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LOAD TESTS ON THE FOUR-SPAN STRUCTURE OF THE RAILWAY BRIDGE OVER THE TISZA AT CSONGRÁD-SZENTES

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Abstract

New bridges can be opened to traffic only after a subsequent load test. The minimal aim of these checks is to show that the structure fulfils the design requirements given in the corresponding Code and its real behaviour approximates the expected one. However, these pieces of information do not provide an explanation for all the deviations. Therefore, if the objective and financial conditions are given, it is advisable to carry out additional measurements, which can be analyzed later to describe more accurately the behaviour of the structure, which, in turn, widens the possibilities of assuming a more realistic structural model and which provides aid and reference point for design practice in the future.

Keywords: Static loading, dynamic loading, strains – stresses, natural frequency, dynamic surplus.

Introduction

The first permanent bridge over the River Tisza between Csongrád and Szentes was constructed at the beginning of the century, through which road traffic started in 1903, while railway traffic in 1906. The original structure consisted of nine simply supported trusses of a different layout and span. Its special feature was a structure of a span of 120 m which would be the longest span truss bridge in Hungary even today.

In World War II this longest span was blown up, which then was divided into parts by an intermediate pier in the course of reconstruction, and — in turn — it was replaced by two independent structures. The mixed traffic through the bridge ceased in 1981 when a new highway bridge was opened to traffic. The construction of the new railway bridge was realized between 1983–86, when the complex of a four-span continuous plate girder and a three-span truss of parallel chords were built. *Fig. 1* shows the layout prior to the re-building of the whole structure and that of the present time.

This paper deals with the most important conditions and results of the load tests carried out on the four-span plate girder over the flood plain.

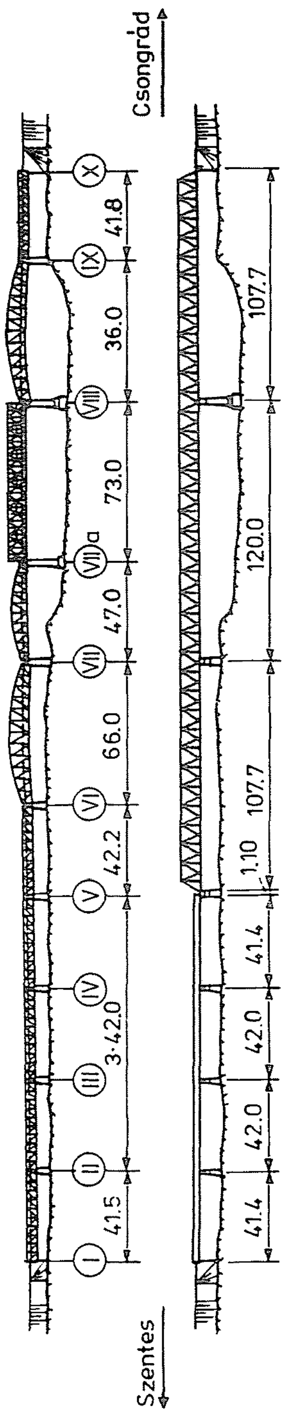

Fig. 1. Layout of the prevoius and the new structure

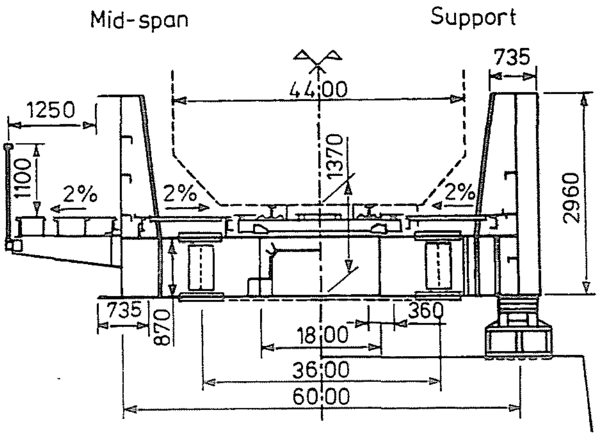

Fig. 2. Cross section of the four-span structure

The length of the whole steel structure is 167.9 m, the length of the outside spans is 41.4 m, while that of the middle ones is 42.0 m. The cross section of the bridge is shown in *Fig. 2.* The distance of the main girders from each other is 6000 mm, their height is about 3000 mm. The width of flanges is uniformly 735 mm, their thickness is varying between 25 and 50 mm. The 1200 mm long butts of the cross girder constitute one manufacturing unit with the sections of the main girder. Manufacturing units were connected on site to each other by HSF bolts.

The assemblage of the structure took place just behind the abutment. In the course of the longitudinal push-in process U 300 profiles were fastened to the bottom chords of the main girder and no auxiliary supports were used. In this way, the structure — in certain phases of the process — was overhanging the actual outside support in a length corresponding to the span. The greatest deflection was about 45 cm, consequently the free edges of the cantilever had to be lifted in a relevant measure prior to putting them on support.

The Aim and Program of Experiments

The fundamental aim of the experimental investigation was the detection of the static and dynamic behaviour of the structure. In the course of it, a narrower group of examinations was aimed to check the conditions given in the actual Railway Bridge Code, while a wider part served as a basis for drawing more general conclusions.

