Continuous composite decks

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Planchers mixtes continus

Durchlaufende Verbundplatten

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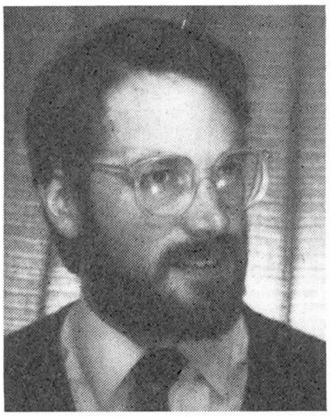

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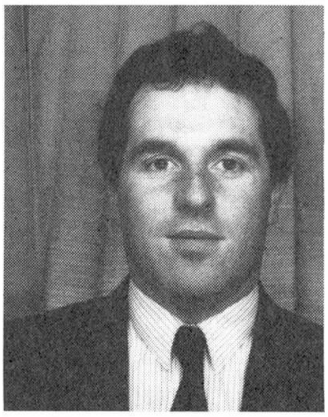

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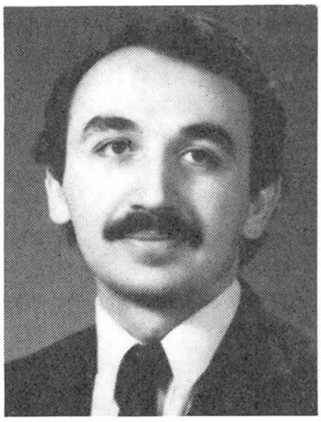

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SUMMARY
Composite floor decks comprising composite slabs acting with steel sections to provide composite beams are a common form of construction. This paper investigates the variation in behaviour brought about by changes in the support condition and continuity between beams. Comparisons are made between simply supported beam tests carried out using roller and web cleat supports and between continuous beam tests with minimal and optimal slab reinforcement.

RÉSUMÉ
Les planchers mixtes, constituées d'une couche de béton interagissant avec des sections métalliques afin d'obtenir des poutres mixtes, sont couramment utilisés en construction. Le présent article étudie l'effet des conditions d'appui et de continuité sur le comportement de la dite structure. On y fait des comparaisons entre des poutres d'essai sur appuis simples avec supports à rouleau et à méplat, ainsi qu'entre des poutres d'essai continues avec armatures minimale et optimale de la dalle.

ZUSAMMENFASSUNG
Aus Plattenelementen und Stahlträgern zusammengesetzte Verbundböden sind eine verbreitete Konstruktionsart. Hier werden Streuungen im Verhalten solcher Teile unter wechselnden Stützenlagen und Durchlaufwirkung untersucht. Einfeldplatten auf Rollenlagern werden mit Durchlaufplatten und Minimal- und Optimalbewehrung verglichen.

1. INTRODUCTION

Composite decks are a common form of flooring system in America and Europe [1]. They are formed by using profiled steel sheeting as permanent formwork and tension reinforcement to the concrete slab. Welded shear connectors may be used to connect the slab to the supporting steel sections to form a composite beam.

In Britain these beams are often designed and detailed as simply supported spans as the steel connection is then uncomplicated and inexpensive. The profiled steel sheeting is normally laid continuously over several spans along with a light mesh which serves as shrinkage and fire reinforcement. It is common for whole floors to be cast in a single uninterrupted operation.

Although the design is for simple connections there exists some scope for the beam to transfer moment to adjacent spans and act as a continuous element. The slab reinforcement will carry some tension and the corresponding compression may then be transferred through the lower part of the connection.

The authors have carried out a series of full scale tests to study the effect of partial shear connection on stiffness and strength [2]. During the tests they have been able to observe the effect of end connection on beam behaviour. Six beams have been tested, four single spans and two single spans with adjacent cantilevers. Fig. 1 shows a typical test specimen and loading arrangement. Table 1 gives the main test parameters.

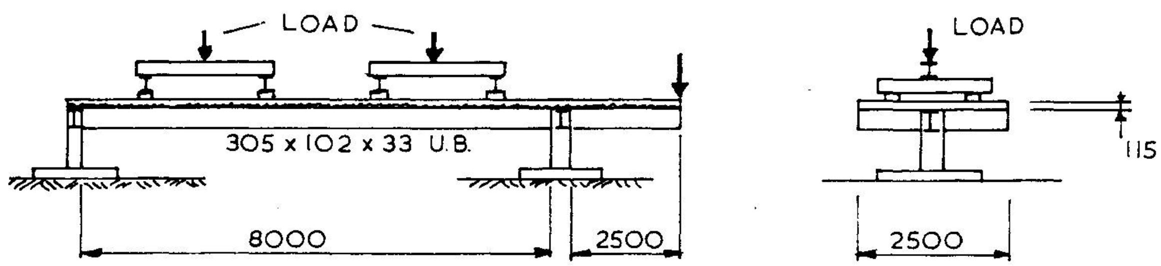

Fig. 1 Test arrangement

Beam	Span type	nominal% connection	Concrete strength N/mm^2	Steel Yield N/mm^2	Reinforcement over support %
1	S/S	50%	42	297	-
2	S/S	30%	44	325	-
3	S/S	40%	40	307	-
4	S/S	20%	40	317	-
5	C	50%	33	319	0.1%
6	C	50%	40	309	1.0%

Table 1 Test parameters

2. SINGLE SPAN BEAM TESTS

The construction of unpropped composite beams gives rise to deformations in the steel section due to the weight of wet concrete. All of the beams tested were cast unpropped with end cleats securely bolted to the stub columns. The web cleats were then removed for initial static tests on roller supports. Each bolt in the connection had to be "hammered out" and there was a definite horizontal movement recorded as the steel section relaxed and rotated at each end. Clearly the web cleats had offered some form of restraint.

