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Spatiostructural Bridges for Rural Roads of Mexico

Ponts spatiostructuraux pour les routes rurales au Mexique

Räumliche Fachwerkbrücken für die Landstrassen Mexikos

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SUMMARY
Experimental engineering has proven useful in the rational design of rural bridges in Mexico. This design uses a combination of spatial trusses built up from welded light rolled steel elements, in the form of modular rectangular base pyramids, and a concrete slab, embedding the elements of the upper chord, which takes the compression stresses and acts as the bridge deck.

RESUME
La recherche expérimentale a montré son utilité dans un projet de ponts ruraux au Mexique. L'ouvrage est une combinaison d'armatures spatiales à éléments modulaires légers en acier laminé soudés, en forme de pyramides à base rectangulaire, avec une dalle en béton armé reprenant les contraintes de compression et constituant le tablier du pont.

ZUSAMMENFASSUNG
Experimentelle Forschung zeigte sich nützlich beim rationellen Entwurf der Feldwegbrücken von Mexiko. Die Brücke besteht aus räumlichen Fachwerken, die aus zusammengeschweissten, leichten Walzstahlelementen in Form von Pyramiden mit rechtwinkliger Basis aufgebaut werden und aus einer Betonplatte, welche die oberen Elemente der Fachwerke einbettet. Die Platte nimmt die Druckspannungen auf und wirkt als Brückenfahrbahn.

SPATIOSTRUCTURAL BRIDGES FOR RURAL ROADS OF MEXICO

1. FOREWORD

One of the main problems of rural roads of Mexico is the construction of bridges; considering the infrastructural restrictions, the socio-economical and environmental factors, it seems desirable to use a structure with the following characteristics:

- The construction works of the substructure and the superstructure should be made simultaneously, in order to use the maximum available skilled and unskilled man power and to reduce construction time.

- The use of scaffolding for the construction of the superstructure should be avoided to eliminate the risk of carrying-away such scaffolding by flood currents, and to allow a continuous work-period throughout the whole year.

- The design of a self-supported superstructure allowing to place an adequate concrete slab deck, with an economical and simple formwork.

- The design of a superstructure of minimum weight, but with an adequate rigidity to support its own weight and the live operating loads, as well as to enable an easy and safe launching operation.

- The design of a structure that allows an easy access for adequate supervision during the construction stage and for maintenance inspections during operation.

- The possibility of enlarging the bridge with future traffic demands.

- The possibility of making bridge repairs without traffic interruptions.

2. STRUCTURAL DESIGN

Among the various alternatives studied by the Mexican technicians, it was found that superstructures of spatial welded steel elements could conform the requirements, as they allow to profit from the steel and concrete characteristics in the best way.

3. DESCRIPTION

The superstructure design consists of a tri-dimensional truss constituted by multiple steel linear elements, geometrically arranged in the position of rectangular base pyramidal edges, opposed to each other and joined by their vertex. With this configuration, a very light self-supported structural system is obtained with a considerable tri-dimensional rigidity, which enables to cover relatively large spans, avoiding the need of scaffolding for its erection.

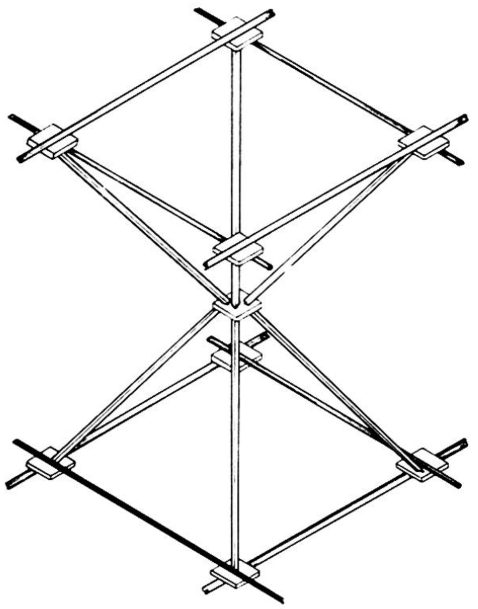


Fig. 1 Basic Modular Element of a Rural Spatiostructural Bridge (Sketch)

