Composite Beams with Precast Slabs and Concrete Cast In-Situ

Poutres mixtes à dalles et béton coulé sur place

Verbundträger mit vorfabrizierten Platten und Ortsbeton

Nie JIANGUO
Wang JUHOU
Zhengzhou Inst. of Techn.
Zhengzhou, China

Arsenije VUJOFIĆ
Dragan DRAGOVIĆ
Titograd Univ.
Titograd, Yugoslavia

SUMMARY

Tests of six simply supported composite steel-concrete beams with flanges composed of precast R.C. slabs and concrete cast in-situ were made to investigate the behaviour of this type of composite beam. An analytical approach for predicting more accurately the real carrying capacity of stud shear connectors in composite beams and ultimate strength of composite beams is proposed.

1. INTRODUCTION

As is known, it is very convenient for construction to use composite beams with flanges composed of precast R.C. slabs and concrete cast in-situ in practical engineering, because the precast R.C. slabs can not only become a part of the flanges of the beams, but also can be used as the forms of concrete cast in-situ, furthermore the concrete cast in-situ can make the floor structures behave well as a whole body. To add to our knowledge of how this type of composite beam behaves six specimens were tested and some analytical predictions were made.

2. SPECIMENS, TESTS AND COMMENTS ON THE TEST RESULTS

Six specimens shown in Fig.1 were designed with the same cross section, but with varying span (designated as L), shear span (designated as L_1, in shear span there were 12 studs with diameter in 16mm for all beams), spacing of stud shear connectors, content ratio of transverse reinforcement (designated as α in percentage) and the strength of concrete. α includes the top transverse reinforcement and the bottom transverse reinforcement previously stretched out from the ends of the precast R.C. slabs without prefabricated slots for studs. The upper surface of the precast R.C. slabs was kept in a natural state of casting to increase the shear resistance of the interaction. All beams were simply supported and loaded with two symmetrical point loads. Deflections, strains and relative slips were measured after each increment of load.

The main test results and the modes of failure are summarized in Tab.1, in which, the modes of failure are designated as F. for flexural failure, F.S. for flexural and longitudinally splitted failure and S. for longitudinally splitted failure.

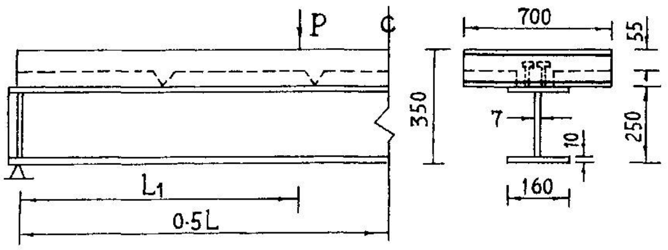

Fig. 1

Beam	L (mm)	L_1 (mm)	α (%)	M·F·	$\frac{M_{ut}}{M_{up}}$	$\frac{V_u}{V_{(1)}}$
A1	4500	1575	0.8	F.	1.05	1.20
A2	3800	1340	0.7	F.	1.03	1.19
A3	3000	1060	0.6	F.S.	1.07	1.15
A4	3000	1060	0.5	F.S.	1.01	1.08
B1	3000	1060	0.4	F.S	0.95	1.04
B2	3000	1060	0.3	S.	0.90	1.02

Table 1

Let P_{ut} represent the maximum load reached during a test. Flexural failure occured with the crashing of upper concrete in midspan, but no longitudinal cracks were monitored. For failure mode F.S.,longitudinally splitted cracks occured along the top surface of concrete as the load was near P_{ut}, and then the concrete of compressive zone in midspan was crashed at P_{ut}. For failure mode S.,longitudinally splitted cracks onset near the load points at $0.95P_{ut}$ and then developed rapidly toward the ends of the beam, no crashing of concrete was observed. So it can be concluded that α equal to 0.7% is the lower bound to prevent the flanges from being splitted longitudinally. Although slots for studs were not prefabricated,no local failure due to high shear resulted from studs occured for all test beams,the onset and propagation of vertical cracks have the same feature as that of general composite beams with concrete flange fully cast in-situ. No relative slip between the precast R.C.slabs and concrete cast in-situ was observed,so the precast R.C.slabs and concrete cast in-situ worked well together,but relative slip existed along the interface of steel beam and concrete, and this is normal for composite beams. Tests have shown that studs possess excellent behaviour of redistributing the shear in this type of composite beam.

Let M_{up} represent the predicted ultimate strength of the beams by using simple theory of plasticity and M_{ut} the test results. Comparing M_{up} with M_{ut}(seeing Tab.1),we can conclude that α equal to 0.5% is the lower bound of the ratio of transverse reinforcement to make the beams develop the strength predicted by simple theory of plasticity.

3. PREDICTIONS FOR CARRYING CAPACITY OF STUDS AND STRENGTH OF COMPOSITE BEAMS

According to the test results,it is reasonable to assume the shear applied on each stud in shear span to be equal at P_{ut}. If the resultant tension existed in steel beam near the loaded point is T,and the amount of studs in shear span is n, we have:

$$V_u = T/n \qquad (1)$$

where V_u denotes the lower bound of strength of studs at the ultimate limit state. To predict T by using the simple theory of plasticity is unreasonable obviously, because at load P_{ut}, not all part of the section of steel beam reached yield point (F_y). Taking the assumption of plane section,we can get:

$$T = \int_A \Phi Y E dA \qquad (2)$$

in which A denotes the whole section of steel beam, Φ the average curvature of the cross section measured from the tests,E the modulus of elasticity. $Y=\varepsilon_b/\Phi$, ε_b is the strain of the bottom fiber of the beam. If $\Phi YE \geq F_y$,putting $\Phi YE = F_y$. According to Eq.(2),we can get detail expressions for different state of strain distribution. Predictions (seeing Tab.1) from Eq.(1) and Eq(2) show that studs in this type of composite beam have higher capacity than that given by Ref.(1),so it can be concluded that the behaviour of studs in this type of composite beam are almost as same as that in general composite beams. On the basis of Eq.(2), we can also predict accurately the centroid of T by:

$$D = Y - (\int_A \Phi Y^2 EdA)/T \qquad (3)$$

where D is the distance from the bottom of steel beam to the acted point of T. Using Eq.(2), Eq(3) and considering the conditions of equilibrium,we can predict more accurately the ultimate strength of composite beams without using simple theory of plasticity. It should be noted that the levels of neutral axis predicted by simple theory of plasticity for all test beams are near the interface, but tests have shown that vertical cracks developed into a higher depth of concrete flange at P_{ut} . The predictions by the methods presented above are well coincided with test. No attempt is made to discuss this problem in detail in the paper.

4. CONCLUSIONS

Composite steel-concrete beams with flanges composed of precast R.C.slabs without prefabricated slots for studs and concrete cast in-situ behave well as whole bodies. α has a nonnegligible effect on the ultimate strength and the modes of failure. The capacity of studs in this type of composite beam can be predicted by the method used for general composite beams. We can use the approach proposed in this paper to further study the prediction of ultimate strength of composite beams without using simple theory of plasticity.

REFERENCES

1. R.P. Johnson, Composite structures of steel and concrete, London, 1982.