des essais sont illustrés par un exemple qui est comparé avec des valeurs théoriques calculées. La concordance était tout à fait satisfaisante.