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Analysis of Bridge Beams with Jointless Decks

Dimensionnement de poutres de ponts à tablier continu

Berechnung von Brückenträgern mit kontinuierlicher Fahrbahnplatte

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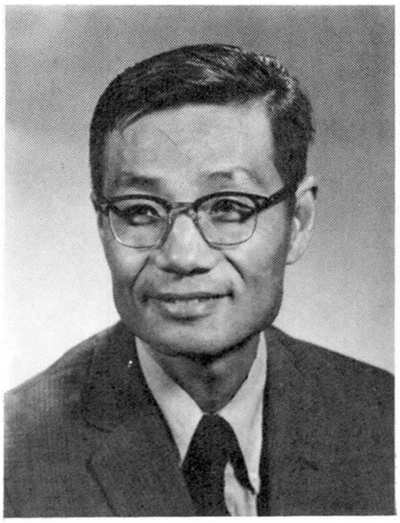

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SUMMARY

The use of beams with jointless decks is presented as an alternative solution for the construction and rehabilitation of multispan bridges. A finite element numerical approach is used for the determination of the instantaneous and time-dependent responses and for the strength analysis of such beams. Analytical results are shown which demonstrate the effectiveness of the method and conclusions are drawn concerning their overall performance.

RÉSUMÉ

L'usage des poutres de ponts, sans joint, à tablier continu présente une alternative pour l'exécution et la réparation de ponts à plusieurs travées. Une méthode numérique, avec des éléments finis, est employée pour la détermination des réponses instantanées et dépendantes du temps et pour l'analyse des états-limites ultimes de ces poutres. Des solutions analytiques mettent en évidence l'efficacité de la méthode. Quelques conclusions sont données sur le comportement de ces structures.

ZUSAMMENFASSUNG

Die Verwendung von fugenlosen Brückenträgern mit kontinuierlichen Fahrbahnplatten stellt eine alternative Lösung für den Bau und die Instandsetzung von Brücken über mehrere Felder dar. Ein finites Elementmodell wird zur Berechnung von anfänglichem und zeitunabhängigem Verhalten verwendet, welches schliesslich zur Analyse der Bruchzustände solcher Träger führt. Analytische Ergebnisse werden dargestellt, die den Erfolg der Methode beweisen und einige Schlussfolgerungen über das Tragverhalten dieser Träger erlauben.

1. INTRODUCTION

The use of jointless construction [1,2] for composite bridge beams has been considered as a possible solution for the persistent bridge maintenance problems due to the existance of expansion joints [3,4]. Expansion joints, regarded as an indispensable design requirement for the proper behavior of bridges, have always been a cause for deterioration of such structures.

Jointed bridges may become uneconomical due to the presence of joints and the ensuing maintenance problems resulting therefrom. The concept of a jointless structure, however, even though demanding some higher effort as far as design and analysis are concerned, has presented numerous advantages on its construction, performance and maintenance.

The idea of eliminating structural joints in the bridge deck, presents yet another interesting possibility. Partial continuity could also be obtained by simply casting a fully-continuous deck over the simply supported girders [2]. Such an unconventional constructional procedure,referred herein as "Deck-Continuous Beams", may prove to be an economical solution not only for the construction of new bridges but also for the rehabilitation of old ones.

Simple and fully-continuous beams, composite or not, under linear and uncracked conditions, can be analyzed satisfactorily by standard methods of theory of structures. Under non-linear and cracked conditions, however, numerical solutions are generally necessary. When only partial continuity is obtained, as is the case of deck--continuous beams, conventional analytical methods are no longer applicable, even for the most simple situations.

The purpose of this paper is to present the results of a full-range analysis of deck-continuous beams [5]. For such analysis a finite element numerical approach is developed. The beams may also be composite, continuous or not, in steel, reinforced or prestressed concrete. Girders may be pre- or post-tensioned, fully or partially prestressed,with bonded tendons. Various constructional sequences may be studied,supporting conditions may be varied, and different loading arrangements assumed. Instantaneous and time-dependent responses are obtained. Time-dependent material properties may be varied, and temperature effects can be included.

2. ANALYTICAL MODEL

A deck-continuous bridge beam may be composed of cast-in-place or precast girders of reinforced or prestressed concrete or steel girders, topped by a concrete deck-slab. Construction sequences and techniques may be varied, as well as cross-sectional shapes and material properties.

In the analysis, the structure is modeled by two distinct elements: a two-noded isoparametric beam element represents cross-sectional and material properties of the girders and deck, whereas the deck portion, connecting the adjacent girders, is modeled by a two noded, uniaxial, spring-like element. Both elements have their stiffness matrices modified to account for a variable nodal position, imperative in representing the actual supporting conditions of a general beam. The presence of pre- or post-tensioned tendons is obtained by a matrix superposition and three levels of mild reinforcement are also considered.

