IIIb: Elevated roadways

IIIb1

Elevated Freeway Structures in the U.S.A.

Routes surélevées aux Etats-Unis

Hochstraßen in den Vereinigten Staaten

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(The writer was asked by the chairman of Working Commission II to report on elevated urban freeway construction in the United States. Correspondingly, he presented at the congress a comprehensive review, largely based on more than thirty photographs of such structures. Most of these were 35 mm color slides not suitable for reproduction in the Final Report. For this reason, only the very general conclusions are briefly presented below.)

The only paper on Theme IIIb in the Preliminary Publication is that by Prof. K. SATTLER. It concerns the possibilities of utilizing precast roadway slabs for composite construction of urban freeways. From the viewpoint of American practice this paper seems most appropriate; indeed, composite construction has proved to be very economical for such structures, although relatively little use is made of prefabrication.

The vast amount of urban freeway construction in the United States, some of it dating back twenty years and more, permits the following observations to be made:

1. For adequate service, urban freeways must be of considerable width, generally from six to ten lanes wide.

2. In order to maintain safe, uninterrupted traffic of great density at high speeds (generally 50 to 65 mph, or 80 to 110 km/h), curves must be smooth and of very large radius.

3. In consequence of 1. and 2., problems of torsion in curves are very minor. In fact, in the majority of the illustrated structures, the curves were formed by polygonal arrangement of straight beams and girders. This permits the use of rolled wide-flange sections for moderate spans or of straight plate-girders for longer spans, without the complications inherent in the fabrication of curved members.

4. Comparative designs show that under American conditions the most economical type of freeway structures is normally represented by composite construction, the reinforced concrete road slabs being shear-connected to the longitudinal steel girders by welded studs, channels, or other shear connectors. In general, continuous rolled wide-flange beams in composite construction

appear to be most economical for spans up to about 70 to 80 ft. and continuous welded plate girders in composite construction for larger spans, although conditions vary from one locality to another. Costs begin to increase very sizeably for spans exceeding about 120 to 130 ft. This information refers to total cost per square foot, including piers and normal foundations.

5. Access ramps are of smaller widths, two or four lanes wide, and much more sharply curved; this is possible because of the much slower vehicle speeds. In such structures the longitudinal girders are mostly curved rather than straight, and torsion becomes a major design factor. Even here composite construction with considerable transverse stiffening is more frequent than closed box-girders, the slab being shear-keyed both transversely and longitudinally for better torsional performance. Piers may consist of single tubular columns, each carrying a double-cantilever transverse box girder which supports the longitudinal girders.

6. To date, orthotropic construction has not become popular, probably because of the large amount of fabrication which is required, and because of doubts in regard to the type of wearing surface which would best resist extremely heavy traffic. However, research and pilot construction in this field are now under way.

Summary

American experience with elevated freeway structures is briefly described. Composite construction, utilizing rolled wide-flange sections for shorter spans and welded plate girders for longer spans is found to be the preferred construction. The paper represents a sharply abbreviated abstract of a profusely illustrated report which was presented at the congress.

Résumé

L'auteur décrit brièvement les expériences faites en matière de viaducs urbains en Amérique. La préférence est donnée à la construction mixte, avec profilés à larges ailes dans le cas de faibles portées et poutres composées soudées pour les portées plus grandes. Il s'agit ici d'un résumé très succinct de la communication qui, avec d'abondantes illustrations, a été présentée au Congrès.

Zusammenfassung

Es werden amerikanische Erfahrungen mit städtischen Hochstraßen kurz beschrieben. Die Verbundbauweise unter Verwendung von gewalzten Breitflanschträgern für mittlere Spannweiten und von geschweißten Vollwandträgern für größere Spannweiten wird bevorzugt. Der Beitrag gibt nur die Schlußfolgerungen des ausgiebig illustrierten, am Kongreß gehaltenen Vortrags wieder.

Discussion - Discussion - Diskussion

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It would be instructive to consider why U.S.A. practice is so different from the European one as far as design of bridges and viaducts is conerned. It was a real pleasure to see the simple unsophisticated designs of almost pre-war era used today by the engineers of the most industrialised country in the world — the U.S.A.

Just compare the slides shown by Professor WINTER with those shown by several European contributors. Rolled beams and riveted plate girders v welded box girders with orthotropic decks.

In particular, I would refer to Professor WINTER's slide showing least weights of girders for different spans. This cannot be correct, because in composite construction welded plate girders with unequal flanges are always lighter (but not necessarily cheaper) than ordinary rolled beams. The slide favoured rolled beams for medium and even long spans. In Great Britain, at any rate, for long spans box girders with concrete and eventually with steel decks are lighter and cheaper than ordinary I-girders. Bracing and intermediate diaphragms between main girders should not be necessary if the R. C. deck slab is properly designed to distribute the vertical loads and to resist lateral forces. This calls for somewhat elaborate calculations, but the saving in cost should be assured.

