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Autor: Pechar, Jii / Faltus, Jii

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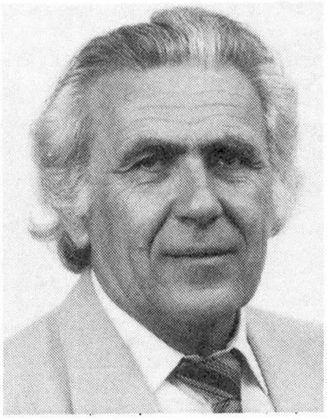
Composite Action in Steel-Concrete Structures

Interaction spatiale dans un pont mixte acier-béton

Räumliche Wirkungen bei Verbundkonstruktionen von Brücken

Jiří PECHAR
Director
Build. Res. Inst.
Prague, Czechoslovakia



Jiří Pechar, born 1930, received his civil engineering degree from the Czech Technical University of Prague. Profesor in the department of steel structures and bridges, CTU.

Jiří FALTUS
Civil Engineer
State Inst. Transp. Design
Hradec Králové, CSSR

Jiří Faltus, born 1945, received his civil engineering degree from the Czech Technical University of Prague. He has worked in transport as a designer of bridges since 1972.

SUMMARY

The paper deals with the investigation of a composite oblique bridge structure and its behavior in space. The structure consisting of main steel plate I-girders and reinforced concrete slag without any cross and longitudinal bracing. Results of theoretical analysis were compared with results of a loading tests on the real bridge.

RÉSUMÉ

L'article concerne les recherches théoriques relatives aux structures obliques mixtes en acier-béton d'un pont et de leur interaction spatiale. La construction se compose de poutres principales en acier à âme pleine à section en I et d'une dalle de tablier en béton armé sans entretoisement longitudinal et transversal. Les résultats de la solution théorique ont été comparés avec ceux de l'essai de charge effectué sur le pont réel.

ZUSAMMENFASSUNG

Der Beitrag befasst sich mit der Ermittlung von schrägen Verbundkonstruktionen von Brücken. Die Tragkonstruktion besteht aus Stahl-Hauptträgern (I-Profil) und aus einer Stahlbeton-Fahrbahnplatte ohne Längs- und Querversteifung. Die Ergbenisse der teoretischen Lösung werden mit den Resultaten, der auf der aufgebauten Brücke durchgeführten experimentalen Belastungsprobe verglichen.

1. INTRODUCTION

In the construction of bridges (mainly roadway) there are widely used structures which are created from steel plate girders and reinforced concrete slab of bridge floor, assembled as composite structure, number of girders can be various. Transverse load distribution depends on the stiffness of main girders, slab and cross bracing girders respectively.

In Czechoslovakia there are most often used carrier structures with three or more main girders. Concrete slab replaces cross bracing girders. This approach allows to use steel I - shaped profiles for main bridge beams. Such beams are produced in series by automatic welding. This type of structures diminishes the structural depth and improves the aesthetics of the bridges. Utilization of steel of main girders of this type of struktures are better because we can use wide assortment of widths and thicknesses of flanges. Possibility of useing of steel light sheeting is further advantage of this type of structures.

The carrier structure was investigated theoretically. Results were compared with results of experimental loading test. Good agreement of results proved correct choice of calculation model.

2. DESCRIPTION OF THE STRUCTURE (Fig. 1.)

The investigated structure consists of four main lateral steel plate girders without cross bracing and reinforced conrete slab of bridge floor cast in situ. Connection between slab and girders is made by stud connectors, welded on the steel flange. Precambered steel girders were not supported during erection.