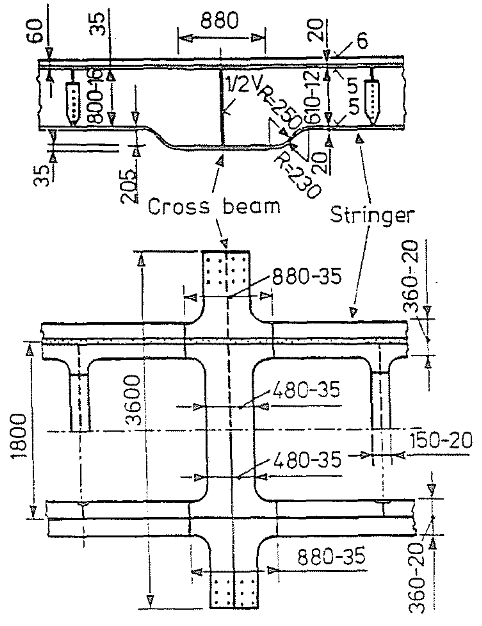

Fig. 3. Details of the floor girders

The floor system of the bridge is of a traditional layout, the acting loads are transferred by cross-ties, by welded stringers and cross girders to the main girders. The connection between the stringers and cross girders is moment-resistant (*Fig. 3*), while between the cross and main girders it can be considered as partly moment-resistant in a different manner corresponding to the vertical and horizontal planes. As stringers are parallel with the mains and through the cross girders they are connected elastically to each other, their internal forces develop as a result of their mutual effect. Accordingly, mutual effect of different measure and character can be assumed between the individual elements of the floor structure, the floor girders and the mains, respectively. In the course of devising the experimental program, this problem was reckoned with as an aspect influencing the arrangement of measuring transducers.

In the course of both the static and dynamic examinations, measurement of stresses (strains) and displacements was basically necessary. Those kinds of transducers were used, which could serve the purpose of both kinds of measurements without any essential modification. In this way, strains were determined by electrical strain gauges, while displacements were measured by inductive transducers.

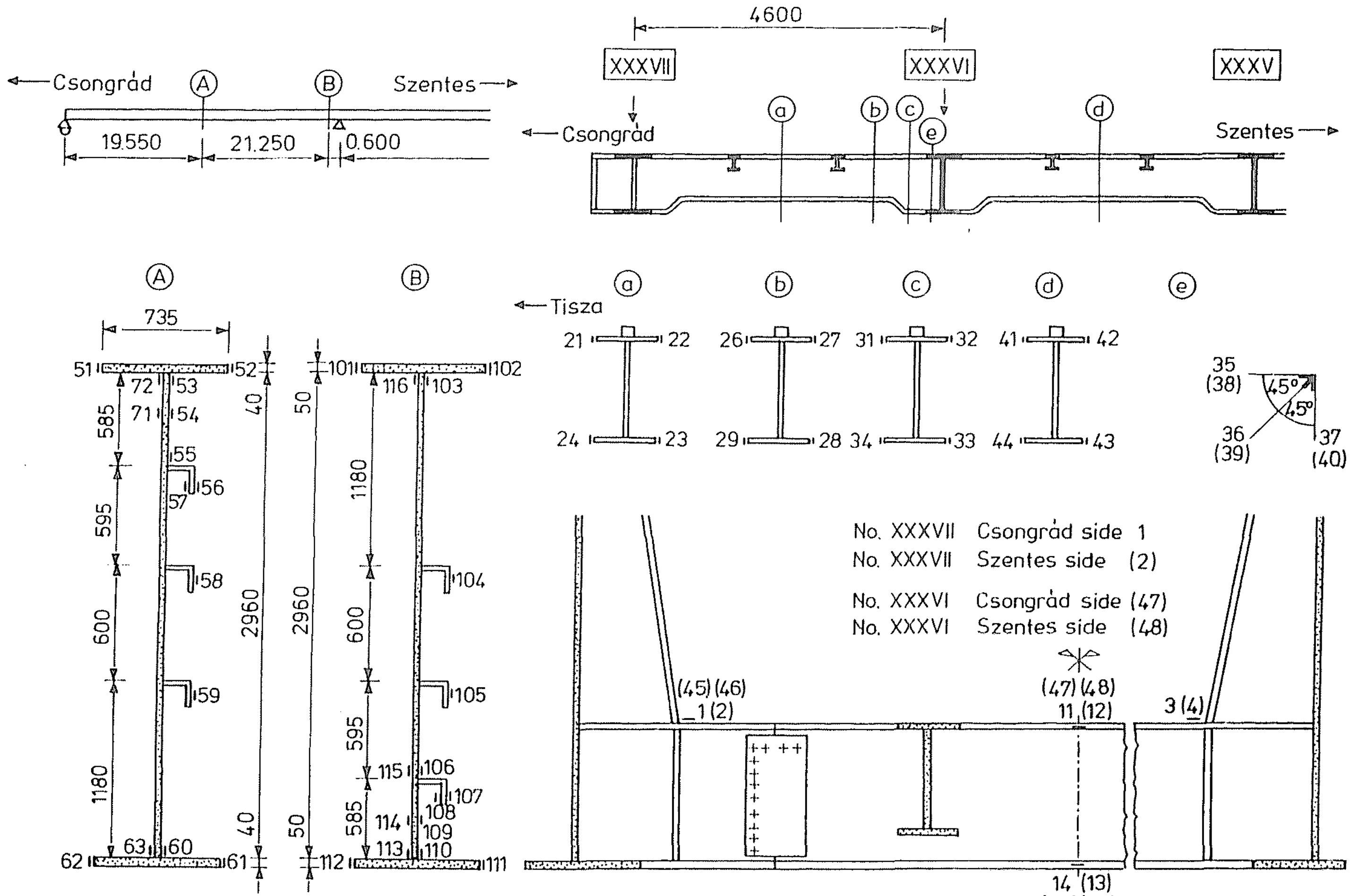

Fig. 4. Location of strain gauges

The vertical displacements were measured in each mid-span of both main girders, while strain measurements took place in a great number of cross sections on the main, cross girders and stringers in one of the outside spans in the arrangement shown in *Fig. 4*.