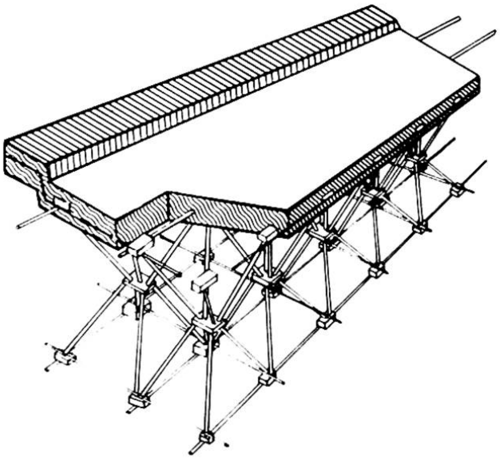


Fig. 2 Isometric Detail of a Rural Spatiostructural Bridge (Sketch)

In the upper part of the truss, a concrete slab of approximately 15 cm deep is casted, embedding the elements that form the upper chord, which collaborates in taking the structural compression stresses, and besides acts as the floor of the bridge, as shown in the above Figures 1 and 2.

4. MANUFACTURING AND ERECTION

To manufacture these trusses, laminated structural angles are used for the diagonals and corrugated steel bars for the upper and lower chords. The manufacturing is made in framed sections of adequate dimensions and weight to facilitate their transportation from the workshop to the jobsite. See Table I.

Nº	ELEMENT IN cm	SECTION	STEEL TYPE
1	3.81 x 3.81 x 0.32		A - 36
4	3.18 x 3.18 x 0.32		
6	2.54 x 2.54 x 0.32		
I	2.54 x 2.54 x 0.32		
II	3.18 x 3.18 x 0.32		
2	3.18 x 3.18 x 0.64		
3	3.18 x 3.18 x 0.64		
5	3.18 x 3.18 x 0.32		
7	2 ϕ # 8		TOR-60
8	2 ϕ # 10		
9	1 ϕ # 10 + 1 ϕ # 12		

Table I Typical Sections for a Rural Spatiostructural Bridge

The sections are taken to the riverside and are there assembled for a further launching into their final position on the substructure. For the correct assembly, adequate joints have to be provided at the end elements of the framed sections: the continuity of the sections is obtained by extending and lapping the steel of the upper and lower truss chords, which are welded when assembling the elements. The casting of the upper deck is made by means of a light weighted formwork suspended from the upper mat of the structure. See Figures 3, 4, 5 and 6.

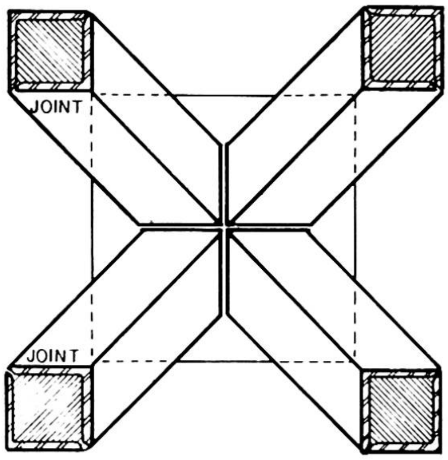


Fig. 3 Upward View of an Intermediate Node (Sketch)

