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Shear Connections for Composite Prestressed Beams

Dispositifs de liaison entre les nervures en béton précontraint préfabriqué et le hourdis coulé sur place, dans les poutres en T composées précontraintes

Schubverbindung bei zusammengesetzten, vorgespannten Balken

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Introduction

In the design of composite prestressed concrete beams, when the capacity of the natural bond between the precast and in-situ members is not sufficient to resist the horizontal shear at the contact surface of the two concretes, steel stirrups extending from the precast concrete into the in-situ concrete are often used. It is not definitely known whether the effectiveness of these stirrups is due to their action in directly resisting horizontal shear, or due to their action in indirectly maintaining and increasing the ultimate value of the shear resistance of the contact surface by tying the precast and in-situ members together.

To study the performance of stirrup shear connections, load tests were carried out on composite T-beams with different types of shear connections between the precast prestressed concrete webs and the lightly reinforced in-situ concrete flanges.

Load Tests

Test Beams

Fig. 1 shows the four types of beams tested.

In Type A, the stirrups were designed to tie down the flange, while offering no direct resistance to horizontal shear at the contact surface between flange and web. Direct resistance of the stirrups to horizontal shear was eliminated by wrapping them with ten turns of electrician's insulation tape. The top surface of the web had an exposed-aggregate finish to bond with the in-situ flange. A central strip, 1.75 inch wide, on the top surface was painted with two coats of bitumastic paint, to ensure a primary shear failure at the contact surface.

In Type B, the stirrups which projected into the flange had open tops, and the length in the flange was thinly coated with bitumastic paint to eliminate resistance to vertical separation of the flange from the web.

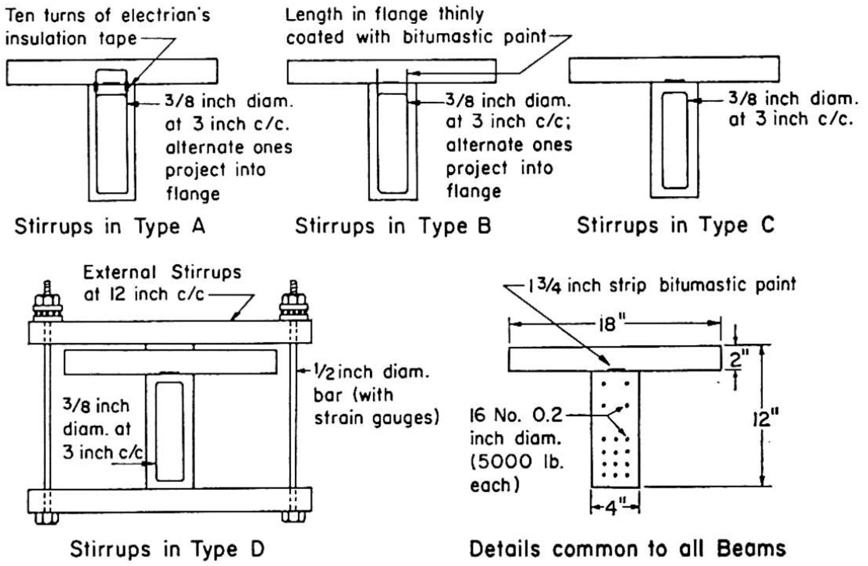

Fig. 1. Details of the four types of test beams (each 10-ft. long overall).

In Type C, natural bond was the only shear connection.

In Type D, external stirrups were used (after the natural bond between the two concretes had been destroyed by loading). The vertical bars of the external stirrups were tensioned by screwing the nuts at their ends until a pressure of 300 lb./sq. in. was achieved at the contact surface between the two concretes. The correct tension was indicated by strain gauges fixed to the vertical bars. Torsional strains in the vertical bars were eliminated by using a thrust ball bearing for each bar.

Instrumentation and Test Procedure

Fig. 2 shows the loading arrangement for Type D beams. The loading arrangement for the other types of beams was the same as that for Type D, except that external stirrups were not used.