In certain special states, additional examinations also were carried out, e. g. with the aim of checking the height alignment of the structure, the distance between the upper chords of the main girder, as well as the deformations at the supports.

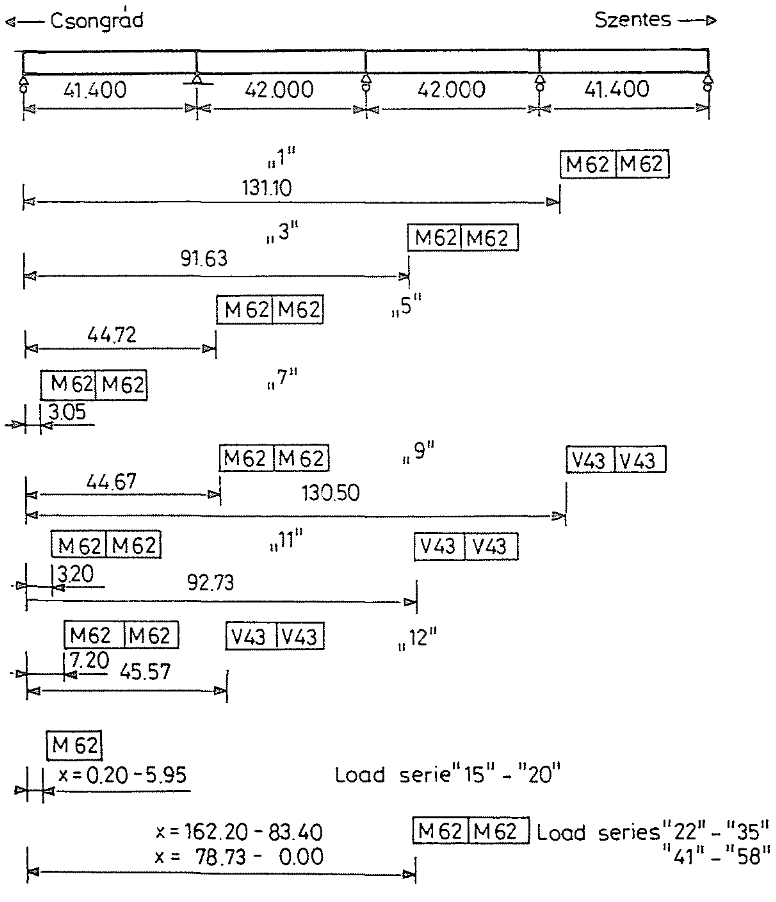

Fig. 5. Static load positions

For loading, a pair of M62 diesel- (mass: 120 t) and V43 electric (mass: 80 t) locomotives were used. The static part of the load test contained four groups of measurements. The first series (load positions 1, 3, 5 and 7) consisted in the so-called 'first' loads (approximating the most unfavourable ones) for the mid-spans, the second series (load positions 9, 11 and 12) consisted in the most unfavourable load for the mid-spans and the measured cross section near to support, the third series (load positions 15–20) consisted in the expectably most favourable load for the examined elements of the floor structure. During the fourth series (load positions 22–39 and 41–58), the so-called 'train influence lines' were measured, in the course of which the loading vehicle of two M62 locomotives passed along the bridge, stopping above each cross girder with its leading axle on, while the measurements on all of the strain gauges and inductive transducers took place. The scheme of the static measurements is presented in *Fig. 5*.

During the static measurements there is a sufficiently long time to switch the individual signals on to the input of the measuring system after one another. Therefore, the transducers were connected to switching units of 50 channels, which transferred the signal to the corresponding (change in resistance or in inductivity) amplifiers and after an adequate amplification to a digital voltmeter. The Hottinger–Baldwin-type measuring system was controlled by a Commodore 64 computer from the initiation of switching the transducers as far as the recording of the results on a magnetic disk.

During the dynamic tests, in addition to the measurement of characteristic strains and vertical displacements, longitudinal and out-of-plane displacements, as well as the natural frequencies were also determined. In the course of these series two M62 locomotives were running along the bridge at a different speed between 5 and 60 km/h.

The amplifiers of the measurement system enabling the continuous measurement and recording were of Hottinger–Baldwin-type, this time, too, while the signals were stored by a measuring tape-recorder of Tesla-type for a subsequent computer-aided analysis.

The result of Static Measurements

Prior to static loading, measurements were carried out with respect to the precision of erection. The vertical alignment of the main girders and the floor structure was in harmony with the designed one.