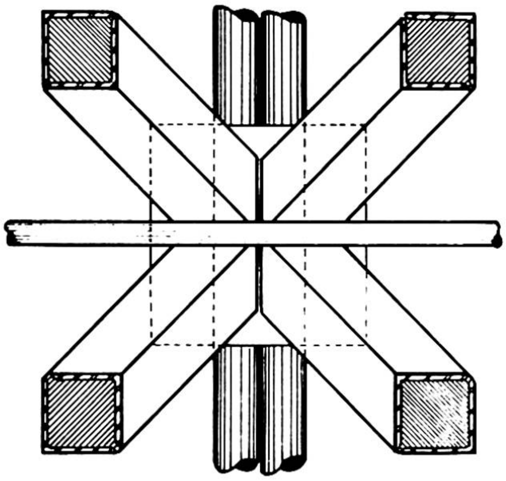


Fig. 4 Downward View of a Lower Node (Sketch)

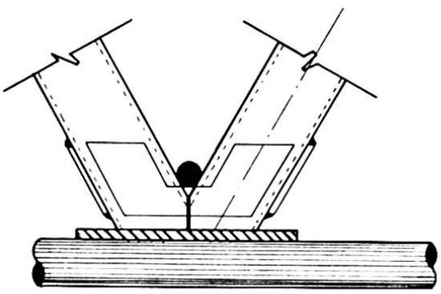


Fig. 5 Longitudinal View of a Lower Node (Sketch)

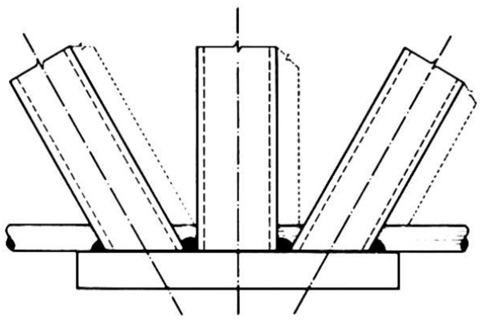


Fig. 6 Detail of a Lower Bearing Node (Sketch)

5. DESIGN ANALYSIS

For the design verification, the superstructure is analyzed as a spatial truss, in which the elements are subject to simple tension and compression stresses. It is considered that the concrete embedding the upper mat helps to prevent buckling of the horizontal members subjected to compression and is used as a floor for the passage of the moving load.

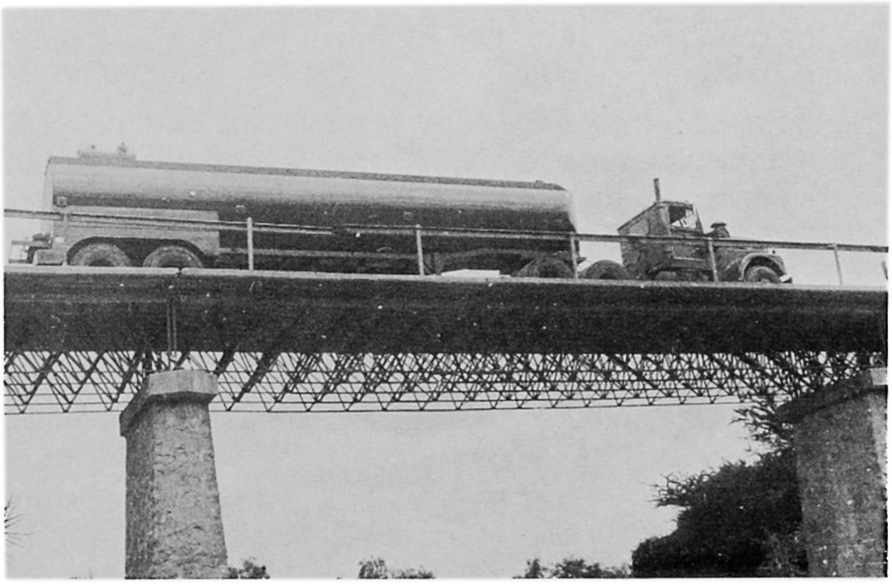
In the analysis, it is implicitly supposed that the load-displacement ratio is linear and also that the displacements produced are relatively small. When a computer is available and a more accurate verification is desirable, more complex procedures may be applied, such as displacement or force methods, on which the matrix analysis of structures is based.

