Developments in steel composite construction with precast hollowcore slabs

Dr Dennis Lam of University of Leeds, UK highlights research supporting some recently developed software for composite steel beam design and further research into semi-rigid beam column connections

The use of precast hollowcore slabs in steel composite construction has experienced rapid growth in stature and popularity since it was first developed in the 1990s. Composite steel beams incorporating precast hollowcore slabs shown in Fig 1, are intended to complement the traditional steel frame / steel decking method and to offer advantages where the use of a steel decking system may be unsuitable.

The main advantages of this form of construction are that precast hollowcore slabs can span up to 15m without propping. Erection of the 1.2m wide precast concrete units is simple and quick and shear studs can be pre-welded on beams before delivery to site thereby offering the savings associated with shorter construction times.

The recent strategic study into *The changing role of structural engineers in society*[1] by the IStructE has highlighted the need to reduce on-site activities and waste. This forms part of a drive to encourage the construction industry to contribute positively towards sustainable development through greater efficiency, improved quality and greater certainty in the delivery of construction projects. For multi-storey buildings, the use of precast slabs in the floors – particularly if this can be done without the need for *in situ* screeds – will drastically reduce the volume of on-site concreting required.

Full size push-off tests with precast hollowcore slabs were first performed by Lam *et al*[2]. These showed that the shear capacity of the stud for this type of construction was not only affected by the tensile capacity of the stud itself, but also by the gap width, the amount of transverse reinforcement, the strength of the *in situ* concrete infill and the presence of the longitudinal joint and transverse joint. Tests on three, full scale simply supported composite beams with variable parameters were also carried out by Lam *et al*[3] to study the flexure behaviour and these were compared with non-composite bare steel beams. The results showed two modes of failure: sudden failure due to loss of shear studs, and failure of the concrete slab due to yielding of the transverse steel bars. The residual moment capacity of all the beams was at least 40% above the moment capacity of the bare steel section only. A beam with a pre-cracked *in situ* / precast concrete joint was also tested. Modelling of the headed studs in steel-precast composite beams using the finite analysis software ABAQUS was carried out by El-Lobody and Lam[4] and good agreement was obtained in comparison to the test results published.

To encourage the use of this form of construction, a computer program based on the research work on simply supported composite beams with precast hollowcore slabs was developed[5]. The program allows full input of material data such as precast hollowcore slabs, concrete strength, shear stud dimensions and transverse reinforcement. From the geometry and loading input, the program can calculate the most economical beam size with partial or full shear connection. The program will check for both the construction stage and the ultimate limited state requirement for the composite beams. It will also check for the serviceability limit states requirement such as deflection and vibration due to natural frequency. Fig 2 shows one of the output pages of the program. In addition, the findings of the research work were also disseminated via the Steel Construction Institute design guide namely *Design guide to composite beams using precast concrete slabs*[6]