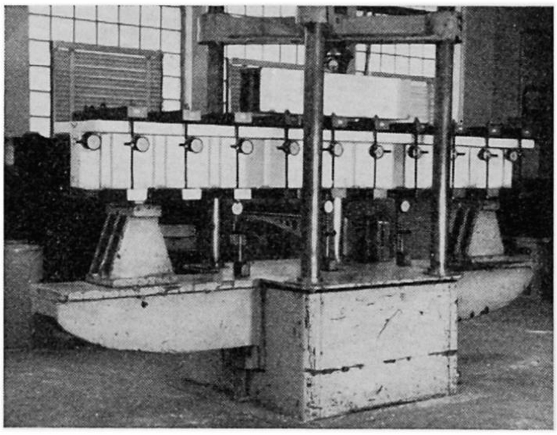

Fig. 2. Loading arrangement for type D beams.

Loads were applied by increments of about $^1/_{20}$ of the ultimate loads. Deflections, strains, crack widths, slip and vertical separation between flange and web were measured for each incremental load.

Test Results

Deflection

Typical deflection curves in Fig. 3 show that, at low loads, the behaviour of all four types of beams was similar, but, at higher loads, deflections and hysterysis effects were least in Type A. For example, the deflection of the Type A beam at $W = 18$ tons was less than that of the Type B beam at $W = 17.4$ tons, and less than that of the Type D beam at $W = 16$ tons.

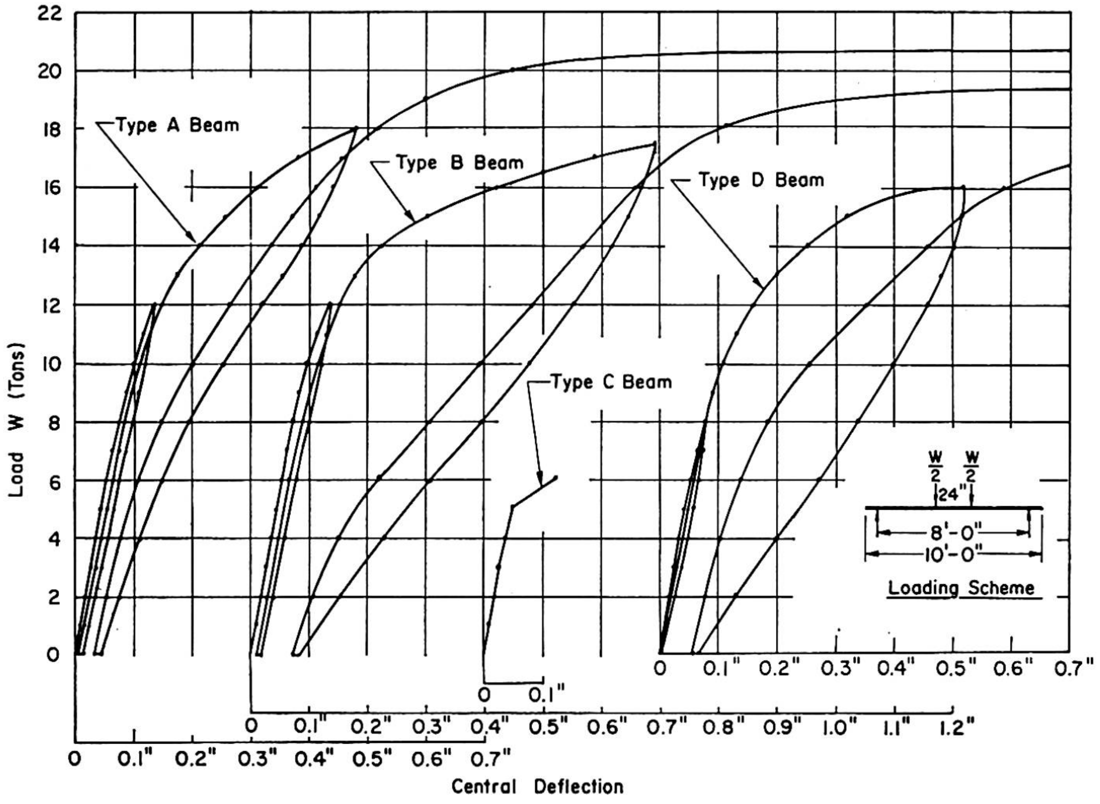

Fig. 3. Load-deflection curves.

