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The Dynamic Effects on Prestressed Concrete Bridges Built without Falsework

Effets dynamiques sur les ponts en béton précontraint construits sans échaffaudage de montage

Die dynamischen Einwirkungen auf im Freivorbau gebauten Spannbetonbrücken

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In course of recent years at the construction of large span bridges the method of construction of prestressed concrete bridges without falsework was generally used. Those are structures of cantilever type mostly continuous with several spans often with various type of hinge connection at the centre of span of single spans.

Theoretic solution of the problem of dynamic effects of vehicles upon larger span bridges is often considered as a beam with an elastic layer over which passes a system with two degrees of freedom. In the case of a simple beam this brings about a system of three simultaneous linear differential equations with varying coefficients, two of them usually being of the second order one partial of the fourth order at "x" and of the second one at "t". As external force we consider the force harmonically variable and we assure the rigidity for vehicles as periodically variable over the whole beam length. In the case of a task it is necessary to define exacting initial and boundary conditions. The entering quantities of the majority of constants depend upon many factors. These parameters, therefore, are idealized but solutions are known for which this task in the case of a simple beam are solved by means of 20 principal and 4 auxiliary entering parameters.For continuous structures the task are still more exacting. That was the principal reason for our decision to examine the bridges built without falsework in an experimental way from the point of view of various parameters which act in a most expressive way upon structure vibration and fatigue.

The quantities obtained experimentally were examined from the point of view of the most often used dynamic parameters of bridge structures such as:

- dynamic deflection coefficient δ_w, relative deformation δ_ε, or stress coefficient δ_ν

- the natural frequency of the unloaded /f_0/ or even of the loaded /f_1/ bridge
- the natural circular frequency of the unloaded /ω_0/ or loaded /ω_1/
- the logarithmic damping decrement ϑ
- the circular damping frequency $\omega_b = \vartheta . f_o$
- the damping coefficient $D = \frac{\omega_b}{\omega_0}$
- the damping frequency $f_b = \frac{\omega_b}{2\pi}$
- the critical speed „C"

The results of the examination of dynamic effect at the prestressed concrete bridges erected by the cantilever construction method in Czechoslovakia have shown that these larger span structures have high dynamic coefficients, slow vibration damping and are eysily brought into some oscillation conditions. The most disadvantageous effects arise at the outer spans at the inner spans occurring a certain damping owing to the connection with the outer fields. It will be necessary to augment the influence of the hinge connection of two cantilevers in the middle of the span.

On the average for the spans and kinds of constructions examined by us we recommend to consider the following coefficients of deflection increase δ_w:

- the inner spans of bridges concreted without falsework provided with steel hinges $\delta_w = 1,35$
- the outer spans of bridges concreted without falsework provided with steel hinges $\delta_w = 1,50$
- the medium spans of bridges concreted without falsework provided with a reinforced concrete hinge $\delta_w = 1,45$
- the outer spans of bridges concrete without falsework provided with a reinforced concrete hinge $\delta_w = 1,70$
- the medium spans of frame-type bridges without hinge $\delta_w = 1,60$
- the outer spans frame-type bridges without hinge $\delta_w = 1,85$

At the same time it is necessary to secure a smooth roadway surface on the bridges and for the region in front on and behind the bridge as the unevenness of the pavement considerably increases the dynamic effects upon the bridges.

It is obvious that relatively high dynamic coefficients for bridges not always mean harmful effects from the point of view of the bridge structure bearing capacity as the design moment for which the bridge is considered is always far more higher. The loads capable of bringing about the design moment required may be attained only with a greater number of vehicles which abolish their mutual effects which means that dynamic effects in this case are much more lower and within the standart limits. It was the reason why we carried out our dynamic tests of the bridges erected by a cantilever construction method by means of vehicles with a wheel and not caterpillar undercarriage for which irregularity and larger caterpillar surface moderate dynamic effects. It was shown also for other frame and other type bridges.

From the above it follows that the dynamic coefficients of bridges become only orientation values and in the future it will be necessary to consider the constructions of this type dynamically at the design. The importance of the examination of dynamic effects consists also in possibility of considering the bridge as to fatigue. This is permitted by cognizance of the natural bridge frequency and of statistic data on transport density.

Very important but often neglected factor is also an estimation of biologic and psychologic effects of strong bridge vibration upon pedestrians not acquainted with the statics, but primarily upon motorists in vehicles travelling across the bridge. On the base of a research in the USA according to Janeway and Oehler the safe limit to a still discomforting oscillation is given by the relation $a.f^3 = 2$ for frequencies of 1 through 6 cycles p.s. and $a.f^2 = 1/3$ for frequencies of 6 through 12 cycles p.s. where „a" is the amplitude in inches and „f" the natural frequency of bridge.

From what was said it follows that the bridges of larger spans we examined from the point of view of biologic action of bridge structure vibration upon man for dynamic effects acting on the bridge are discomforting. For instance in the case of the Kollárovo bridge /fig.1/ at the 2nd span during the passage of one vehicle weigting 20 t the $a_{dyn} = a_{sts} \cdot \delta_{nr} = 0{,}585\ cm \cdot 1{,}35 = 0{,}312$ i. for $f = 2{,}56$ c/s. Then $af^3 = 5{,}22 > 2{,}0$, i.e. the structure may have infavourable effects from biologic and psychologic point of view upon the driver. It might lead to a breakdown especially in the case of an adequate resonance during the passage of two vehicles moving against each other. It will be necessary to solve this problem for the design of modern subtle bridge structures.

Fig.1 The 5-span bridge concreted without falsework across the river Váh at Kollárovo during testing

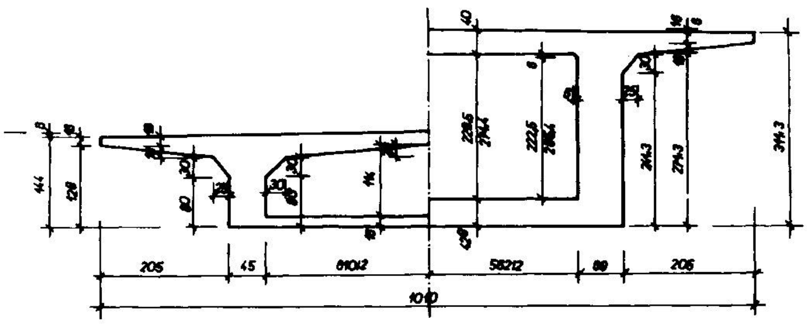

Fig.2 A scheme of cross-section of the bearing structure of the bridge Kollárovo.

SUMMARY

The results of the examination of dynamic effects at the prestressed concrete bridges erected by the cantilever construction method have shown that bridges with larger span have high dynamic coefficients and slow vibration damping. A very important factor is also the estimation of biological and psychological effects upon the drivers travelling across the bridge.

RESUME

L'analyse des effets dynamiques effectués sur ponts en béton précontraint construits en encorbellement a permis de déceler la présence de coefficients dynamiques considérables ainsi qu'un amortissement de chocs trop lent pour les ouvrages de grande portée. Un problème très important est l'évaluation des effets biologiques et psychologiques sur le conducteur.

ZUSAMMENFASSUNG

Die Prüfungsergebnisse der dynamischen Einwirkungen an im Freivorbau gebauten Spannbetonbrücken haben bei grösseren Spannweiten grosse dynamische Beiwerte und langsame Dämpfung gezeigt. Sehr wichtig ist auch die Abschätzung der biologischen und psychologischen Einwirkungen auf den Fahrzeuglenker, welcher die Brücke benützt.