Proc. Instn Civ. Engrs, Part 2, 1979, **67**, Dec., 1133–1135

8182 DISCUSSION

Optimum design of concrete cellular spine beam bridge decks

A. B. TEMPLEMAN & S. K. WINTERBOTTOM

Professor D. Bond and Mr A. M. Abbas, University of Sheffield

The Authors show in Fig. 5 that for 20–50 m spans and 10–30 m deck widths single cell decks are cheaper than those with two or three cells, except that a three-cell deck is economical for the shortest span and greatest width. We agree that in general the single cell is superior, but there are circumstances when multi-cell or multi-spine decks are best. Although the number of cells is dependent on the span lengths and overall widths of decks, other design parameters such as unit costs of construction, tendon accommodation, traffic lane and footpath loading influence the choice of the best number of cells.

40. The Authors compare cell widths with overall deck widths for a single cell in Fig. 9 and have extended the formula in fig. 7a of Swann's paper[1] to a width of 30 m. We consider that this formula is unreliable above 15 m because only one of the decks in Swann's survey (design 53) has a width greater than this, and it may not be representative of designs in this region.

41. The cross-sections of bridge decks with overall widths of 12 m, 20 m, 25 m, 30 m and 35 m were designed using our computer program which includes the longitudinal effects described in reference 2 and the influence of HB and HA loading combinations[13] on transverse bending, shear lag, cross-sectional distortion and torsion.

42. Each deck had three continuous spans of 30 m, 50 m and 30 m, with depth varied parabolically between supports, and there were two vertical rows of 65 mm ducts to accommodate tendons in each web. The lower ranges of unit costs of three tenders submitted in January 1979 were used for labour, plant and materials for vertical formwork, and average unit costs were used for other items. Each deck had a footway 2·15 m wide each side.

43. Many decks illustrated by Swann[1] have footways which are protected from traffic. The influence of this on computed designs using the footway loadings in BS 5400[13] is shown in Table 3. Our ratios for 12 m wide decks can be compared with Swann's value of 0·43; the three-cell ratios are similar to those of Swann and the Authors. Our other ratios are higher than their values.

44. Although optimum design programs such as these use unit costs which include labour and plant in addition to the costs of materials, they have been criticized with justification for searching only for minimum quantities of concrete, reinforcement, formwork and falsework rather than for true minimum cost. The latter depends on the ingenuity and experience of the designer who should anticipate the constructional methods which will be used by the site engineer. It is essential to heed the advice of practising engineers such as Bellamy[3] when developing these programs, and the sensi-

Paper published: *Proc. Instn Civ. Engrs*, Part 2, 1979, **67**, June, 389–409.

Table 3. Bridge decks with different widths and footway loadings

Total width of deck, m	Unprotected footways		Protected footways	
	Number of cells	Cell ratio*	Number of cells	Cell ratio*
12	1	0·48	1	0·38
20	1	0·56	1	0·50
25	2	0·35	2	0·32
30	3	0·25	2	0·33
35	4	0·20	3	0·24

* Cell ratio = width of one cell measured from centres of webs/total width of deck.

tivity of designs to variations of unit costs within the limits of recent tenders should be tested.

45. We agree with the Authors that such programs as these will become useful design aids and relieve the engineer of much routine numerical work.

Dr Templeman and Dr Winterbottom

Table 3 confirms our belief that very simple empirical formulae such as those suggested by Swann[1] are of little value for deck design. There are just too many variables, parameters and conditions which affect the design to allow a simple formula to be fully representative. It would have been surprising if values for a major design parameter such as cell ratio had proved to be similar when evaluated using our program, Professor Bond and Mr Abbas's program and Swann's formula. Our results are for a single span constant depth deck, Professor Bond and Mr Abbas's are for a three-span variable depth deck and Swann's formula attempts to generalize for all types of deck.

47. Swann's work was not intended to be used as a design aid but was rather an examination of existing bridge designs to see whether any general trends could be isolated. In our view it is valuable in that it shows fairly clearly the most economical ranges of different bridge types (single or multiple spans, constant or varying depth, and so on) and it is also useful in estimating the likely cost of a bridge for different combinations of span, width and so on. Any more detailed generalization than this tends to break down in the face of the great variety of bridge deck configurations. When writing the Paper, we were aware that although we were tackling the same subject as Bond[2] there was little possibility of comparing results because the two pieces of work were applied to different bridge types. This difficulty faces the bridge designer also: experience of the efficient design of long multi-span bridges does not transfer easily to the economical design of a short single-span deck, and vice versa. For this reason, we favour the idea of small computer programs as design aids for specific bridge types rather than a large all-embracing program.

48. Professor Bond and Mr Abbas stress the importance of cost data in minimum cost design. We agree that minimum materials cost is not necessarily the true minimum cost. Obviously, it is essential that all the major cost elements should be represented in the cost function in the correct proportions. Our opinion is that excessive concentration on the minutiae of cost data can be non-productive. Our impression is that the actual configuration and dimensions of a bridge deck are relatively insensitive to changes in unit costs. The studies we have carried out indicate that it requires a very large change in the unit cost of one element relative to all the others for a noticeable change to appear in the actual deck design. Had the converse been the case, it would have been disturbing, and it would have suggested that minimum cost was not a stable criterion on which to design. Consequently, we believe that the cost function should be

correct in overall shape and proportion but does not need to be minutely exact. Occasional checks on the relative movements of unit costs are all that is needed.

Reference

13. BRITISH STANDARDS INSTITUTION. *Steel, concrete and composite bridges.* British Standards Institution, London, 1978, BS 5400, Part 2.