6. EXPERIMENTAL VERIFICATION

As no data concerning the results of any previous experience related with the behaviour of bridges with this type of structures were available, some of them have been instrumented with electrical strain gages of SR4 type. In some cases, the instrumentation has started at the cutting and welding stage of the steel elements to register the historical evolution of stresses in these elements, as well as to know the influence of the variations produced in the stresses due to the effect of labour in the assembling and erection procedures.

Once completed the construction, and before the instrumented bridges are put into operation, some load tests have been carried out with heavy loaded trucks parked in the most critical positions, as shown on Figure 7.

Fig. 7 Load Test



7. RESULTS

In general, the results show that measured stresses are lower than those calculated and that they are far from reaching the allowable design stresses, which implies that the adopted hypothesis for the calculation are adequate and secure. On the other hand, the low registered values for the measured stresses suggest the convenience of optimizing the design; for this reason, an experi

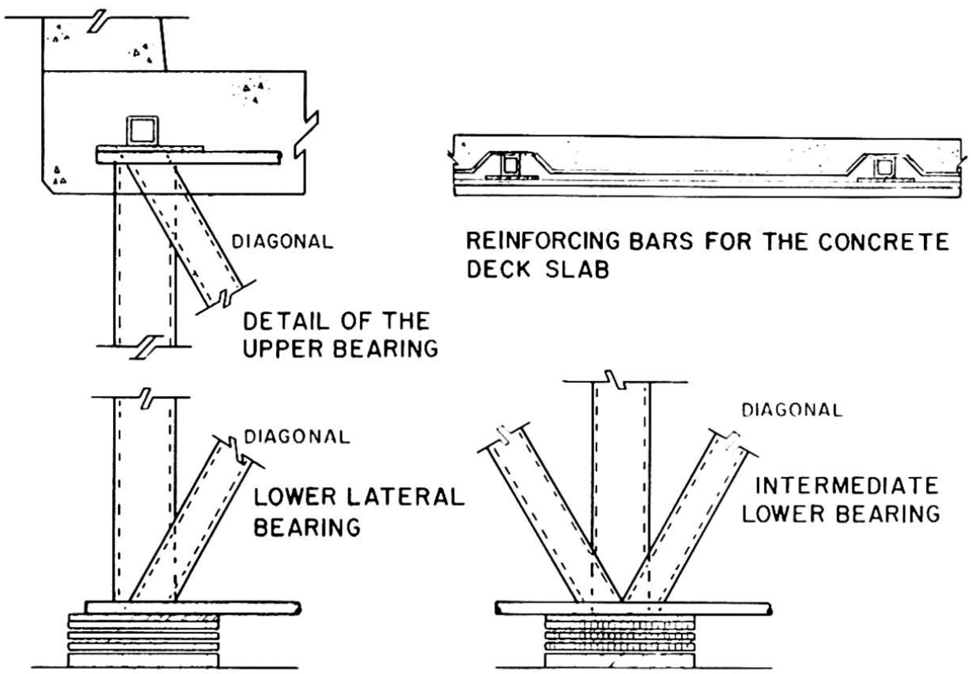


Fig. 8 Bearing and Reinforcing Details

mental engineering research is already being carried out, by means of physical models, in order to improve the calculation hypothesis. It has to be kept in mind, nevertheless, that any optimization in the design requires of more accurate supervision and quality control during the construction stage.

8. CONCLUSIONS

The successful results of the Mexican experience, make clear that the uncertainties created by rational designs in developing countries may be evaluated by means of an adequate application of experimental engineering, because with an instrumented observation of models and prototypes, it is possible to anticipate in a true and reliable way the actual behaviour of the designed constructions.

For these reasons, we believe that experimental engineering is one of the most promising resources for the technological independence of the developing countries.

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