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Strengthening Beams with Externally Bonded Flexural and Shear Reinforcement

Renforcement de poutres par des armatures extérieures adhérentes

Verstärkung von Stahlbeton T-Querschnitten mit aufgeklebter Bewehrung

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1. INTRODUCTION

There are difficulties in predicting the contribution that bonded plates make to the flexural strength of reinforced concrete beams or slabs which are strengthened by gluing steel plates onto the tension face of the concrete, because ripping or peeling off of the plate can occur before the full strength of the steel plate is developed. Even when the yield strength of the steel is achieved, the member may be lacking in ductility due to the sudden parting of the plate from the concrete. Also, a beam may not have the shear strength to carry the load which the increased flexural capacity would permit. Tests are reported here which indicate that external shear reinforcement can be used to inhibit ripping failure, to increase shear strength and to enhance the ductility of tee-beams which are strengthened in flexure by external reinforcement bonded with epoxy resin adhesive. These tests also indicate that conventional reinforced concrete design procedures may be used to determine the external flexural and shear reinforcement required, provided that additional shear reinforcement is located near the ends of the flexural plate.

2. DESIGN OF EXTERNALLY REINFORCED T-BEAMS

Reinforced concrete tee-beams were designed on the basis of conventional procedures; in this case, the procedures of the British code, BS8110. An ordinary reinforced concrete tee-beam was designed to have the same load carrying capacity in flexure and in shear, for the intended arrangement of applied loads, and with links at the maximum spacing allowed. Two thicknesses, of externally bonded plates were chosen, which gave width to thickness ratios of 33 and 20, and the design flexural strengths for the plated sections were determined, following BS8110 procedures as closely as possible. The effective depth of the section was taken as the distance from the compression surface to the centre of the tensile force, taking account of the area and the yield stress of the ordinary reinforcing bars and the bonded plate. The additional shear reinforcement required to bring the load carrying capacity of the beams in shear up to the enhanced load carrying capacity in flexure was then determined. The design included the curtailment of the flexural plates, so that their ends were located where concrete was not influenced by compression caused by concentrated forces acting on the beams. General details of the beams are shown in Fig.1. The ultimate flexural strength of the sections were also calculated using strain compatability and assuming perfect bond between the plate and the concrete.

3. BEAM TESTS

Load deflection curves for a series of test beams are shown in Fig.2. Beam B2 was the basic ordinary reinforced concrete beam and exhibited the ductile behaviour of an under-reinforced beam failing in flexure. Beam B4 had a 3mm plate added. The plate peeled off when the load W reached 40kN. Beam B5 had a 3mm flexural plate and 2mm by 10mm shear straps at 150mm centres added. The straps were bonded to the sides of the web and in holes through the flange. Failure was caused by fracture of a strap at the end of the flexural plate. Beam B7 was similar to beam B5 but the ends of the shear straps were bent across the top of the beam and were welded together, and an enlarged strap, 3mm by 10mm, was used at the end of the flexural plate. The load-deflection curve indicates considerable ductility before failure, which in this instance was by shear-compression in the unplated region of the beam. Strain measurements confirmed that the flexural plate had yielded at mid- span.

4. CONCLUSIONS

The tests carried out indicate that conventional design procedures may be used to determine the dimensions required for externally bonded flexural and shear reinforcement used to strengthen existing reinforced concrete tee-beams, provided extra shear reinforcement is used near to the ends of of the flexural plates, to carry the additional peeling forces at these locations. Further investigation is required to determine the amount of this additional reinforcement required and its optimum location. To be fully effective, external shear links must be securely anchored and be in contact with the top and bottom surfaces of the beam. With careful detailing of the external shear reinforcement, flexural ductility may be achieved in beams which are strengthened with externally bonded reinforcement.

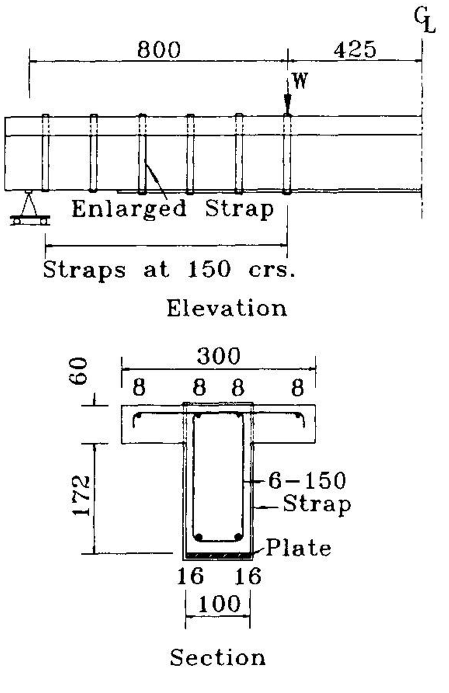
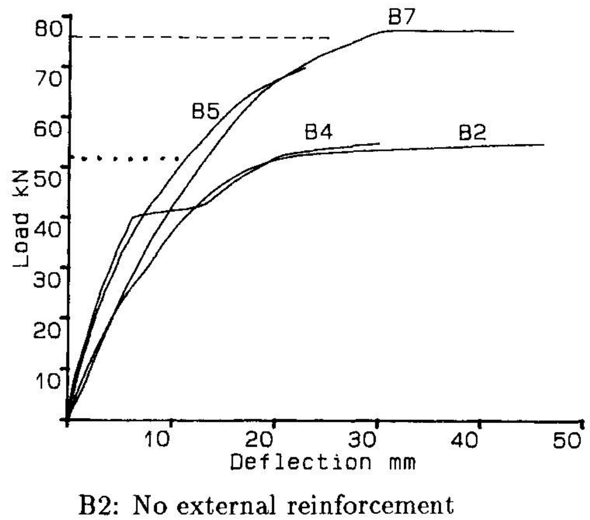


Fig.1 General details of plated beams



B2: No external reinforcement
B4: With plate only
B5: With plate and straps
B7: With plate and enlarged end strap
... Calculated ult. flexural load, B2
- - Calculated ult. flexural load, B4,B5,B7

Fig.2 Load/deflection curves for beams with 3mm plate and 10mm by 2mm straps