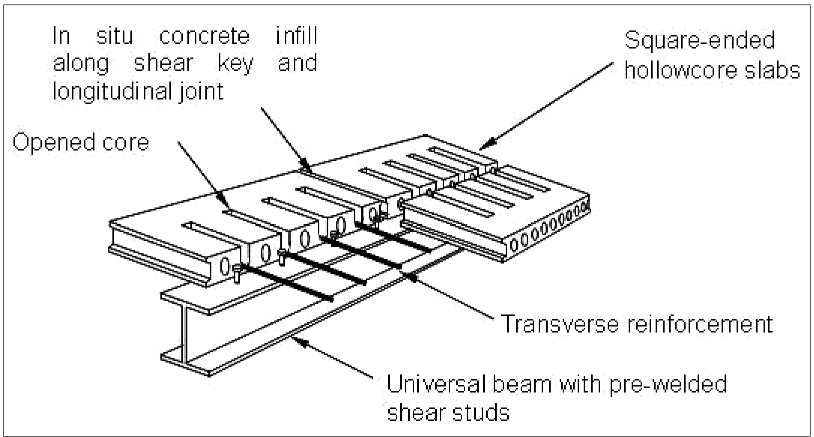

Fig 1. Composite beam with precast hollow core slabs

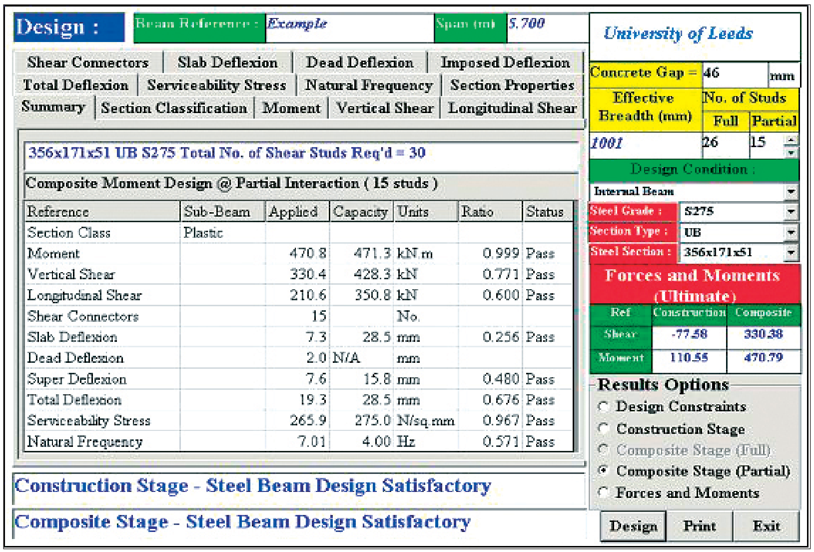

Fig 2. Summary of composite beam design

Fig 3. Beam – column connection test set-up

Currently, research work in Leeds on composite steel – precast hollowcore construction is focused on developing the semi-rigid beam column connection for this form of composite construction. The use of semi-rigid composite connections has been well recognised by designers for a long time. They can reduce beam weight, which in turn will reduce the beam depth, the overall building height and cladding cost, etc. It can also improve serviceability performance due to the increased stiffness. It can provide greater robustness and as a result, improved continuity between frame members and better crack control in the floor slabs.

Although much work has been done towards rotation and moment capacity of the composite connections, all the research carried out so far has either been on solid concrete slabs or on metal deck flooring. No work has been done towards a precast hollowcore floor system.

The cruciform test arrangement, as shown in Fig 3, is set up to simulate the internal beam-column joints in a semi-rigid composite frame. The main parameters investigated are degree of shear connection and the spacing of the headed studs. Initial results show that these joints combine simple and efficient construction and yet provide worthwhile levels of moment capacity, rotational stiffness and ductility.

Further experimental work to consider the amount of longitudinal reinforcement and the different depths of the hollowcore slabs is currently being planned. It is proposed that this form of composite construction be included into the next revision of the Eurocode 4[7]. se

REFERENCES

1. May, I.: *The changing role of structural engineers in society*, IStructE, September, 2004 (see website under My Area and Member Reports: http://www.istructe.org.uk/members/db/594.asp)
2. Lam, D., Elliott, K. S. and Nethercot, D. A.: 'Push-off tests on shear studs with hollow-cored floor slabs', *The Structural Engineer*, **76**/9, 1998, pp167-174
3. Lam, D., Elliott, K. S. and Nethercot, D. A.: 'Experiments on composite steel beams with precast concrete hollow core floor slabs', *Proc. Institution of Civil Engineers: Structures & Buildings*, **140**, 2000, pp.127-138
4. El-Lobody, E. and Lam, D.: 'Modelling of headed stud in steel – precast composite beams', *Steel & Composite Structures*, **2**/5, 2002, pp. 355-378
5. Bison Concrete Products Limited, 'Composite steel beam design' program, Version 2.1, 2004
6. Hicks, S. J. and Lawson, R. M.: *Design guide to composite beams using precast concrete slabs*, Steel Construction Institute, 2003
7. prEN1994-1-1: *Eurocode 4*, *Design of composite steel and concrete Structures*: *Part 1.1: General rules and rules for buildings*, British Standards Institution, London, 2005