In the distance between the upper chords of the main girder a deviation of 18 mm as maximum was found prior to first loading, and the measured differences were characteristically greater along one half of the bridge length. The checking after static loading — as shown in *Fig. 6* — revealed the interesting result that in spite of the fact that the changes of the previously measured distances were of mm order, which were not

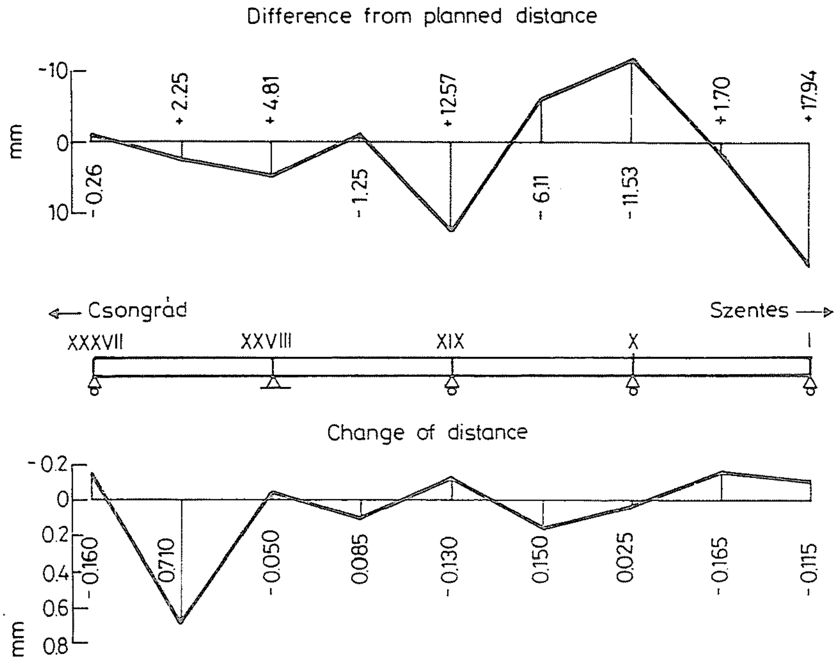

Fig. 6. Differences and changes in the distance of upper flanges

of a considerable extent, they were characteristically greater just on the opposite half of the bridge.

The results of displacement measurement provide an overall view about the behaviour of the structure as a whole, and the influence of local effects can be separated from them in a reduced measure. The calculations, which were carried out before the tests, involved approximate cross sectional characteristics and, in addition, only the rigidity of the main girder was taken into account. Its natural consequence is that the measured vertical displacements deviated from the calculated ones more or less; they were characteristically smaller, as it is illustrated in *Fig. 7* by the results of the fourth series of loading. After a more thorough comparison, it also can be seen clearly that the ratios of the calculated and measured displacements deviate to a different extent with respect both to deflection and uprise and along the length of the girder. The calculated deflections are greater generally by 20%, while the uprises by 50% as compared to the measured ones. These differences can be reduced to a relatively small extent, if the rigidity is determined with the assumption of full mutual effect of the main girders and stringers.

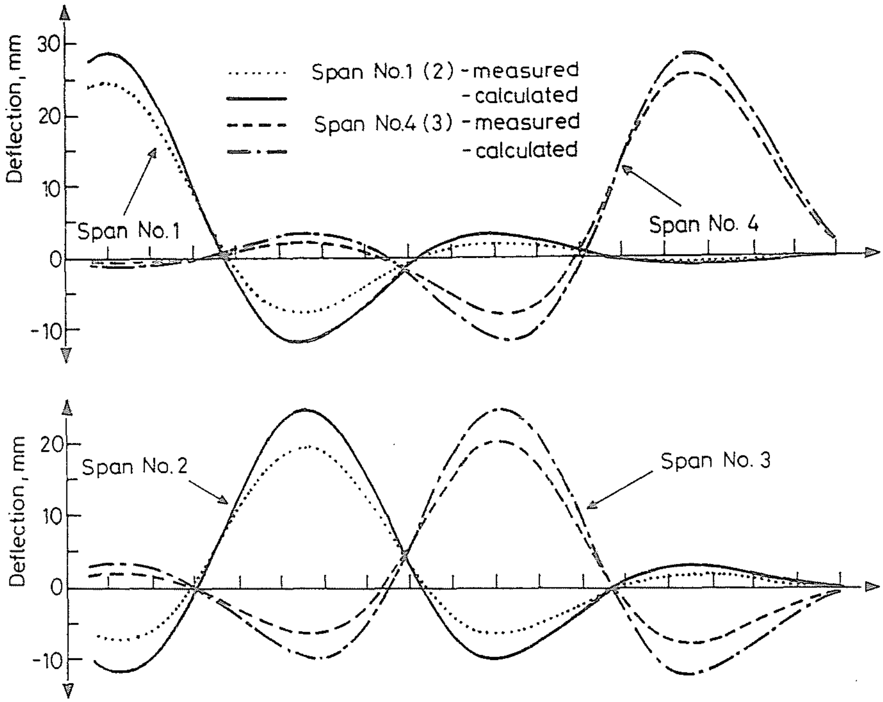

Fig. 7. Comparison of vertical deflections

The stress distribution measured in two cross sections of the main girder (*Fig. 8*) show that in addition to vertical bending it is influenced also by considerable torsion. It can also be clearly seen that the web-stiffening angles fully contribute in load carrying.

The change in the stresses measured on the four edges of the midspan cross section shows (*Fig. 9a*) that in addition to vertical bending, other non-negligible internal forces are mainly caused by the effect of direct loading. With the assumptions that (i) the state of stresses is elastic and resultant of the interaction of normal force, vertical and horizontal bending and torsion, and (ii) the cross section is double-symmetric, the normal stress components can be separated and on this basis the internal forces can be calculated.

