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An Optimality Criterion Method for Composite Bridge Deck Design

Une méthode basée sur le critère de l'optimalité pour le calcul du tablier composite d'un pont

Eine Optimierungsmethode für die Berechnung von Verbunddecken im Brückenbau

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Gellatly and Dupree (1) have discussed some of the important limitations which arise from application of mathematical programming techniques to structural problems. The need amongst others for the evaluation of derivatives of objective functions and constraints in most mathematical programming methods often leads to the expenditure of large computer time for the solution of realistic size structures, whose accurate description depend on large numbers of design variables. Whilst recognising that some new developments are directed towards ameliorating some of these problems, there is yet no indications that all of them have been solved.

On the other hand the broad group of methods, classed as optimality criterion approach, employ completely different techniques from those of mathematical programming and are thereby free from the weaknesses of the latter, although they have their peculiar shortcomings. In this discussion an example of the application of the method to the optimum cost design of composite bridge deck is presented.

In developing an optimality criterion approach for this problem, it is considered necessary to introduce the following simplifying assumptions:

1. The width of the bridge deck is fixed and the configurations of the deck are as shown in Figure 1.

2. For the steel girders, only universal beam sections with tabulated section properties from manufacturers are used.

3. The design of shear connectors is not considered although it is assumed that adequate shear connectors are provided between the slab and the beam to make it possible to use transformed section theory.

4. Shored construction is assumed to reduce the number of load cases to be considered.

The characteristics of the objective function are studied (2) through the aid of a computer program written to design the deck to the requirements of the British Code for Composite Construction (CP 117 1967 Part 2) and for Design of Steel Girder Bridges (BS 153 1966 Part 3 & 4).

Amongst the characteristics studied are:

1. The variation of deck cost with depth of slab for different cost of concrete, μ for a given girder. A typical example Figure 2 shows that the cost of concrete has very little influence on the cost of the deck.

2. The variation of deck cost with depth of slab for different cost of steel, λ. Figure 3 shows that the cost of girder has a predominant effect on the cost of the deck.

3. The variation of the deck cost with depth of slab for girders of the same serial size but of different weights. Figure 4 for four 914mm x 305mm girders shows that if a feasible design region exists with the possibility of choice of girders, the optimum design is obtained for the girder with the lowest value of weight per unit length.

These points dictate the mode of procedure for the optimization process. It is considered reasonable from the relatively minor contribution of the slab cost to choose, as a first approach, a slab depth based only on satisfaction of strength and deflection constraints. The table of girder section properties is ordered with respect to the weight per unit length to create a logical direction of search. A direct search method (3) with variable travel steps, controlled by a sensitivity device, is used to determine the optimum girder.

One of the main points to be emphasised here is the fact that the assumptions stated above, though restrictive, are necessary for application of the concept of optimality criteria. Secondly the knowledge of the characteristics of the problem is the principal factor responsible for the easy development of the simple direct search scheme. Lastly the problem falls into the first class of hierarchy discussed by Gellatly and Dupree (1) and further illustrates the point that optimality criterion methods are very efficient at dealing with only one or two of the hierarchy at a time.

R E F E R E N C E S

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APPENDIX 1 - NOTATION

C_c Cost of concrete per cubic metre.

C_r Cost of reinforcement per cubic metre.

C_g Cost of girder per 100 kilogram.

$\lambda = C_g/C_c$

$\mu = C_r/C_c$

SUMMARY

An example of the application of an optimality criterion method to the design of composite bridge deck for minimum cost is presented. Simplifying assumptions which facilitated the application of the method are discussed. It is argued that a study of the characteristics of the problem contributed immensely to the development of a simple direct search scheme for the optimal solution.

RESUME

On donne un exemple de l'application d'une méthode basée sur le critère de l'optimalité pour le calcul du tablier composite d'un pont,pour des frais minima. Puis des hypothèses simplificatrices qui ont facilité l'application de cette méthode sont considérées. Il est montré qu'une étude des caractéristiques du problème a contribué énormément au développement de combinaisons simples et directes pour la recherche d'une solution optimale.

ZUSAMMENFASSUNG

Ein Beispiel für die Anwendung einer Optimierungsmethode zur Berechnung von Verbunddecken mit minimalen Kosten im Brückenbau wird angegeben. Vereinfachende Voraussetzungen werden diskutiert, welche die Anwendung der Methode erleichtern. Das Studium der Problemscharakteristiken hat sehr viel dazu beigetragen, dass ein einfacher und direkter Lösungsweg gefunden werden konnte.

