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Artikel: Stressing and factor of safety of reinforced concrete trussed girders

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Stressing and Factor of Safety of Reinforced Concrete Trussed Girders.

Beanspruchung und Sicherheitsgrad der Eisenbeton-Fachwerke.

Sollicitations et degré de sécurité des poutres réticulées en béton armé.

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It was found in the author's own experiments on reinforced concrete trusses that structures of this type offer exceptional resistance to impact and dynamic stresses.

The tests were carried out in the laboratory for testing materials at the Swiss Federal Institute of Technology at Zürich,[1] the specimens being two reinforced concrete trusses such as are used in bridge work (Fig. 1). The span of these girders was 6 m, their height 1.50 m and they were subject to an isolated load of 50 tons at the centre.

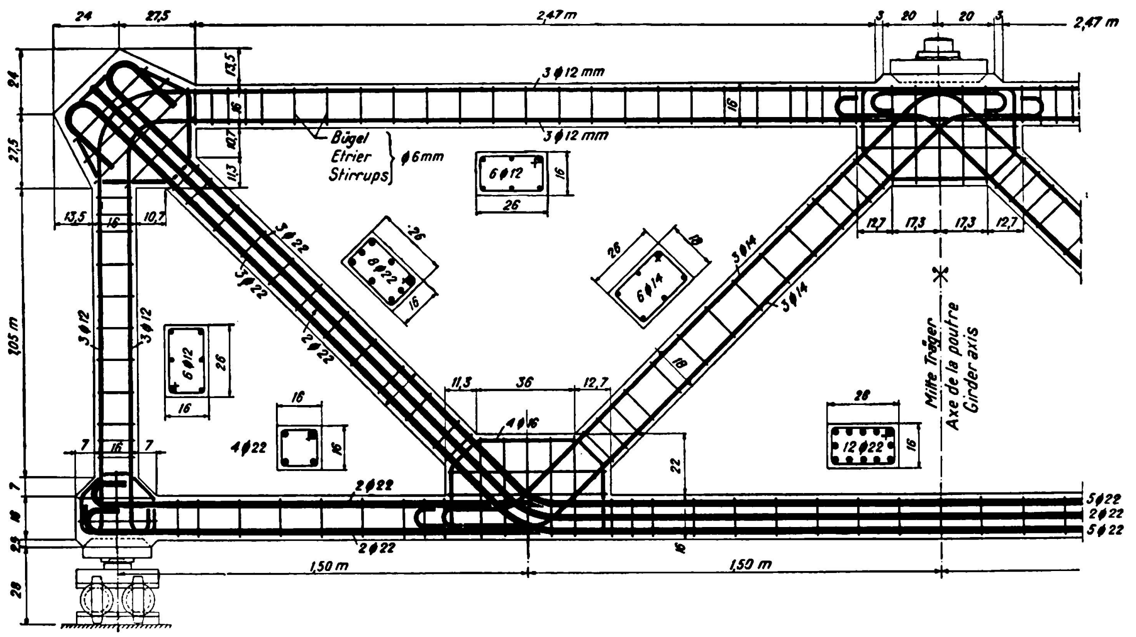

Fig. 1.
Details of the Test-Girder.

[1] *Mortada:* Beitrag zur Untersuchung der Fachwerke aus geschweißtem Stahl und Eisenbeton unter statischen und Dauerbeanspruchungen. Dissertation, Zürich, 1936.

The age of the concrete at the time of the experiment was 90 days, its prism strength ${}_p\beta_d$ was 360 kg/cm² and its fatigue strength $\sigma_u = 220$ kg/cm² amounting to approximately 0.6 of the prism strength. The reinforcement consisted

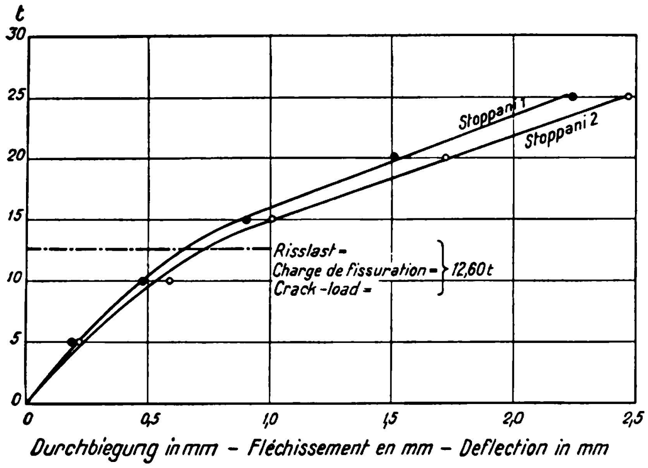

Fig. 2.

Determination of crack-load.

