Tests on a prestressed concrete hollow-box bridge deck*

by F. W. Gifford, B.Sc.(Eng.), Ph.D., D.I.C., M.I.Struct.E., A.M.I.C.E.

Contribution by L. Clements

(*Ministry of Commerce, Northern Ireland*)

Dr Gifford's tests are most interesting to us as we have built a number of bridges of this type. In every case a full uniform transverse prestress designed in accordance with the Cement and Concrete Association's equivalent elastic slab method has been provided.

In Dr Gifford's model, four 10 g wires gave a total of 8,330 lb, being equivalent to only 75,000 lb in a full deck. If the " non-structural concrete topping " is neglected, this force provides an average transverse stress in the concrete between units of

$$\frac{8{,}330}{6 \times 120} = 11{\cdot}6 \text{ lb/in}^2$$

As the cables are at the third-point, the maximum stress at the soffit is only 23 lb/in^2.

In view of the width to span ratio, I would expect that a transverse prestress of about 500 lb/in^2 would be required. If this is so, the tests so far have proved only that a deck with a very small fraction of full transverse prestress is little better than one with none.

I would like to see further tests to measure the ultimate load capacity of a deck with the transverse prestress designed to ensure a residual compression of about 50 lb/in^2 under the worst case of calculated transverse moment for abnormal load, and then to compare this load with the maximum load supported by a deck having the same mechanical key and 0·5 in^2/ft mild-steel transverse reinforcement.

The use of the so-called non-structural topping was unfortunate, as it must have affected the results appreciably. Tests on individual beams show an increase in ultimate moment of about 40%. No doubt the topping had a similar effect on the ultimate resistance of the slab and I would like to see a full series of tests without topping, or alternatively the topping should have proper shear connexions and be allowed for in the design.

Contribution by A. R. Cusens and A. F. Abbasi

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Dr Gifford's excellent paper was of great interest to us, since we are in the final stages of an investigation of the effects of transverse prestress on the ultimate strength of prestressed concrete slab bridges. Dr Gifford's main object was, of course, to prove the efficacy of the in situ concrete key between the individual hollow-box beams making up the bridge deck, and it speaks well for this particular system that adequate transverse stiffness can be provided, within the range of the design load, without recourse to any transverse reinforcement.

Dr Gifford investigates the effect of varying amounts of transverse prestress up to a value expressed as 1·5 × maximum load to come onto any beam. If we interpret the paper correctly, this figure represents less than 2% of the longitudinal prestress. We are not familiar with the specification which makes this requirement, but agree that it is certainly conservative. For elastic behaviour the amount of transverse prestress does not affect the transverse stiffness of the deck, as Robertson† has already pointed out; the amount of transverse prestress is too small to give any marked increase in the transverse moment of resistance, and it is obviously ineffective against shear in beams. It seems pertinent to ask what purpose it is supposed to serve.

Dr Gifford's results in Figures 7 and 9 are all based on deflexions measured when the deck is behaving elastically. The main effects of increased transverse prestress would be felt in the inelastic range. However, the transverse prestress would have to be several times the quoted value for its effects to be appreciable. For the central loading considered by Dr Gifford, we estimate that a transverse prestress of about 15% of the longitudinal prestress should convert the collapse mechanism to the form shown in Figure I, giving an ultimate load in excess of 55 tons.

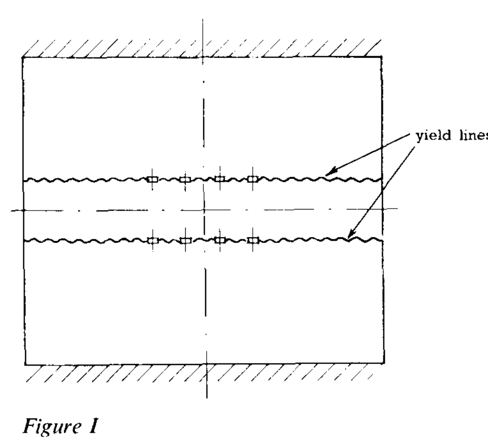

Figure I

*Pages 149-156 of *Magazine* No. 39

†ROBERTSON, R. G. Discussion on Load distribution in prestressed concrete bridge systems by Morice and Little. *The Structural Engineer*, Vol. 33, No. 1, January 1955, pp. 27-28.