Material´s data :

steel - yield strength 340 MPa
tensile strength 480 - 630 MPa
modulus of elasticity 210 000 MPa
concrete - compresive strength after 28 days (cubes) 40 MPa
- modulus of elasticity 33 000 MPa

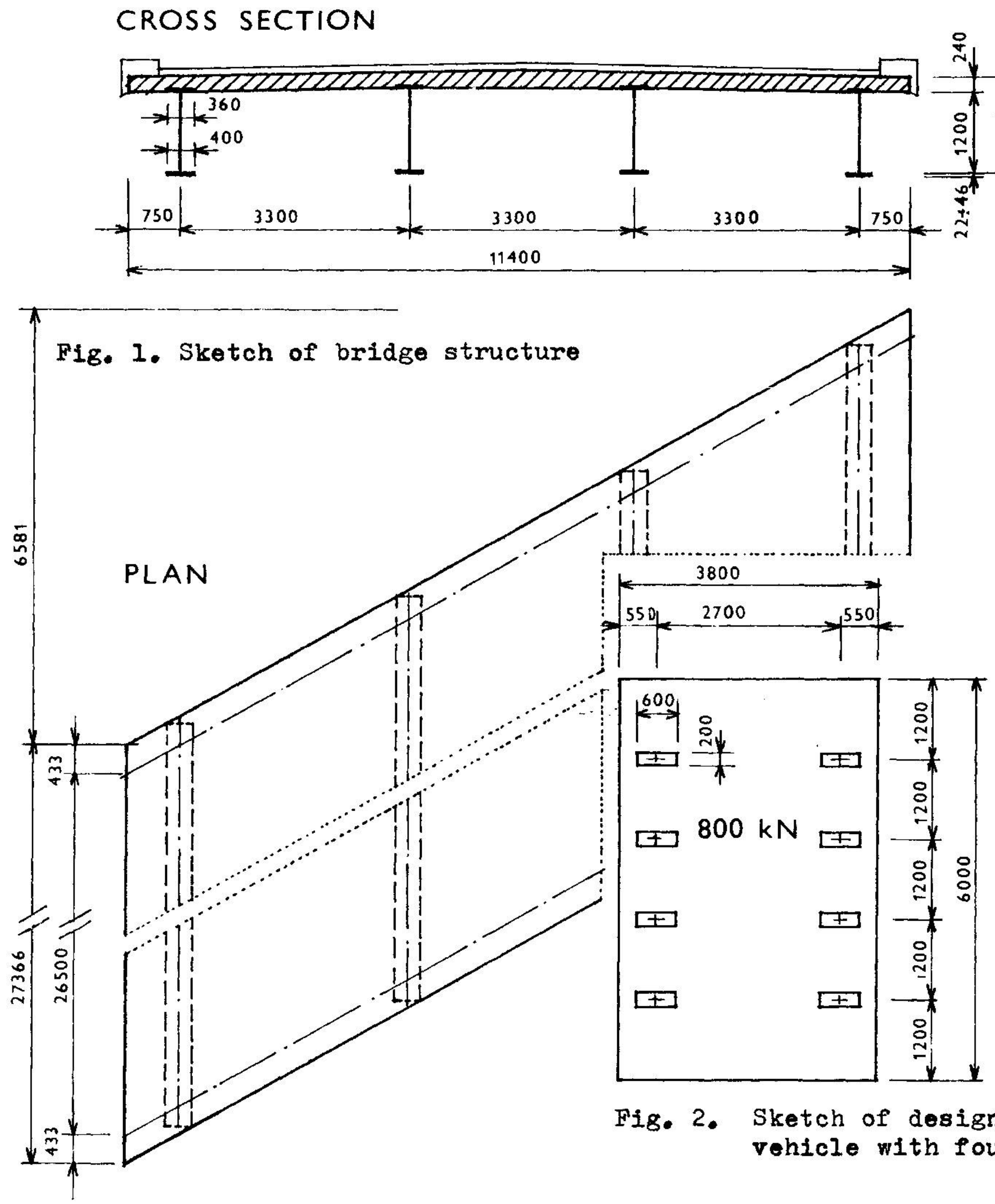


Fig. 1. Sketch of bridge structure

Fig. 2. Sketch of design load vehicle with four axles

3. THEORETICAL ANALYSIS

3.1 Design load

During theoretical investigation we considered all required kinds of load. For the investigation of transverse load distribution both uniform surface load and load by design vehicle with four axles were used. Weight of vehicle is 800 kN (Fig. 2.). Creep: $\varepsilon_d(t) = \varphi(t)\frac{\sigma}{E_b}$ Shrinkage: $\varepsilon_z(t) = \frac{\varepsilon_{z\infty}}{\varphi_\infty}\varphi(t)$

