Zeitschrift: IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen

Band: 8 (1971)

Artikel: Bridge construction

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DOI: https://doi.org/10.5169/seals-9524

IV

Bridge Construction

Exécution de pont

Ausführung im Brückenbau

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Although a large bridge may contain many like elements which can be mass fabricated, the most likely object for mass production appear to be standard structures. These are or can be employed, i.a., for the following classes of work:

A - small and moderate size bridges for highways
B - vehicular and/or pedestrian overpasses over highways and railways
C - elevated highways
D - overpasses and flyovers (permanent and temporary).

In each of the above mentioned classes, steel will be used at least for the main girders, whereas materials for the deck and piers may vary.

To bring into focus classes A, B, C, D and the "state of the art" in each class the following examples may be useful:

Class A - Small and moderate size bridges for highways

a_1) On the Western Bypass Highway of Milano (Italy) three bridges featuring standard 45m spans, use 52 identical girders for a total weight of 1600 t. (Ref. 1)

a_2) Loudwater Viaduct (G.B.) The overall lenghth of 620 m. includes eleven 36.6 m spans requiring a total of 132 identical girders. (Ref. 2)

a_3) Tinsley Viaduct (G.B.) A double deck highway 1034 m long which contains eight 163'6" and nine 181'9" spans. Total weight about 12000 t. (Ref. 3)

a_4) Yanley Lane Viaduct, Somerset, (G.B.) includes eleven 80 foot spans requiring a total of 88 identical girders.
(Ref. 4)

Class B – Vehicular and/or pedestrian overpasses over highways and railways.

b_1) Standard overpass of the Italian Motorways
(Ref. 5)

b_2) Motorway overbridges
(Ref. 5)

b_3) Footbridges over the Madrid-Andalusia Motorway
(Ref. 6)

Class C – Elevated highways

c_1) Genoa (Italy) expressway
(Ref. 7)

c_2) Tokio and Osaka expressways.
(no reference required!)

c_3) U.S.A. expressways.
(no reference required!)

Class D – Overpasses and flyovers (permanent and temporary)

a) Permanent

d_1) Opelkreisel Flyover, Frankfurt/Main, (W.Germany) featuring an orthotropic steel deck and 5 spans of 25,7; 30,0; 45,0; 30,0; 25,7 m.

d_2) Chapel Street Flyover, Luton (G.B.) composite steel-concrete construction, featuring five spans of 57'4" containing 12 U B rolled beams each.

d_3) Moat Street and Hill Cross Flyovers, Coventry (G.B.) also a steel-concrete composite construction, using box type steel girders.

d_4) Croydon (G.B.) Flyover, again a steel-concrete construction featuring Preflex type longitudinal beams.

d_5) Gelsenkirchen (W.Germany) Flyover also a composite steel-concrete construction featuring portal piers and box girders.

b) Temporary

d_6) Temporary Flyover at Frankfurt/Main (W. Germany).

An all steel construction, to allow exceptional speed of erection. Beams and deck panels are of standard size, while the supports must vary in type and disposition to suit their random locations.

d_7) Movers Lane Flyover at Barking (G.B.).
The deck is a composite structure with a reinforced concrete slab cast on a preassembled beam frame. After curing, the deck units were laid on steel portals.
(Ref. 8 for d_1 to d_7 inclusive).

Of all the above mentioned classes the greatest user of steel could be the elevated highway, which to be economically advantageous should carry a concrete deck possibly prefabricated or even prestressed over steel girders.

Discussions therefore should be invited on the following points:

1) Type of steel girder best suited for collaboration with concrete deck

There are essentially two types in use i.e. open section and box section.
To exemplify:

Open sections are used generally in Italian Motorways, in most USA and Japanese elevated highways, in many of the examples mentioned previously and practically in all temporary Flyovers.

Box sections are found instead in the Genoa Expressway (Italy) in the Tinsley Viaduct (G.B.) in the Coventry (G.B.) Moat Street and Hill Cross Flyovers.

-Open sections are clearly favourable in production, erection and maintenance, therefore they are generally chosen. For composite concrete-steel structures, H sections, preferably non symmetrical, can be mass produced today by automatic processes. Symmetrical sections are sometimes used when the saving in weight appears too small to justify the higher production cost.
Open sections, moreover, allow an easier connection to prefabricated deck slabs.

-Box sections may have to be chosen for the following main reasons:
- Good torsional strength of the individual girders particularly valuable in curved spans
- Better aesthetic results, specially when the work shows prominently in natural or architectural surroundings, as is the case with the Genoa (Italy) Expressway.

Box girders may present design problems in trying to conciliate their cross dimensions with the requirements due to the span length, to the slab width, the general appearance and economical consideration. Narrow box girders are difficult for bolted joints that otherwise allow a quicker erection. Wider box girders have the advantage that many pipes and conduits can be accomodated provided the interior remains accessible for maintenance.

2) Type of deck slab best suited to collaborate with steel girder

Except for temporary jobs the great majority of deck slabs within the scope of this report are designed to collaborate with the steel supporting structure. This collaboration has found a very general acceptance and a discussion should preferably concern the extent of the collaboration (whether it should include dead loads or be limited to live loads) and on the best way to obtain it (for instance by induced bending) and aim at the practical issues rather than at the underlying principles already widely discussed.