Slip Distribution and Development

The general distribution of slip was the same in all four types of beams, i.e. least at mid-span and largest between loading points and supports. For the same loads, slip was least in Type A. The superiority of Type A was very evident at high loads.

Fig. 4 shows typical load-slip curves.

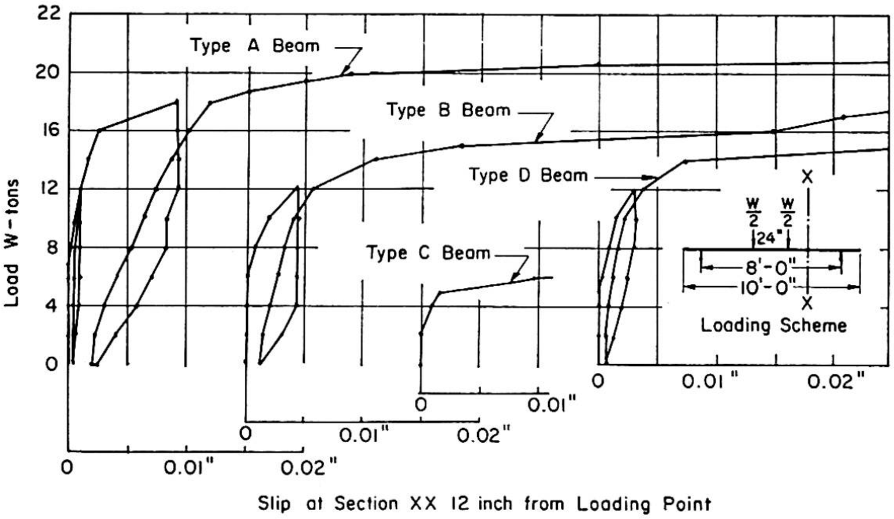

Fig. 4. Load-slip curves.

Vertical Separation between Flange and Web

Vertical separation occurred in every type of beam. Fig. 5 shows that initially such separation was negative, i. e. the flange and web moved towards each other, showing that a small crack had existed between flange and web before loading tests started. Such cracking was probably due to differential shrinkage and creep.

At high loads, vertical separations were all positive and were least significant in Type A.

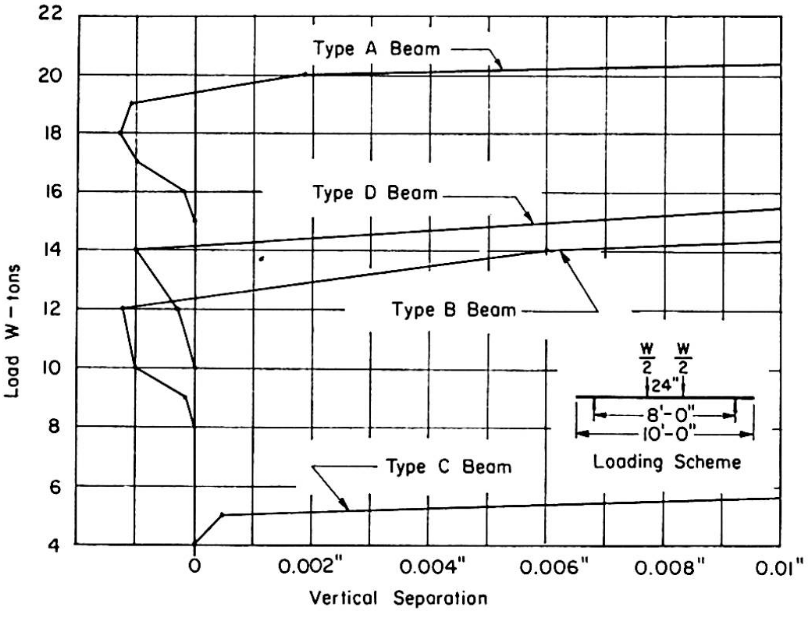

Fig. 5. Vertical separation between flange and web measured at end of beam.