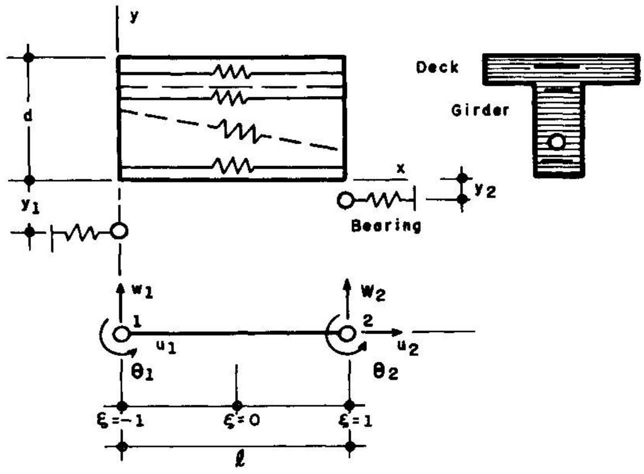

Fig. 2.1 - Beam element

Cracking is assumed through the Smeared Cracking Model and two different constitutive relationships are used for both girder and deck concretes.

The solution for instantaneous, static loading, is obtained by either increments of load or displacement, using the tangent stiffness matrix of the system and covering both the linear and nonlinear ranges of behaviour of the members. The effects of support displacements and temperature variation are also included in the instantaneous analysis. Time-dependent analysis considers the effects of aging of concrete, differential creep, differential shrinkage and prestressing steel relaxation. A time incremantal procedure is assumed and the suggested models of ACI Committe 209 [6] and PCI Committe on Prestress Losses [7] are adopted for both concrete and steel properties, respectively. Different loading sequences and construction stage may be predefined and solved in one single analysis, for a general beam type of any number of spans.

The model is validated by the analysis of eighteen different beam cases, results have shown in very close agreement with analytical and measured data, as shown in details in reference [5].

3. RESULTS

A deck continuous beam, as shown in Fig. 3.1 for only two spans may, under vertically applied loading, behave in two different ways: compression or tension may be induced in the deck connection between two adjacent girders. Such situations are primarily dependent on the supporting conditions and each dictates a different behavior of the structures. As illustrated in Fig. 3.2, a combined bending and rigid-body movement of the girders, supported at their bottom flanges, may produce either a pulling or squeezing effect on the deck connection, condition that can be set as a design variable.

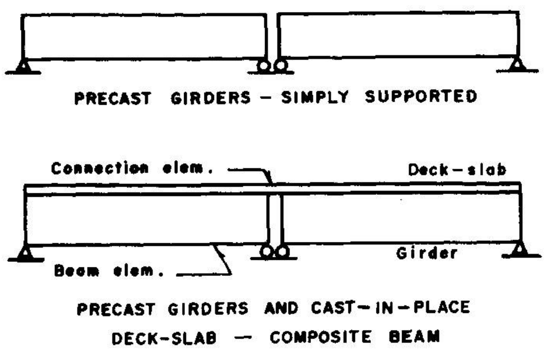

Fig. 3.1 - Deck-Continuous Beam

Compression in the deck-connection is obtained by allowing both girders to move inwards as in Fig. 3.2(b). Such situation produces an extra compressive force component which enhances the stiffness capacity of the member under bending. Should the structure be overloaded, however, such increasing compressive effect may overcome the compressive strength of the concrete connection, inducing an early failure of the member without enough ductility capacity (see Fig. 3.3, case c). Here failure is assumed when the ultimate compressive strain of the concrete is reached.

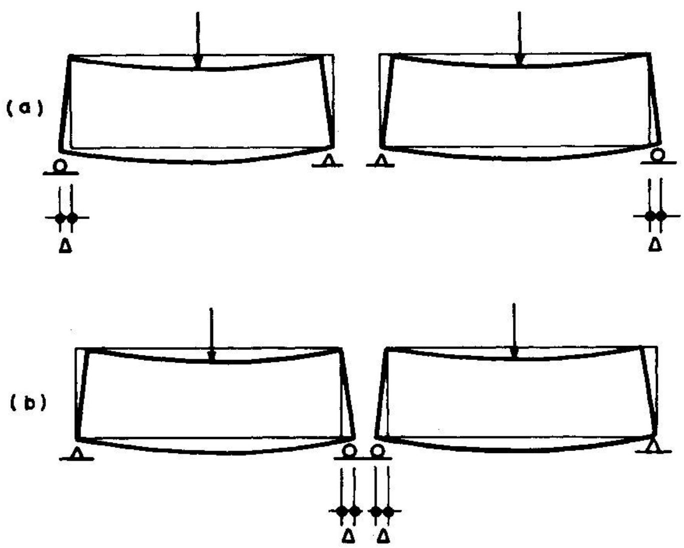

Fig. 3.2 - Girder movements under different supporting conditions.

