

Automated determination of concordant profiles

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This Paper tackles one of the challenges of our time: to find effective roles for the power of the computer in the engineering design process. For this application, the Author sets out alternative approaches in §§ 7 and 8. He opts for the linear transformation method. At Ove Arup & Partners, we have designed scores of post-tensioned continuous bridges in recent years, and we have found the alternative procedure to be more effective.

58. The use of linear transformation is limited because it requires the prestress force to be uniform along each span. However, this force will not be uniform for the following reasons.

- (a) The form of construction (e.g. cantilever construction) requires a varying force.
- (b) Even with span-by-span construction (the method most likely to be covered by the Paper), the designer will often find significant benefit in overlapping cables over the piers. This can reduce the quantity of prestressing cable, and it reduces the number of connector anchorages which are large and can often be troublesome.
- (c) Friction losses vary the cable force along the span.
- (d) Even without friction, the creep losses act differentially along the span.

Hence the method is limited to preliminary stages in the design, when (c) and (d) can be treated approximately, and it is limited in its range of bridge types.

59. In the design office, the support and maintenance of computer programs is very expensive. Therefore, to give an economic return, programs must have a wider field of application. In particular, it is not practical to support different computer procedures for preliminary and detailed design.

60. The PREPAK program developed within Ove Arup & Partners treats secondary moments as part of the loading: its role is limited to analysis. This program produces diagrams of the range of top and bottom fibre stresses along the structure. The designer uses his/her judgement to adjust the profile to produce the desired pattern of stresses. In § 8, the Author comments that the user will require considerable experience. This is only partly true. A lack of experience can result in a large number of iterations, which will provide the user with a considerable amount of experience. We find that the procedure effectively harnesses the abilities of both machine and user.

61. Finally, I would also like to comment on the Introduction to the Paper, where the Author sets out the current state of rational design for continuous

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prestressed members. He suggests that reference 3 considers the problem only after the cross-section is fixed. This is true on the whole, but in Fig. 4 of that paper the function dP_3/dA is introduced. This shows how the cross-sectional shape can be altered to reduce the prestress force required.

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Mr Low's expertise, and that of his colleagues at Arup's, is well known. Their understanding of the parasitic moments that arise in continuous prestressed concrete bridges, and their use of such actions to enhance structural performance, is shown to particularly good effect in their design of continuous double-tee section viaducts. Such structures can work only if there are sufficient sagging secondary moments to relieve the hogging moments over the piers. The purpose of the Paper was not to belittle one particular design method, but rather to show that the design of the line of thrust itself was amenable to solution.

63. Mr Low's comments stem from the fact that most structures do not have a constant prestressing force. This was referred to briefly in §§ 54 and 55, but it is worth considering the implications in more detail. The comments attach too much importance to the linearity of the 'linear' transformation. It is true that if the prestressing force varies along the beam, then the transformation between the line of thrust e_p and the actual cable profile e_s will no longer be linear. What will always vary linearly is the secondary moment M_2 , since this is caused by a variation in the distribution of the support reactions. Therefore, if a cable profile e_s is chosen, such that $P(e_p - e_s)$ varies linearly, then the line of thrust will not alter. If the variation in P is known, this is a trivial modification to the procedure.

64. Perhaps of more consequence to the Paper would be the question of how a concordant profile can be derived for a cable whose force varies along the length. It was noted in § 13 that the bending moment corresponding to any (notional) external load could be regarded as a scaled concordant profile; the method works by building up combinations of such profiles. As it stands, that statement is also true only for constant prestressing force, but if the bending moment diagram that results from the notional load were scaled in inverse proportion to the prestressing force (since a smaller force must be applied at a larger eccentricity to cause the same curvature), a concordant profile for the varying force would result. As before, such profiles can be combined.

65. More advanced design programs based on expert systems are likely to be available in the near future.⁷ Those programs will have a very clear distinction between aspects of the design that can be calculated, and aspects derived from heuristic rules, even if they appear integrated to the user. I would contend that, in such programs, it would be more efficient to calculate that which can be calculated, leaving the rule-based portions of the system to deal with things which cannot be calculated. It is accepted that this may be a different balance from that which occurs in current *design* practice, although it reflects the similar change that happened in structural *analysis* with the introduction of the computer and matrix methods.

Reference

7. BURGOPYNE C. J. and SHAM S. H. R. Application of expert systems to prestressed concrete bridge design. *Civ. Engng Syst.*, 1987, 4, 14-19.