Crack Widths

Fig. 6 shows the average width of the cracks in the region between the loading points. Up to about 14-ton load, there was no appreciable difference in crack widths in the different types of beams. After 16-ton load, the superiority of Type A beams became evident. Referring to Fig. 4, it is seen that at 16-ton load the slip in Types B and D beams was very excessive as compared with slip in Type A beams.

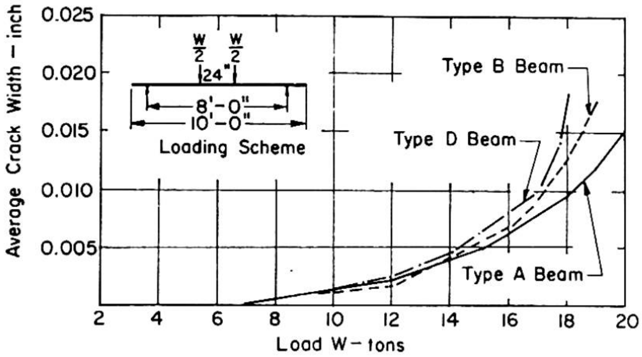

Fig. 6. Average width of cracks between loading points.

Ultimate Strengths

Test results show that, on average, experimental ultimate strengths were 98.1% of theoretical values (assuming full composite action) for Type A beams. The corresponding percentages were 88.6 and 87.2 respectively for those of Type B and Type D. These percentages reflect the degree of composite action achieved, and show that Type A beams were the most satisfactory.

Conclusions

1. Natural bond plus steel stirrups which effectively tie the precast and in-situ members together is an efficient shear connection, even when the stirrups do not offer direct resistance to horizontal shear at the contact surface of the two concretes.
2. Stirrups which offer direct resistance to horizontal shear but do not tie the two members together are inefficient.
3. Where natural bond has been destroyed, appreciable composite action can be achieved again by imposing a normal pressure at the contact surface, i. e. by creating mechanical friction to resist the horizontal shear.
4. Natural bond by itself is not a satisfactory shear connection, even for low stresses, because failure occurs with little warning.

Summary

Load tests were carried out on composite T-beams with the following types of shear connections between the prestressed precast concrete webs and the reinforced in-situ concrete flanges: (A) Stirrups which tied the flange and web together but offered no direct resistance to horizontal shear at the contact surface of the two concretes. (B) Stirrups which offered direct resistance to horizontal shear but did not effectively tie the flange and web together. (C) Natural bond by itself. (D) External stirrups. It was observed that Type A shear connection was the most efficient and reliable type of connection.

Résumé

Des essais en charge ont été effectués sur des poutres en T composées, en utilisant les types suivants des dispositifs de liaison entre les nervures en béton précontraint préfabriqué et le hourdis en béton armé coulé sur place: (A) Des étriers qui liaient le hourdis et les nervures mais n'offraient aucune résistance directe au cisaillement le long de la surface de contact des deux types de béton; (B) Des étriers qui résistaient directement au cisaillement longitudinal mais ne liaient pas efficacement le hourdis et les nervures; (C) Adhérence naturelle seulement; (D) Etriers extérieurs. Il a été constaté que la liaison du type A était le type le plus efficace et sûr de tous les dispositifs essayés.

Zusammenfassung

An Plattenbalken mit vorfabriziertem, vorgespanntem Steg und an Ort hergestellter Platte wurden Belastungsversuche durchgeführt. Steg und Platte wurden dabei folgendermaßen miteinander verbunden: (A) Mit gut verankerten Bügeln, die jedoch an der Kontaktstelle von Steg und Platte keinen direkten Schubwiderstand aufweisen. (B) Mit Bügeln mit direktem Schubwiderstand an der Kontaktstelle, aber mit schlechter Verankerung im Beton der Platte. (C) Nur mit natürlichem Verbund ohne Armierung. (D) Mit außerhalb des Betons angeordneten Bügeln.

Die Versuche zeigten, daß Typ (A) die leistungsfähigste Verbindung von Steg und Platte gewährleistet.