Coefficients for thermal prolongation :

For steel $d = 1{,}2 \cdot 10^{-5}$ for concrete $= 1{,}0 \cdot 10^{-5}$

3.2 Calculation model

Calculation model for theoretical investigation by finite element method was assembled to respect real common work of concrete and steel as a whole in space. We used finite element method for solution of three dimensional problem and we respected the whole shape of the structure and its individual elements. Diferent physical and mechanical properties of materials, of individual elements of structure including shear connectors were considered too. Calculation model alowed to consider skrinkage and creep of concrete, effecte resulting from temperature changes, different coeficients of linear thermal expansion for steel and concrete elements. Model enables to respect real location of design load, working load, test load.

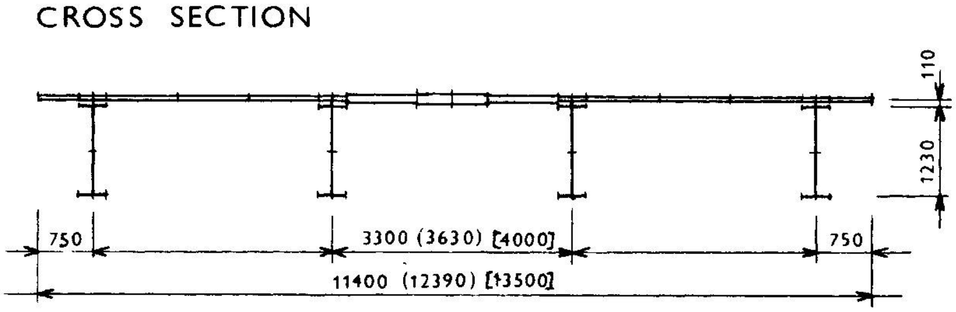


Fig. 3. Sketch of calculation model for FEM

3.3 Survey of theoretical investigation - results

On base of theoretical investigation of real structure in space following conclusions can be derived :

- reinforced concrete slab is a structural element which provides usualy sufficient stiffness for transverse load distribution on the main girders. Even in the case when additional cross section bracing is used the slab plays decisive role in transverse load distribution.
- It is necessary to provide the longitudinal slab reinforcement also at the top surface of the concrete slab because of the bending stresses in slab from transverse load distribution.
- Uplift stresses in studs due to transverse bending of the slab are not as a rule greater then those due to longitudinal bending. The combination of both effects is not particularly important for studs design.

- The change of longitudinal bending stresses in concrete slab due to shear lag is significantly affected by the cross section deformation (i.e. by the distance between bridge neutral axis and concrete slab)
- Top flanges of main girders are stressed by transverse bending due to slab deformation. Therefore the top flange width should be limited as much as possible.
- In skew structures the increase of normal stresses in the slab corners area due to negative bending moments should be considered. This takes place especially under the excentric load at the longitudinal unsupported edge of the slab.
- Midspan vertical deflections from design load are illustrated on fig. 4. Deflections are illustrated for following main girders, spacings : A. 3,3 m (real bridge), B. 3,63 m, C. 4,0 m. The structures were without cross section bracing except the lastly structure (4,0). In this structure were considered in addition with and without rigit cross bracing (cases D, E).