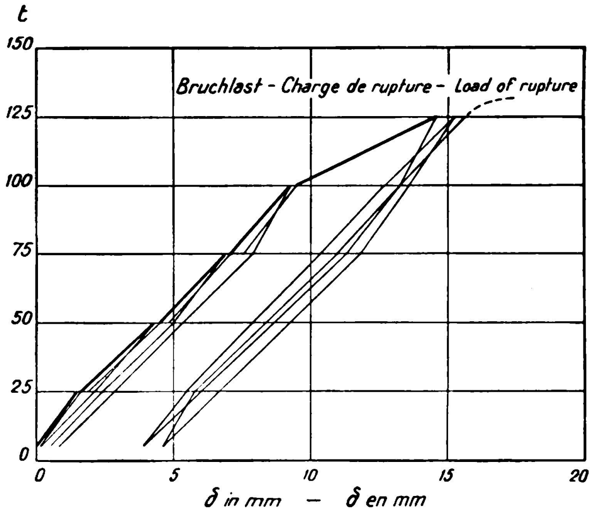

Fig. 3.

Break-test: Loading-Unloading-Deflection Diagram.

of round bars of ordinary steel having a yield point of 2700 kg/cm², a tensile strength of 4200 kg/cm² and a fatigue strength of 2500 kg/cm².

One of the two girders was subjected only to statical tests, in order to study its behaviour under static loading and finally its static breaking load. The second girder, however, was subjected to fatigue tests before being tested statically in exactly the same way as the first. In this way it was possible to ascertain how far the effect of fatigue influenced the statical behaviour and carrying capacity of a structure of this kind.

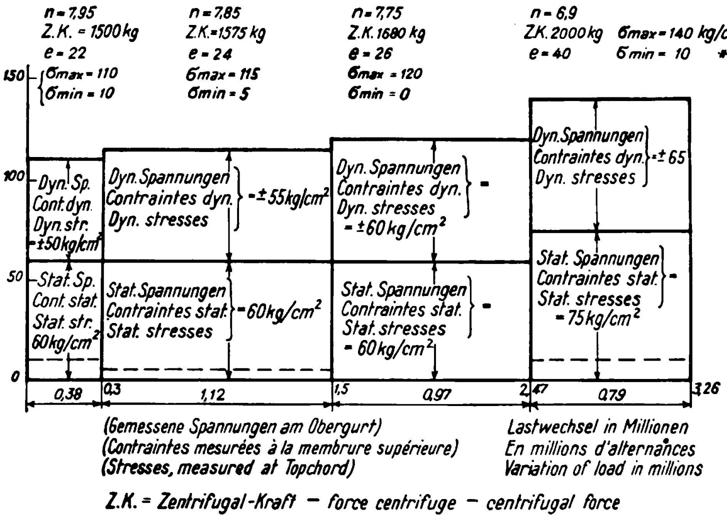

Fig. 4.

Fatigue-test: Measured stresses at different test-phases.

Preliminary experiments were made to ascertain the cracking load and the amount of permanent deformation which occurred after the concrete had cracked. The effect of cracking at various points in the concrete is to introduce irregularities in the stress-strain curve and this enables the cracking load to be determined (Fig. 2), amounting in this case to approximately $^1/_4$ of the calculated live load. The average breaking stress of the concrete in tension corresponding to the cracking load amounted to 17 kg/cm² though the tensile strength of the concrete itself was 40 kg/cm². The large difference between these two values is to be explained on the following grounds:

a) Pre-stressing of the concrete in tension as the result of shrinkage.
b) Incompleteness of the cracking of the concrete when related to the whole of the cross section.

The cracking of the concrete naturally resulted in large permanent deformations, amounting to about 25 % of the elastic deformation under live load. In structures of this kind the secondary stresses (especially those in the compression members) are exceptionally high, amounting to as much as 110 % (on the average they may be put at 70 %) while at the same time the bending stresses in tensile members are very low.

It was found that at the moment when the stress in the reinforcing steel reached the yield point the maximum compressive stress in the concrete was of the order of 220 kg/cm², which is equal to the fatigue strength of the concrete. The load corresponding to this was twice the live load. Since the fatigue strength of the concrete and the yield point of the steel are the criteria for resistance to repeated loading, it follows that in reinforced concrete trusses there exists a factor of safety of 2 against fatigue effects. Under stresses of this order the permanent deformations amount to 5.5 % of the total (Fig. 3) and may, therefore, be taken as accurate for practical purposes.