In the design of this type of bridge, there is an obvious advantage in the use of an appreciable transverse prestress but none in the use of a trivial amount. Moreover, to design purely by elastic methods does not take much account of this.

Reply by the author

Mr Clements' contribution is interesting as it serves to draw attention to a point which is appreciated by some engineers but not by all. The test has shown that a bridge consisting of hollow-box units with absolutely no transverse prestress, but otherwise designed by the normal method now acceptable for inverted T beams placed side by side, transversely reinforced and filled solid, is quite adequate to carry the Ministry of Transport abnormal loading vehicle, and provides a more than adequate factor of safety.

Mr Clements says that the tests so far have proved only that a deck with a very small fraction of full transverse prestress is little better than one with none. This is not so. The test has shown that such bridge decks are adequate for the purpose for which they are designed, and the conclusion from this is that, if the equivalent elastic slab method calls for a transverse prestress of 500 lb/in^2 when either 23 lb/in^2 or no prestress is adequate, then surely it is wrong to apply this particular theory, as in doing so an extremely wasteful design will result. Again, this fact is known by a number of prestressed concrete engineers.

In my opinion, we have possibly become too theoretically minded. Instead of establishing theories to suit facts, we simply make assumptions, and then apply the theories which develop from these. I am not criticising the equivalent elastic slab theory, but am, in fact, simply saying that it should not be applied here. Surely it is high time that a theory be developed which is more applicable to the case—if a theory is required at all. Long before prestressing was developed as an efficient, normal method of construction, precast units were placed side by side and adequate transverse distribution was obtained by shear. It is suggested, therefore, that if any theory is required, it should be for longitudinal beams which are capable of transferring load from one to the other by shear, but which do not require elastic slab action.

I have already pointed out that it was a little unfortunate to use the so-called non-structural topping, but allowance has been made for this. This topping is frequently used on bridges, and it is, perhaps, not quite so unfortunate, as it does draw attention to the fact that there is a considerable reserve of strength where a so-called non-structural topping is used which is not allowed for in design. Mr Clements suggests that the topping should be allowed for in the design as long as a proper shear connexion is provided. I agree with this and suggest that, in view of the very small shear stresses involved, a proper shear connexion would be obtained by simple bond, provided that the top surface of the precast units were clean and not completely smooth.

I also agree that more tests would be worth while. A test with a transverse prestress of about 550 lb/in^2 which would provide a reserve of 50 lb/in^2 residual compression above the theoretical 500 lb tension calculated by the equivalent elastic slab method, would no doubt provide an even higher factor of safety; but as nominal transverse prestress is more than adequate, there seems little point in this unless the basis of design to carry working load is re-assessed.

In connexion with the contribution of Messrs Cusens and Abbasi, the figure of 1·5 times the maximum load for the transverse prestress on an individual beam is, in fact, the figure at one time agreed to by the Ministry of Transport as a nominal transverse prestress to be used when designing the beam in the longitudinal direction to carry the load which would come onto an individual beam from the wheels themselves, assuming no transverse distribution.

The purpose of the transverse prestress could be to satisfy anyone who would feel that the unit could spread apart, if no transverse steel were provided. I do not agree with the statement: " In the design of this type of bridge, there is an obvious advantage in the use of an appreciable transverse prestress but none in the use of a trivial amount ". There is no point at all in putting in any more transverse prestress than is necessary, and if a trivial amount is adequate then this should be used. There would be merit in putting in more transverse prestress only if a saving in the longitudinal design were acceptable. At the moment this is not so. Also it must be borne in mind that for bridges of the span discussed, it may well be a lot more economical to forego any saving in the longitudinal design if the very expensive transverse prestressing can be kept to a minimum or omitted altogether. One must always bear in mind that the best engineering structure is the one which serves the purpose required at the minimum cost, and not with the minimum of material.