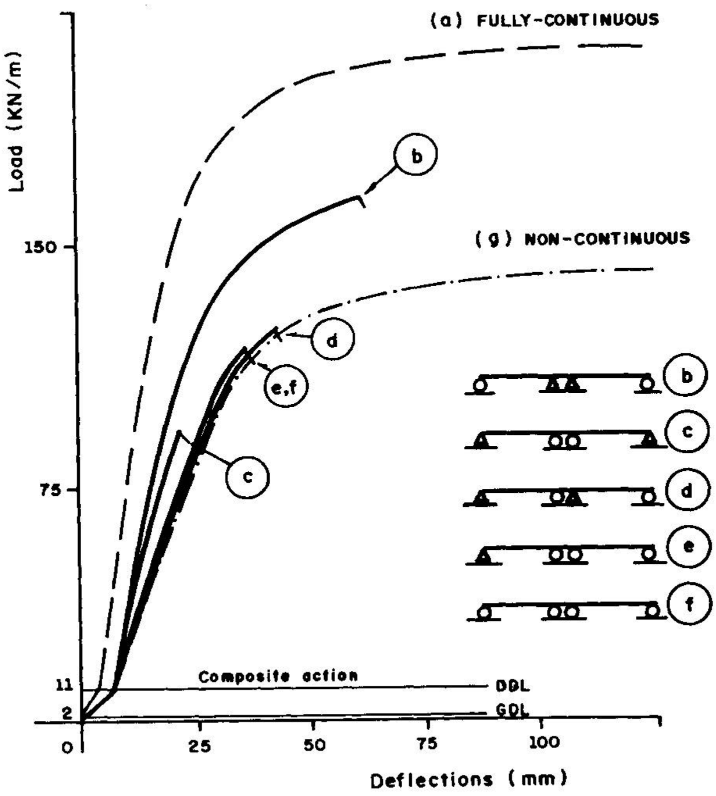

Fig. 3.3 - Load-deflection responses for various support arrangements, under unshored deck construction and full-span loading.

By permitting both girders to move apart from each other, when supported as in Fig. 3.2(a), tension is induced in the deck connection, equilibrated by coupled reactive forces at the interior supports. In this situation, the negative moment created at the connection also helps increasing the structure's bending stiffness. It makes use of the high tensile capactity of the negative mild reinforcement rather than the weak contribution from the concrete material.

Both cases, under compression and tension of the deck connection, are compared with the upper and lower bound cases of full and no continuity, respectively. As seen in Fig. 3.3, several load--deflection relationships are shown, corresponding to the different cases: girders and deck are fully-continuous (a), the deck is fully--continuous but over two simple girders (b,c,d,e and f) and there is no continuity whatsoever (g), both composite beams are simply supported. All three cases correspond to a two 15,25m span beam with W33 x 118 steel girders and a 2,13m by 0,18m reinforced concrete deck slab. Unshored construction is assumed and the load is uniformly distributed.

As seen in their instantaneous load-deflection responses, the tensile behavior of the concrete deck connection (case b) presents a reamarkable enhancement in strength and ductility, with slightly greater bending stiffness, as compared to the compressed connection (case c). Failure, in this case, is likely to be determined by yielding of the mild reinforcement in the connection.

Similar behaviors are found for beams containing more then two spans, with either reinforced, prestressed or steel girders. The effects of temperature variation and the time-dependent effects from creep and shrinkage have been observed to produce, in the deck-continuous beams (case b) , the same type-behavior that would be found if the beams were fully-continuous, as in case (a).

By having the girders simply supported at all aupports, i. e. by providing elastomeric bearing pads or rollers, as in case (f),the structure's response is observed to be slightly stiffer than the one presented by the jointed beams (case g). Cracking at the deck connection is expected under overload conditions; however, this seems to be less demaging to the structure than the presence of a joint. Should failure occur, by extensive yielding or rupture of the deck connection, the structure will provide all the ductility capacity as the jointed beams. This situation is likely to be found when jointed bridges are rehabilitated, by casting a fully--continuous deck-slab over the still serviceable girders.

4. CONCLUSIONS

The use a fully-continuous, jointless deck-slab has been presented as an alternative solution for the construction of composite bridge beams with cast-in-place or precast girders, as well as for the rehabilitation of jointed bridges. The behavior of deck-continuous beams has been observed to be very satisfatory under dead and service load stages. The behavior is primarily affected by the external boundary conditions. Under some specific conditions of the beams, a conservative and simplified design approach could be used, as to consider the different spans as independent simply supported composite beams. Should a more realistic design approach be needed the structure shall be analyzed by some appropriate numerical procedure, such as the one presented herein [5].

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