It would appear that in U.S.A. composite action is not normally ensured in the region of negative moment, as shear connectors are omitted beyond the point of inflection. It would be interesting to learn the reasons for this. Is it the fear of fatigue or of excessive cracking of the concrete? The slab, however, will initially adhere to the steel flange (unless the flange is greased) and therefore cracking is almost unavoidable. So why not provide shear connectors and add a significant area of reinforcing bars to the top flange sections of the main girders? There is also the problem of the effective moment of inertia of the girder that should be assumed when calculating the various live load effects. Cracking should be controlled and the deck waterproofed with asphalt which, incidentally, also provides an excellent and renewable wearing surface.

Undoubtedly there are good reasons for this studied simplicity by expert engineers. It is suggested that these are:

1. High cost of office and manual and field labour.
2. Demand for speed in design and construction.
3. Standardisation to permit mass production of hundreds of bridges, although complex structures can also be mass produced.

It is interesting to speculate which approach (European or American) will eventually prevail, or perhaps, with the advent of the computor and automation they will be blended into one "Optimum Design", i. e. the best for any given set of circumstances.

Summary

The author draws attention to the considerable differences between the United States and Europe as far as the design of bridges and urban viaducts is concerned.

Résumé

L'auteur attire l'attention sur les différences notables existant entre les Etats-Unis et l'Europe quant à la conception des ponts et des viaducs urbains.

Zusammenfassung

Es wird auf die bemerkenswerten Unterschiede aufmerksam gemacht, die in bezug auf die Gestaltung von Brücken und Hochstraßen zwischen den Vereinigten Staaten und Europa bestehen.

Reply - Réponse - Antwort

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Dr. KERENSKY raised two points concerning the bridge design practices in the United States:

1. omission of shear connectors in the negative moment region of continuous bridges of composite construction; and
2. general simplicity of elevated structures.

The omission of shear connectors in the negative moment regions is by no means a general American practice. The AASHO specification[1]) states:

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[1]) "The American Association of State Highway Officials: Standard Specifications for Highway Bridges", 8th edition, Washington, D.C., 1961, Section 1.9.4.

"The negative moment portions shall be designed on the assumption that concrete on the tension side of the neutral axis is not effective except as a device to develop the reinforcement steel embedded in it. In case reinforcement steel embedded in the concrete is not used in computing the section, shear connectors need not be provided in these portions of the spans."

Thus, the utilization of the slab reinforcement to develop composite action over the supports is clearly permitted.

The principal reason for omitting the shear connectors in the negative moment region was the lack of information concerning the fatigue strength of the steel beams over supports. Studies of the effect of stud shear connectors, the most popular connector in the United States, on fatigue strength of the flange of a steel beam were completed recently at the University of Illinois[2]). The results showed significant reduction of the fatigue strength resulting from the attachment of the studs and, at the same time, furnished the designer with factual basis for consideration of fatigue in the negative moment regions. This writer agrees with Dr. KERENSKY that the principal reasons for the simplicity of American designs are the high cost of office, shop, and field labor, and the demand for speed in the design and construction. The latter reason has been particularly important in recent years because of the tremendous increase in the volume of bridge building associated with the construction of the interstate network of freeways. On the other hand, standardization to permit mass production of steel elevated freeways cannot be considered at present as among the principal influences in this trend toward simplicity.

A recent development that will lead to further simplification of the field work may be of interest in this discussion: the use of unpainted steel. Certain high-strength low-alloy structural steels, such as the Mayari-R steel produced by Bethlehem Steel Corporation, develop a closely-grained and tightly-adherent oxide coating when subjected to ordinary atmospheric exposure. The coating acts as a barrier to moisture and oxygen, and effectively prevents further corrosion of the steel. This "weathering" unpainted steel has been used recently in a number of architectural applications on the exterior of buildings, and it is now being introduced into the bridge field. The Michigan State Highway Department has under construction three bridges that will rely on the oxide coating for protection against deterioration.

Summary

The author answers questions put by Dr. KERENSKY regarding shear connectors in the negative moment region and simplicity of elevated structures.

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[2]) K. A. SELBY, J. E. STALLMEYER, W. H. MUNSE: "Fatigue Tests of Plates and Beams with Stud Shear Connectors". Civil Engineering Studies, University of Illinois, 1963.

Résumé

L'auteur répond aux questions de M. KERENSKY concernant les goujons de liaison dans les régions à dalle tendue et la simplicité de la construction des viaducs urbains.

Zusammenfassung

Der Verfasser beantwortet Fragen von O. A. KERENSKY, die sich auf die Bolzenverdübelung in Zonen mit gezogener Betonplatte und auf die Einfachheit in der Konstruktion von Hochstraßen beziehen.