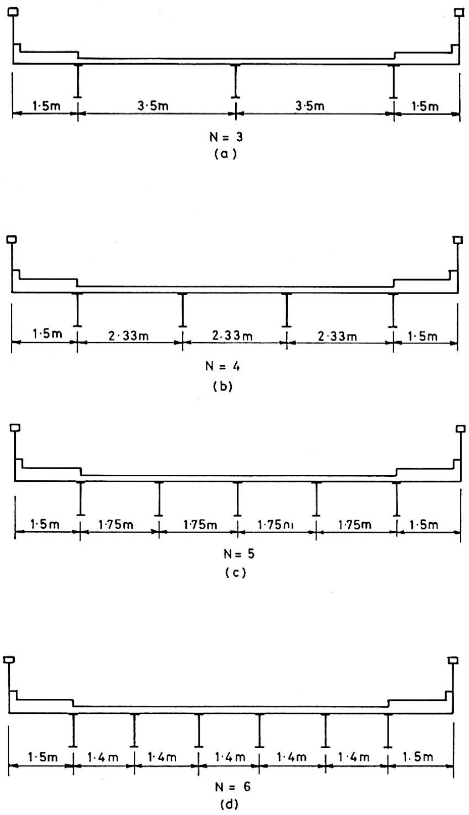

FIGURE 1

BRIDGE DECK CONFIGURATION

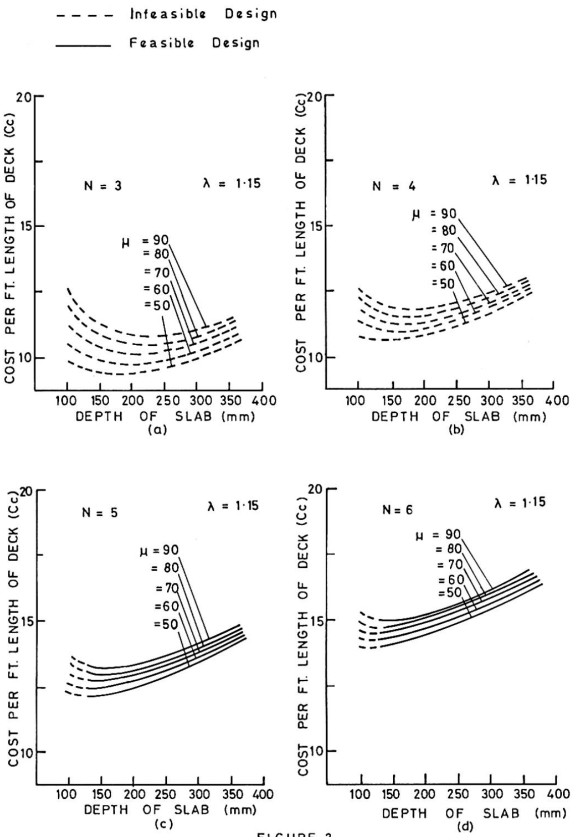

FIGURE 2

VARIATION OF DECK COST WITH DEPTH OF SLAB FOR DIFFERENT μ (762mm x 267mm x 194kg UB)

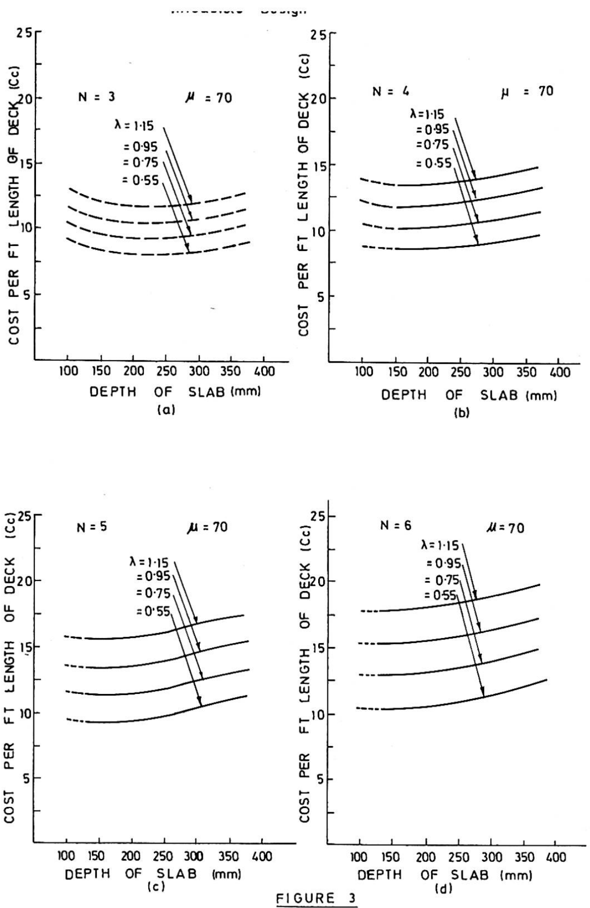

FIGURE 3

VARIATION OF DECK COST WITH DEPTH OF SLAB FOR DIFFERENT λ (914mm x305mm x224kg UB)

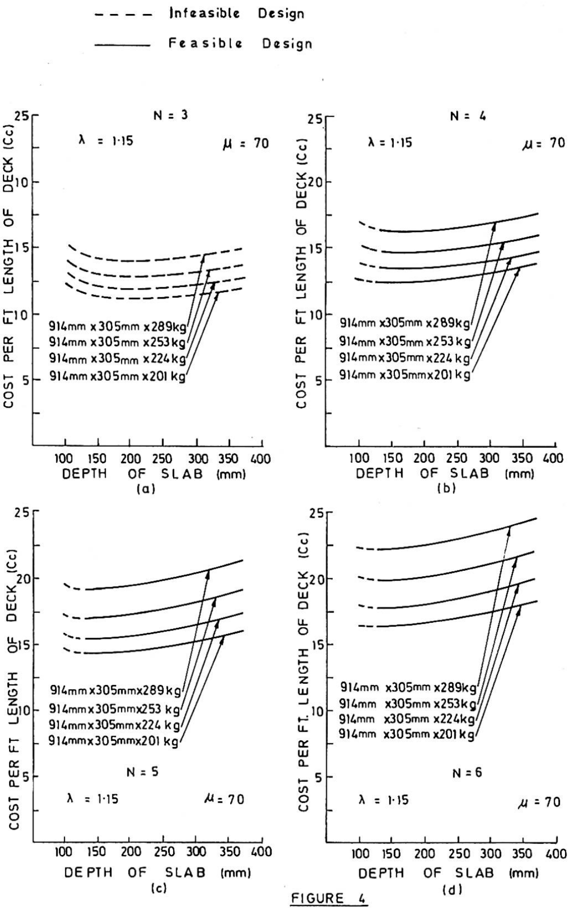

FIGURE 4

VARIATION OF DECK COST WITH DEPTH OF SLAB FOR GIRDERS OF SAME SERIAL SIZE

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