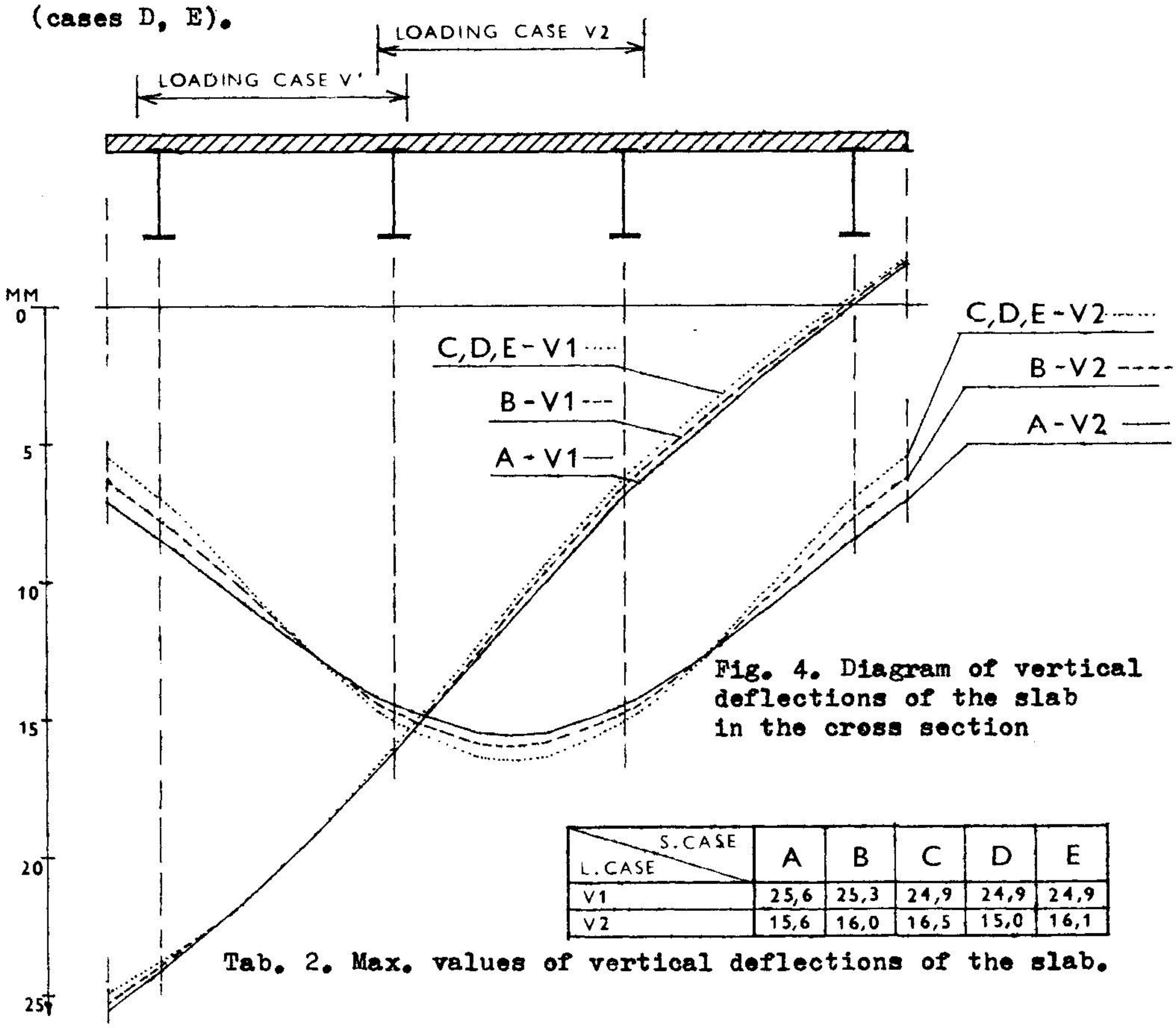


Fig. 4. Diagram of vertical deflections of the slab in the cross section

S.CASE / L.CASE	A	B	C	D	E
V1	25,6	25,3	24,9	24,9	24,9
V2	15,6	16,0	16,5	15,0	16,1

Tab. 2. Max. values of vertical deflections of the slab.