The above said are confirmed clearly by *Fig. 9b*, presenting the separated stress components. Using the calculated normal stress and area of cross section, a normal force of such a high value could be calculated which could not be explained as a consequence of the blocked displacements of support. An obvious explanation which is also in harmony with

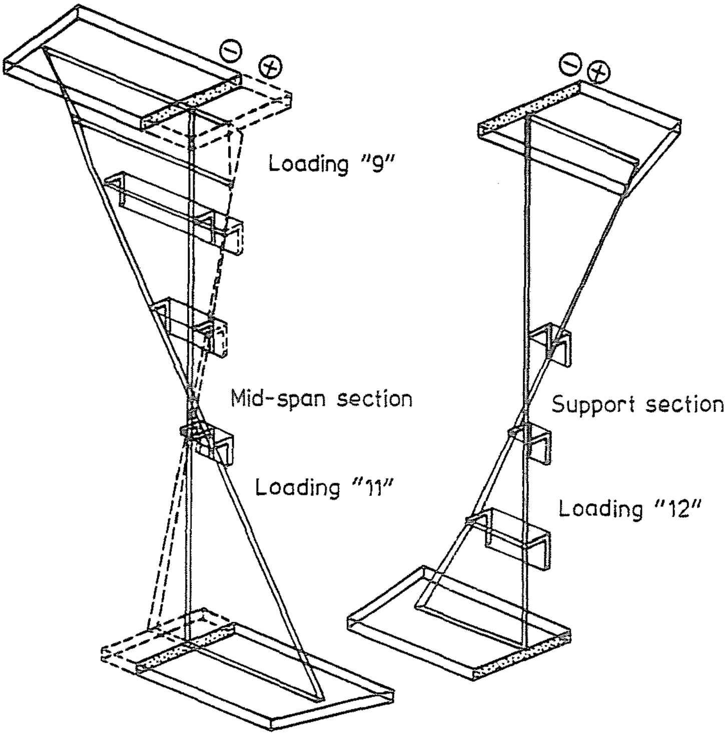

Fig. 8. Characteristic stress distributions

other results is that the centroid in reality is closer to the bottom of the cross section because of the cooperation of the stringers in load carrying. In *Fig. 9c*, the vertical bending stresses of the bottom fibre, as separated from measurement results and as calculated with supposing mutual effect of different measure are compared to each other. This Figure shows that the measure of mutual effect is not constant for different load positions. In case of direct loading the measured stress can be approximated with the supposition of partial mutual effect, while if the loading is acting far from the measured section, the measured stress will be even lower than that calculated by reckoning with full mutual effect.

The non-uniformity of stresses in the two measured spans of the stringer is increased by the effect of direct loading (*Fig. 10*). In this case, too, it can be seen from the separated stresses, that the stringers take their share in load carrying of the main girders and their other internal stresses are the consequence of direct loading.

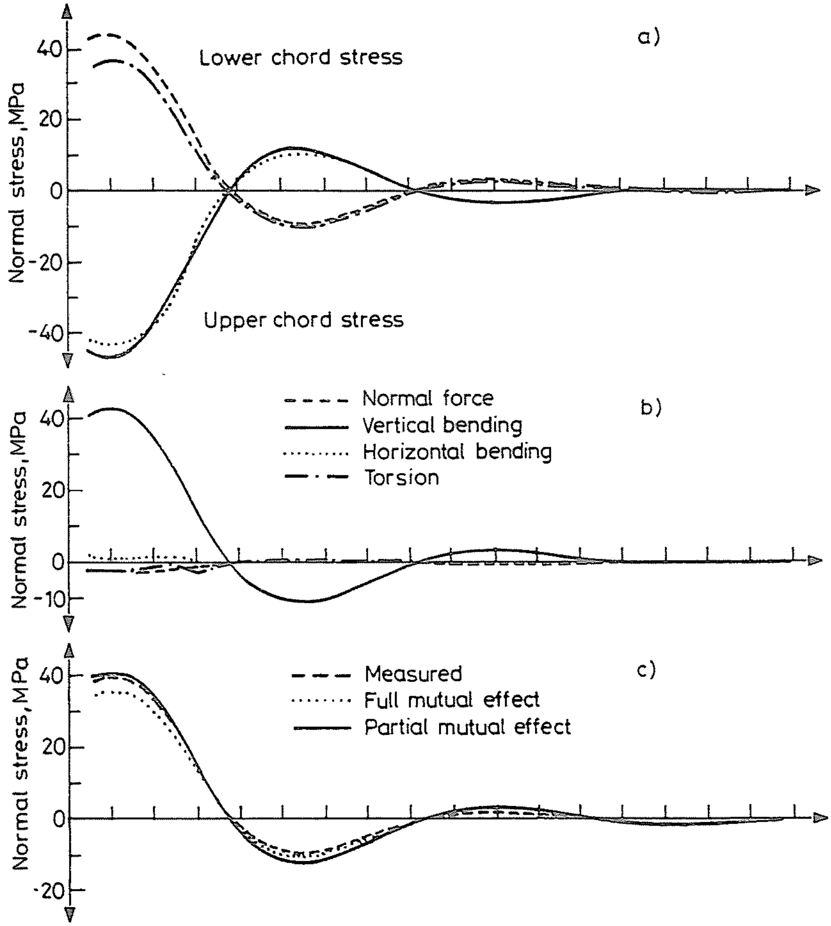

Fig. 9. Analysis of normal stresses of main girder

The mutual effect of the main girders and the floor structure is perhaps best illustrated in *Fig. 11*, representing the horizontal bending stress measured in the middle section of the cross girder above the side support. If it is compared to the vertical bending stress of the main girder illustrated in *Fig. 9*, a full conformity can be seen between them.