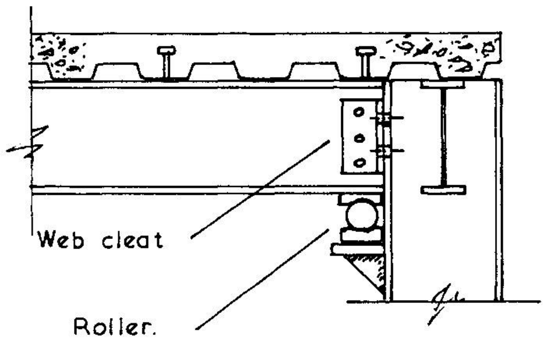

Fig. 2. Support details

The beams were loaded to working load with the ends resting on the roller supports shown in fig. 2. They were then off-loaded, the web cleats replaced and then reloaded to failure. The deflections at mid-span were recorded in each test and this allowed comparison between the stiffness of the roller supported and web cleated end conditions. In addition comparisons were made with stiffnesses predicted using simple beam theory with the assumption that 100% interaction occurred.

The comparisons are shown in the interaction diagram, fig. 3 which is a plot of test stiffness over theoretical stiffness against degree of interaction. This figure records approximately 20% difference between the roller supported and web cleated condition. It is apparent that the assumption that the web cleats give rise to an idealised pin support is conservative. It can also be seen that the analysis is less than conservative, especially for the beams with low interaction levels.

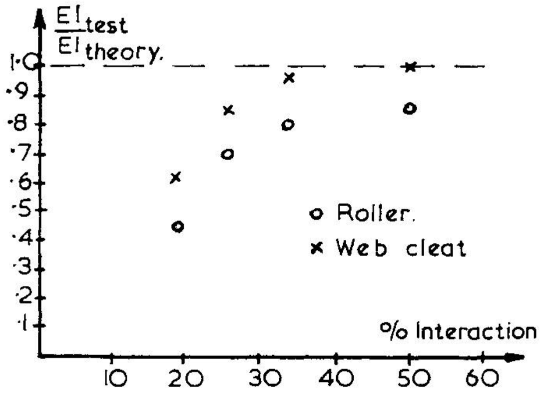

Fig.3. Effective stiffness for varying interaction

The beams were designed for partial interaction levels below 50% and consequently as the beams were loaded to failure the slabs moved in relation to the steel section. This movement or slip is shown in fig. 4 and it can be seen that the maximum end slip generated is in the order of 1.0mm. This slip may not occur if the slab was continuous between spans as each adjacent span would give rise to opposing movement in the slab.

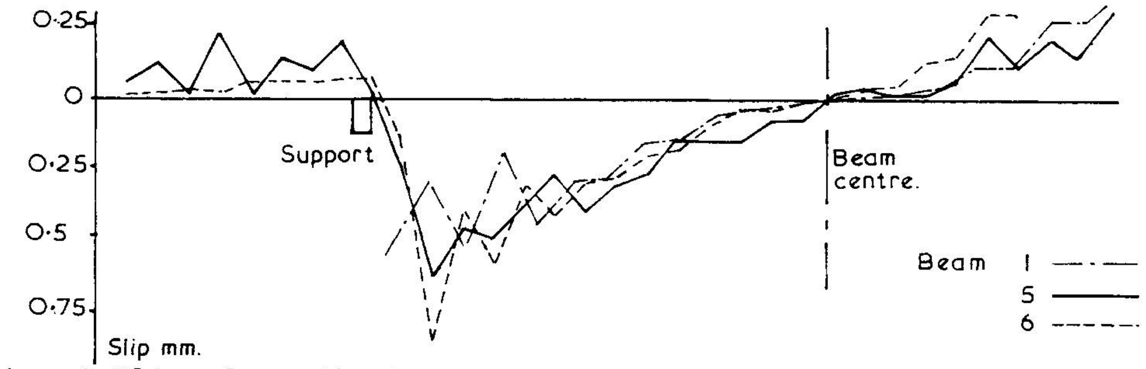

Fig. 4 Slip along the beams

3. CONTINUOUS BEAM TESTS

The simple span tests had shown that web cleat connections offer some moment restraint between the beam and column. The continuous span tests were devised to investigate the increase in this restraint once the slab continued over the support. The first of the two beams tested (beam 5) used web cleat connections and light mesh reinforcement as before so simulating a beam detailed for idealised pin connections. The second beam (beam 6) used a full end plate and substantial slab reinforcement over the connection area. This enabled a comparison of the moment transfer generated in a beam designed and detailed as simply supported and a beam designed to provide maximum continuity but using the same steel section and slab geometry.