4. EXPERIMENTAL INVESTIGATION

Prefabricated concrete road panels were used as a load in experimental loading test in situ. The total weight of panels was 540 kN. Panels were placed on wood pads (size 0,2 m x 0,2 m) directly upon the concrete slab of the bridge structure. Structure was investigated in three loading cases.

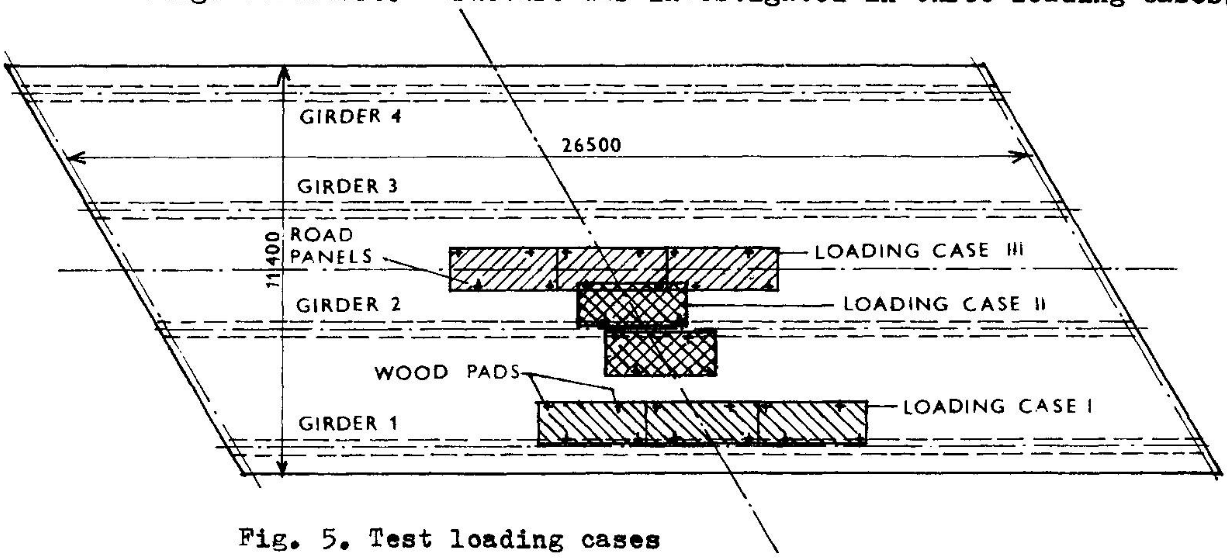


Fig. 5. Test loading cases

Comparison results of theoretical and experimental investigation is done for vertical midspan deflections of main girders (Tab. 1.) and for normal stress in lower flanges of main girders in the middle of span (Tab. 1.)

LOADING CASE			I		II		III	
			THEOR	EXP	THEOR	EXP	THEOR	EXP
σ (MPa) STRESS	GIRDER	1	59,7	54,2	29,0	26,3	14,0	16,0
		2	30,6	29,6	45,6	40,6	32,5	33,5
		3	8,6	9,3	24,0	20,5	32,5	32,8
		4	−2,4	−1,7	6,2	8,1	14,0	17,1
y (MM) VERTICAL DEFLECT.	GIRDER	1	19,2	17,4	10,0	8,9	5,2	4,7
		2	10,0	9,0	11,8	11,2	9,7	9,2
		3	3,0	2,5	7,5	6,8	9,7	9,0
		4	−1,2	−1,3	2,3	1,8	5,2	4,6

Tab. 1. Values of normal stresses and vertical deflections

5. CONCLUSION

Results of theoretical and experimental investigation of composite action in space of the composite bridge structure verify the agreement of theoretical solution which includes all elements of structure into the bearing capacity. Results verify that both for working and design load we can consider the whole function of structure. Use of modern design procedures is the way how to improve optimalization of design of structure from the point of view of reliability, serviceability and economy.