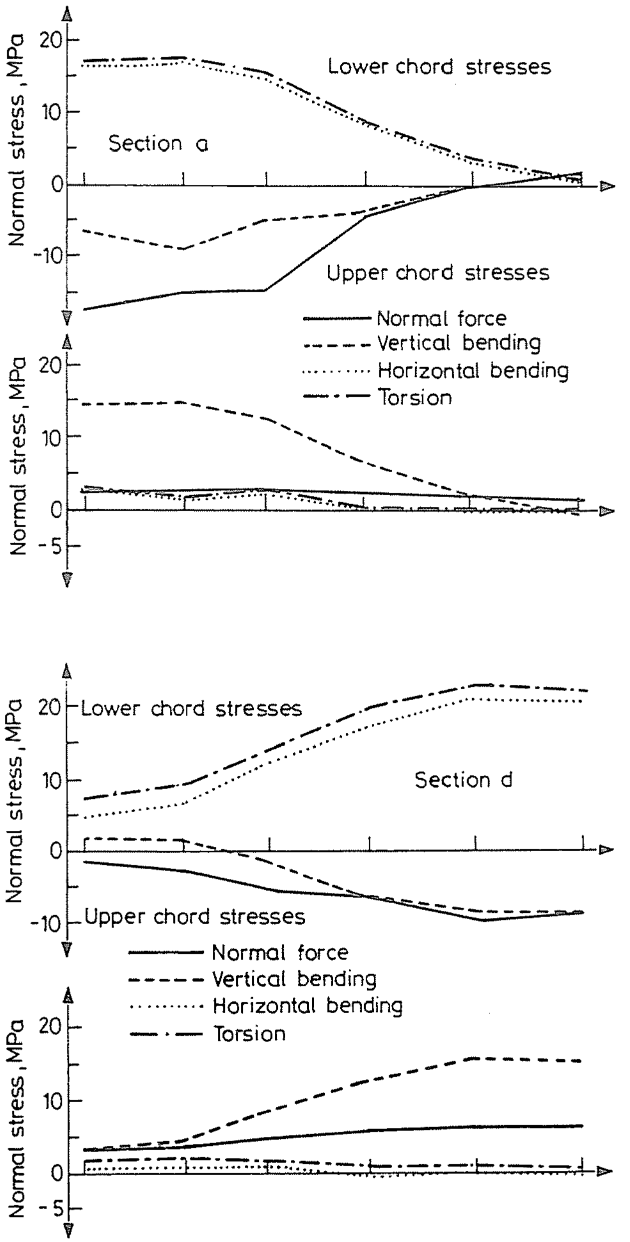

Fig. 10. Analysis of normal stresses of stringers

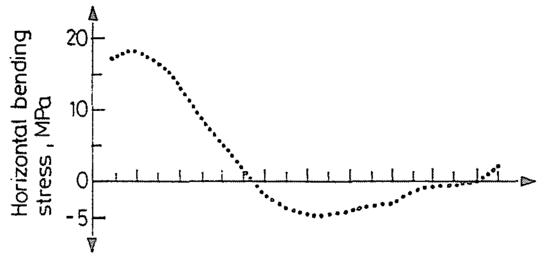

Fig. 11. Horizontal bending stress in cross girder

Dynamic Behaviour of the Bridge

One of the characteristics influencing fundamentally the dynamic behaviour of civil engineering structures, among them the bridges, is their natural frequency. This parameter can generally be determined in practice from the analysis of oscillations caused by some loading effect. However, there is another possibility of determining the natural frequencies on the basis of accelerations of the oscillations caused by very small excitations (ground motion, wind effect, motion of pedestrians, etc.) acting on a structure even in a so-called unloaded state. These excitations can be considered as stochastic signals not involving regular harmonic components, therefore the power spectrum of excitation can be assumed more or less permanent, or constantly decreasing, respectively. The transfer function describing the connection between the excitations and the response signal (e. g. acceleration) is significant in the vicinity of natural frequencies, and it emphasizes the natural frequencies in the power spectrum.

In *Fig. 12*, a fraction of the quasi-stochastic acceleration–time function can be seen, which was measured for determining the vertical natural frequencies. In each mid-span of the bridge, a similar time function of about 300 sec long was recorded, and as a result of computer processing, the power spectra shown in *Fig. 13* were obtained by using FFT (Fast Fourier Transformation) procedure. The read-off values of natural frequencies are: 2.0 Hz, 3.25 Hz, 3.7 Hz and 4.2 Hz. The peak at 5.3 Hz is the natural frequency of the transducer itself.