Initially each beam was loaded with a point load on the cantilever alone. This was to investigate the transfer of moment and rotation between loaded and unloaded spans. The concrete slab over the support cracked early during the loading of the beam with simple end connections. Despite this cracking it was possible to achieve over 40kNm. support moment in a beam that was designed as simply supported. During this test it was noted that almost no moment transfer or deformation occurred between spans and it was assumed that the moment generated was resisted by the very stiff column support. Far fewer and smaller cracks were noted in the test on the beam full slab reinforcement. This connection carried a support moment of 185kNm which was almost equal to the value expected from the design. Fig. 5 shows a comparison of the moment rotation characteristics for both beams.

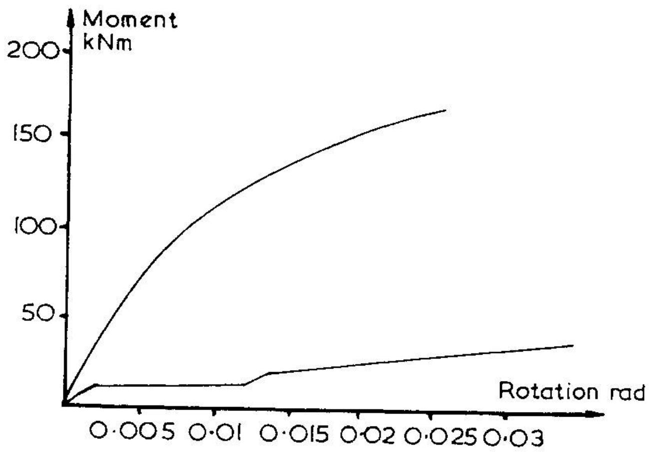

Fig. 5 Moment rotation

Each beam was then loaded on the main span with an eight point load system as used in the single span tests and with a point load at the end of the cantilever. The loads were applied to ensure that the rotation of the beam and the cantilever remained the same over the support throughout the test. This simulated an internal support for beams loaded uniformly on each span and provided further information on the moment capacity and moment rotation characteristics for this joint. In addition it was possible to investigate the stiffness of the beams and the longitudinal slip between slab and steel section.

Table 2 gives a resume of the loads achieved in each of the tests and it can be seen that the effects of continuity on the load carrying capacity of the beams is marginal. For simple connections the continuity of the concrete makes little difference to the maximum load achieved. The provision of full end connection and substantial reinforcement achieved an increased load capacity of 23%.

Beam	Maximum Test Load kN	Design Load kN
1	196	184
2	158	158
3	174	169
4	128	134
5	195	186
6	240	212

Table 2 Test Results

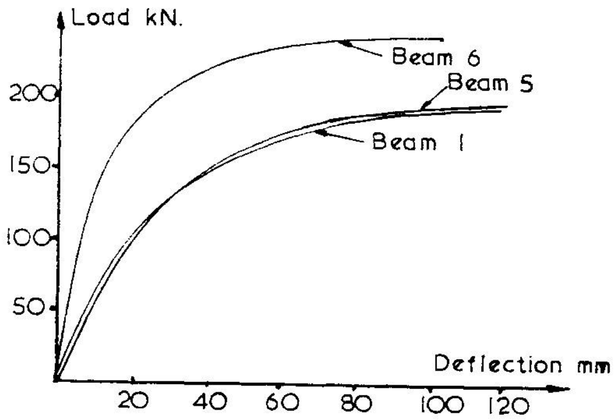

Fig. 6 Load deflection curves

Fig. 6 shows the relationship between the mid-span deflection, recorded for the main span, and the load applied for tests 1, 5 and 6. It can be seen that there is no difference in behaviour between the two tests that have simple end connections. This may show that the continuity of the concrete slab has little effect on the beam stiffness. The test carried out with a designed continuous connection was considerably more stiff than the other beams.

It is interesting to note the distribution of slip between the slab and steel section and to make comparisons with the slip distribution found in the simply supported beam. Fig. 4 shows the slip distribution for beams 1, 5 and 6. For both the continuous beams tested there is no slip present at the support point. However the slip recorded only 300mm away is similar for each of the three beams. This is possibly explained by the slip strain close to the support matching and cancelling the strain generated due to the hogging moment in the concrete.

4. CONCLUSIONS

This paper has described results from a series of composite beam tests. The comparisons made between simple span beams, continuous beams with simple connections and continuous beams have given the following conclusions:-

a) Simple span beams with web cleat connections are approximately 20% stiffer than simple span beams with roller supports.

b) The ultimate loads obtained in the tests for simple beams and continuous beams with simple connections did not vary by a large amount.

c) The stiffness of beams with simple end connections are similar for both simple spans and for the condition where the concrete slab is continuous.

d) The stiffness and strength of continuous beams that have been designed to transfer moment is substantially greater than for beams with simple end connections.

5. ACKNOWLEGEMENTS

This work has been carried out under the sponsorship of the Steel Construction Institute and the authors would like to thank their sponsors for the help and encouragement provided during the programme.

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