Current types of deck slabs include the flat slab (of uniform thickness) and the raised slab (of variable thickness, sometimes much greater over the girders) which may prove useful when the center to center distance of the supporting beams and the cantilever portion of the slab induce fairly high negative moments over the beams, and would therefore require a very thick flat slab.

Since the beams must be connected almost to the top of the concrete to insure its collaboration extra long shear connector become necessary.

If the slab rise is large, part of the concrete may fall within the tension area of the composite cross section and cease to collaborate in compression.

The flat slab, within the generally used thickness (18 to 25 cm) presents no connection problems, requires only flat form work, which is important if sliding forms are adopted.

Further aspects of the deck problem are reviewed under the following point 4).

3) <u>Type of connection of deck to girder and sequence of erection required to obtain maximum collaboration between deck and girders</u>

For cast in place slabs there is little to discuss, since many types of shear connectors are satisfactorily in use.
The interest centers rather on the types of connectors for prefabricated slabs.
The present types would limit prefabrication severely because of the necessity to leave extensive gaps for the casting of concrete over the connectors after the erection.

An alternative example is offered by Dörnen and Meyer in "Stahlbau" of July 1960 (Die Emsbrücke Hembergen) but not many are available.

The sequence of erection opens many questions as to the practical possibility of full collaboration of prefabricated decks with the supporting structures.

4) <u>Type of connection between slabs to give trouble free performance and minimize traffic noise</u>

Unless a substantial wearing layer is added to cover the prefabricated slabs the traffic noise due to the joints cannot be avoided.
Many arrangements are thinkable to meet the mechanical requirements of prefabricated slab junctions but the noise problem remains.

A minimization of the noise might perhaps be obtained by arranging the junctions at a slant to the direction of traffic, but this would raise other problems in the shape, size and reinforcement of the slabs. This point is therefore open to imaginative thinking and discussion.

For the mechanical aspects of the connection between prefabricated slabs while it appears feasible to take care of vertical and horizontal forces it may be impossible to ensure the transmission of bending moments as it would be desirable **even assuming full** collaboration with the supporting structures.

The wish to obtain full collaboration is due to the idea that the quest for economically progressive construction may find an answer in prefabrication.

The converse point of view, that the answer may lie in further mechanization of the cast-in-site deck, is probably shared by the majority of designers but a thorough investigation of the possibility of prefabrication should not be neglected, in our opinion, before dismissing it from the roster of desirable solutions.

5) Type of safety curb to be embodied in deck slab (plus guardrails)

Very scanty material on safety curbs is available for discussion, probably due to the reliance on the superposed guardrails.

However it is felt that a prefabricated slab could be easily shaped at the free ends to ensure an efficient obstacle to the lateral deviation of vehicles. An idea perhaps worth investigating envisages turning up and than back the deck slab itself in order to provide a raised obstacle that a wheel cannot easily climb and a good hold for the guardrail.

Traffic experts should contribute their knowledge and experience to this important detail.

6) Use of steel in piers

Consideration of present relative costs of steel and concrete rule out the use of steel for tall piers.
Even for the comparatively low piers of elevated highways the bare comparison of costs appears to be against the use of steel; specially if the piers have traditional concrete foundations, since in this case the piers can be economically built by the same organization engaged in foundation work.

There are cases however where special types of foundations require a minimum of concrete, and the cost differential shows a margin on the side of steel.

An example worth mentioning, although not directly connected with highway construction, is found in the piers and foundations for the underground stations at Milano (Italy) Piazza Duca d'Aosta (Ref. 9) and München (W. Germany) Karlsplatz.

If special foundations should be adopted (such as bored piles incorporating steel columns, or driven tubular steel piles filled with concrete) the use of steel could lead to a completely prefabricated construction and thus allow, by an overhead method of erection progressing along the highway itself, to dispense with the cumbersome work at ground level that, is some areas, may constitute a major difficulty.

7) Although the problem of foundations is probably outside the scope of our Symposium some thoughts should be given to the very important fact that an elevated highway weighs substantially less than solid earthwork.

This again may make an incredibly important difference when the highway has to cross poor soils, specially if at a side slope with actual or potential danger of downslide. While an elevated highway can be supported on either steel or concrete piers resting on limited foundations that do not disturb the soil, the earthwork of a conventional highway will cut through the existing soil structure, remove or impose very considerable loads on the subsoil and completely disrupt both deep and surface watershed.

Other general advantages of elevated highways, such as:

- continuity of all existing ground structures (land and estates, roads and railways, telephones and low voltage distribution lines, drains and minor canals, etc.),
- avoidance of overpasses and fences,
- independence of carriage ways, which could be easily transposed, between exits, so that the slow traffic lanes, rather than the fast traffic lanes, would be adjoining those of the opposite direction and thus minimize the hazards of head-on collisions.
  Moreover, by arranging service areas between the transposed carriage ways, both traffic directions could use the same area,
- possibility of carrying pipes, conduits and cables under the deck,
- protection against wandering cattle and other intruders,
- speed of construction,

make the elevated highway a very desirable development.

It is therefore necessary to reduce its construction cost to the point where economical considerations will not overrule the other advantages.
This point is well worth discussing because, as already indicated, elevated highways are the most promising single user of mass fabricated structures.

On the subject see also Reference 10) and 11).

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