The difficulty to determine the horizontal natural frequencies in a similar way is caused by the fact that the decrement of horizontal vibrations on an unloaded structure is much faster, a sufficiently long registration for FFT cannot be produced in this way. To replace it, the magnitude of horizontal (out-of-plane) displacements of the bridge was measured during

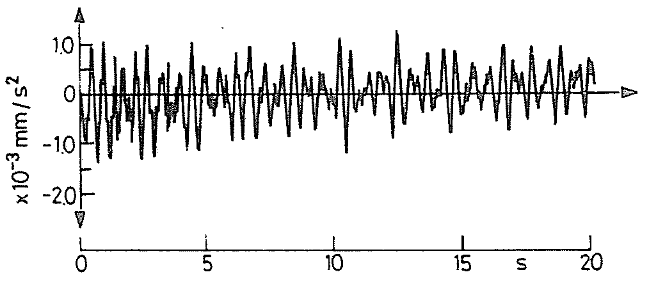

Fig. 12. Fraction of the acceleration – time function

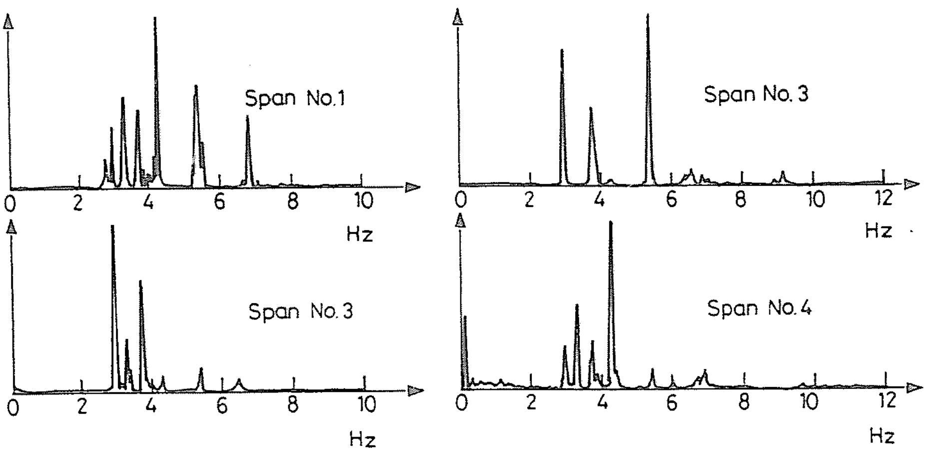

Fig. 13. Power spectra resulted by FFT analysis

dynamic tests. In *Fig. 14*, the horizontal displacements recorded in the first and second spans are presented at speeds of 15 km/h and 60 km/h. The magnitude of displacements, the maximum being 1 mm, remained under the limit value of span length/5000 given in the Railway Bridge Code.

Because of the smooth character of the registration of the vertical displacements in *Fig. 15*, recorded at a speed of 60 km/h, a relatively small dynamic surplus can be estimated. Comparing it to another one, recorded at a speed of 5 km/h, the dynamic surplus of deflections is under 5%.

The dynamic surplus can be determined on the basis of stresses measured on different structural elements, as well. As for the selected strain