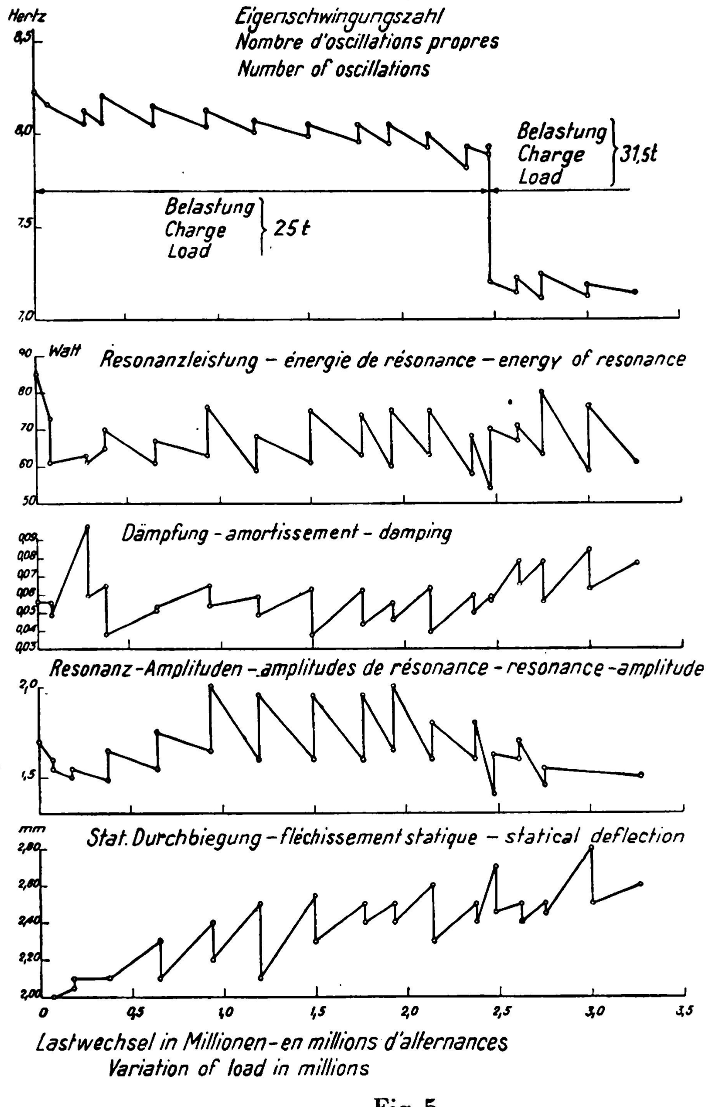

Fig. 5.

Fatigue-test: Change of dynamic-values with the Fatigue.

The factor of safety against statical breakage amounted to 2.6. The ratio between the respective factors of safety against repeated and statical loading is, therefore, that of $2/2.6 = 77$ %.

The ranges of stress and corresponding numbers of changes of load in the fatigue tests are indicated in Fig. 4. After a very large number of repetitions of load ($3^1/_4$ millions) within the permissible limits of stress (or even slightly in excess of those limits) no appreciable change in the statical or dynamical properties of the test girders could be observed and neither their carrying capacity nor their factor of safety were in any way affected.

A number of notable observations were made in the process of the fatigue tests (Fig. 5). Thus it was found that in the course of the process the damping and the static deflection increased, while at the same time, the restoring force and natural frequency of vibration decreased. Resonance tests carried out under the same experimental conditions showed that the power consumed by the vibration testing machine (Fig. 6), as well as the amplitude and the magnification, decreased with the fatigue, to be followed by subsequent recovery of stiffness. During certain periods of the tests a state of inertia was found to be established after a certain number of repetitions of load.

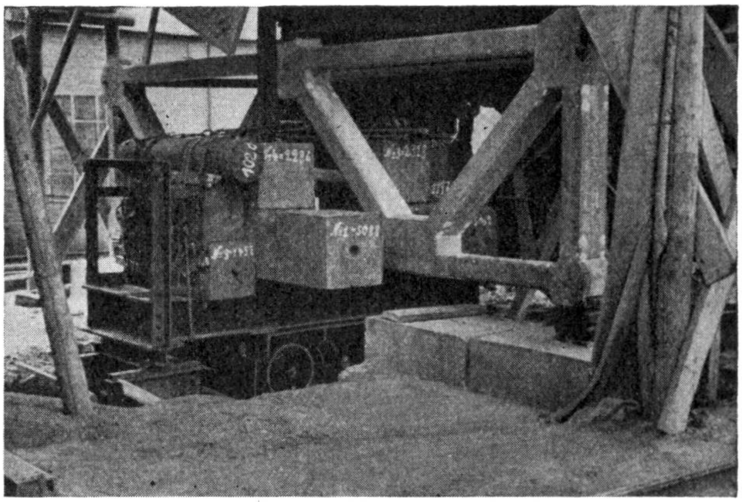

Fig. 6.
Arrangement of Fatigue-test.

From a practical point of view the most important conclusions to be drawn from these experiments on reinforced concrete girders are the following:

Frequently repeated stress within the observed limits (fatigue strength) does not adversely affect either the elasticity or the carrying capacity or the dynamical properties of reinforced concrete trusses, and in structures of this kind safety as regards static loading may also be taken to imply adequate safety against the effects of repeated loading.