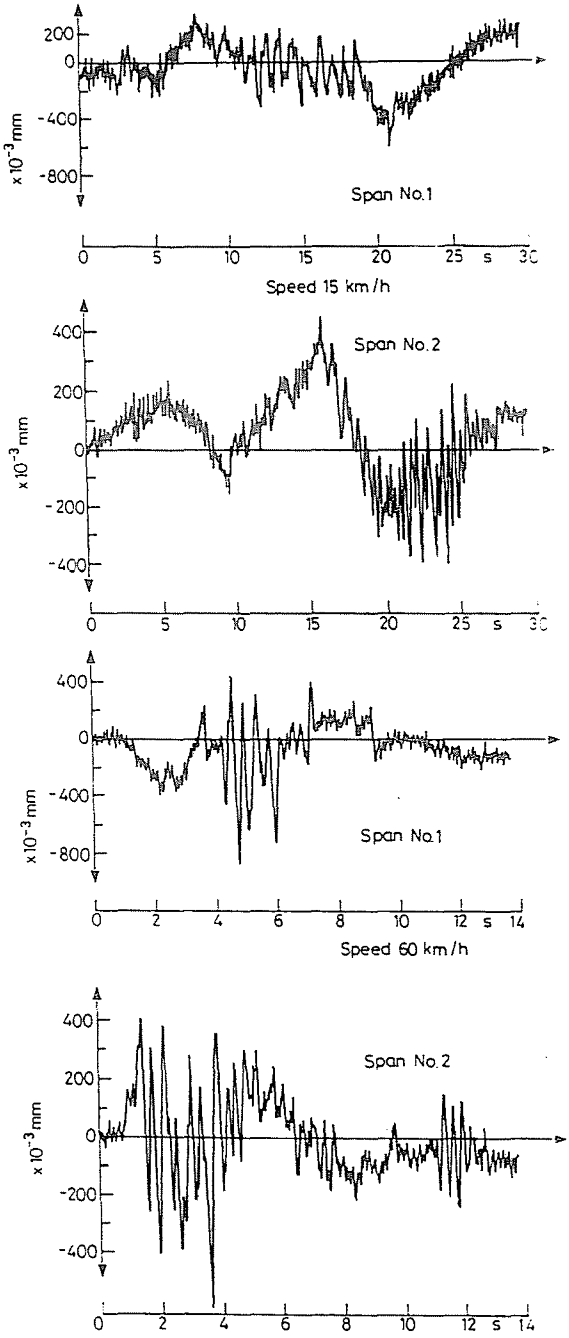

Fig. 14. Out-of-plane displacements at speeds of 15 and 60 km/h

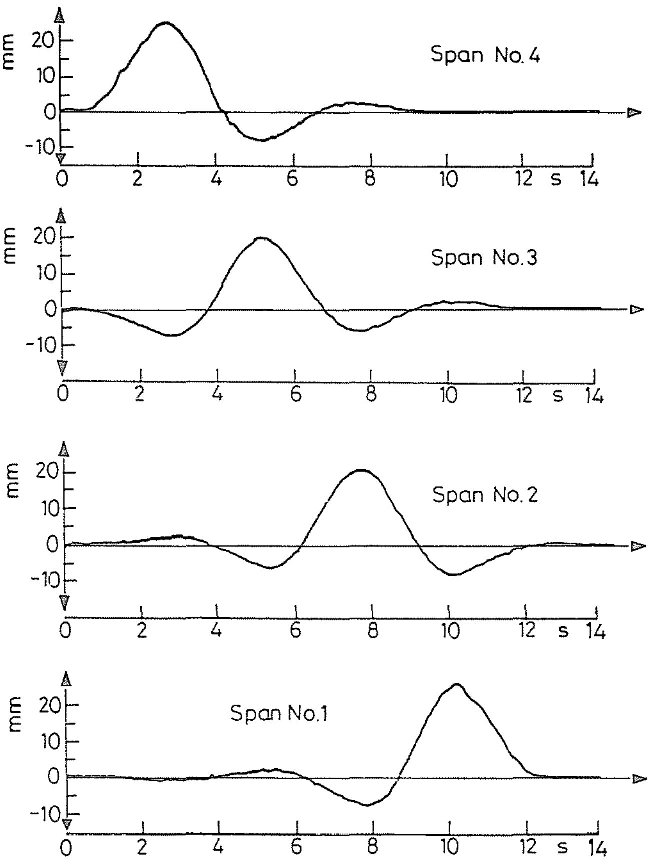

Fig. 15. Vertical displacements at speed of 60 km/h

gauges on the main girder, from the registration of gauge No 52 in *Fig. 16,* the maximum value of 8.3% could be determined.

The dynamic effect is generally greater on directly-loaded structural elements. The characteristic registrations of the floor structure are shown in *Fig. 17.* Strain gauge No 11 was positioned on the cross girder, here the measurable dynamic surplus was 7.2%, while on strain gauge No 44 located on the stringer showing the surplus as high as 15.7%.

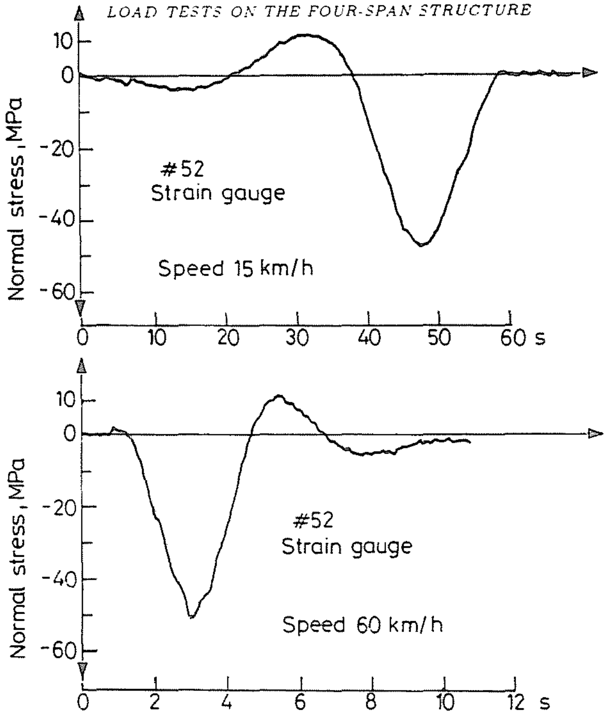

Fig. 16. Normal stresses measured at different speeds on main girder

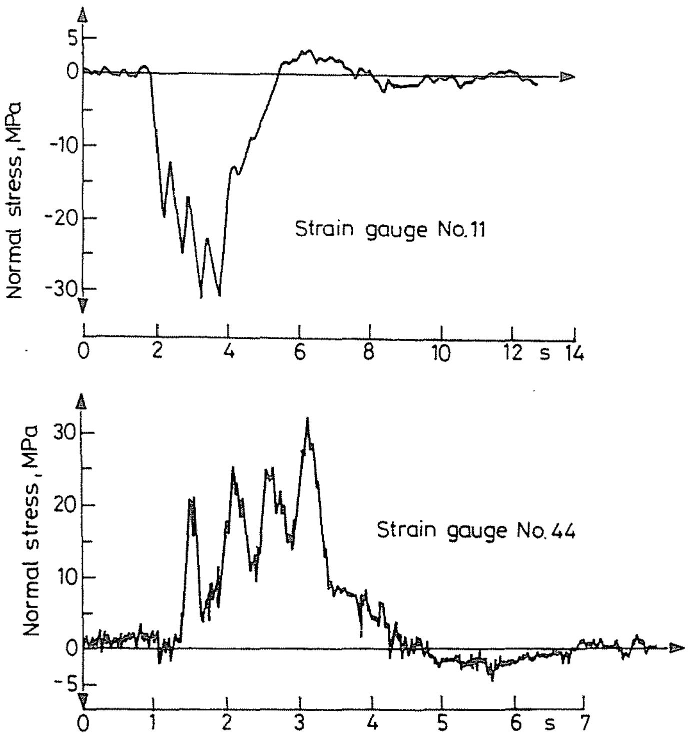

Fig. 17. Normal stresses measured on floor girders

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