Researches on the performance of shear connection in composite beams

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Abstract

This paper presents the results of the researches on the performance of shear-connection in composite beams based on the finite element software ABAQUS. It is found that the shear-connection behaviour of composite beams is significantly affected by the depth of embossments. The capacities of shear connection obtained from the finite element analysis were compared with the design strengths calculated using the American Specification, British Standard and European Code for headed stud shear connectors in composite slabs with profiled steel sheeting perpendicular to the steel beam.

Keywords

Performance, formatting shear-connection, the-finite-element analysis, steel sheeting, ABAQUS.

1. Introduction

The behaviour of shear-connection in composite beams with profiled steel sheeting depends on many factors including strength and dimensions of headed stud shear connectors, geometries and direction of profiled steel sheeting, reinforcement area and position, compressive strength of concrete and location of the stud within the ribs of the profiled steel sheeting. The shear connection capacity is assumed to be the failure load divided by the number of connectors. The characteristic resistance of a stud embedded within a solid concrete slab has been evaluated from push test data by considering the possibility of stud shank failure or crushing of the concrete. Finite element modeling of shear connection can provide an efficient alternative to costly and time consuming full scale push-out tests. The results obtained from the finite element analysis compared well with the experimental results. The efficiency of the composite action of steel sheeting in composite beams is obtained from the test information. The design of composite beams is currently based on the test information for a particular steel-sheeting profile. To achieve the desired composite action, shearing forces have to be transferred between the concrete beam and the steel sheeting. This is usually accomplished by the mechanical inter-locking devices rolled onto the surface of the steel sheeting.

2. Experimental programme

2.1 Specimen description.

Advances in computational features and software have brought the finite element method within reach of both academic research and engineers in practice by means of general-purpose nonlinear finite element analysis packages. The program offers a wide range of options regarding element types, material behaviour and numerical solution controls, as well as graphic user interfaces (known as GUIs), auto meshers, and sophisticated post processors and graphics to speed the analyses. In order to obtain accurate results from the finite element analysis, all components associated with the shear connection must be properly modeled. The main components affecting the behaviour of shear connection in composite beams with profiled steel sheeting are concrete beams.

2.2 Material modelling.

The stress–strain relationship is linear elastic up to yielding, perfectly plastic between the elastic limit (ε y) and the beginning of strain hardening and follows the constitutive law used by Gattesco [1] for the strain-hardening branch:

$$\sigma_0 = f_y + E * \Delta\varepsilon (1 - \frac{\Delta\varepsilon}{4\Delta f_y} E) \quad (1)$$

where fy is the yield tensile stresses of the steel component, respectively; E and ε are the strain hardening modulus and the strain at strain hardening of the steel component, respectively. The values measured in the experimental tests for the material properties of the steel components (steel beam and reinforcing bars) are used in the finite element analyses. The concrete tensile strength and the Poisson's ratio are assumed as 1/10 of its compressive strength and 0.2, respectively. The concrete elastic modulus is evaluated according to Eurocode 4 [2], i.e.:

$$E_C = 10000\sqrt{\gamma_c / 24}\sqrt[3]{f_c + 8} \quad (2)$$

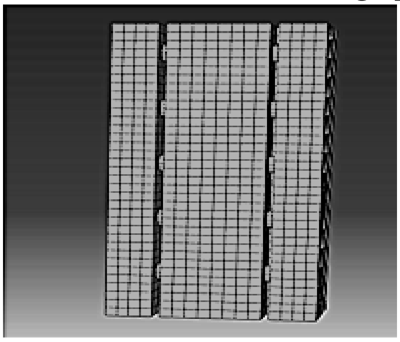
where: γ_c is equal to 25 kN/m 3. As far as the shear connector behaviour is concerned, the load–slip curves for the studs are used (obtained from available push-out tests) by defining a table of force values and relative displacements (slip) as input data for the nonlinear springs.

2.3 Boundary conditions.

All nodes along the middle surface of the steel beam are restricted from moving in the X direction due to symmetry. All concrete nodes, profiled steel sheeting nodes, reinforcement bar nodes, steel beam flange nodes, steel beam web nodes and headed stud nodes that lie on the other symmetry surface are restricted from moving in the Y direction because of symmetry.

2.4 Finite element and mesh type

The finite element types considered in the model are as follows: elastic-plastic shell (SHELL43) and solid (SOLID65) melements for the steel section and the concrete slab, respectively, and nonlinear springs (COMBIN39) to represent the shear connectors. Two finite element models (Model (A) and Model (B)) were developed, as shown in Figs.1 and 4, respectively. Model (A) presented the actual trapezoidal geometry of the profiled steel sheeting. This model is suitable to investigate the behaviour of headed studs welded through profiled steel sheeting with mild side slopes. In this case, the concrete within the ribs of the profiled steel sheeting can be modeled properly. Model (B) simulated the trapezoidal shape of the rib by an equivalent rectangular shape. This model can be used to investigate the behaviour of headed studs welded through profiled steel sheeting with stiff side slopes.



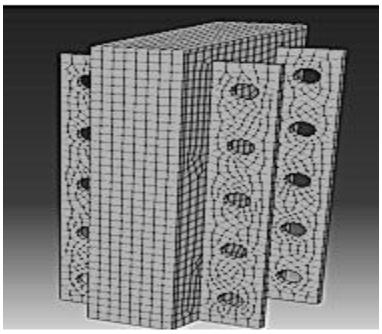


Fig1.Finite element mesh of model(A) Fig2.Finite element mesh of model(B)

3. Verification of of finite element model

The shear connection capacity per stud obtained from the tests and finite element analysis as well as the load–slip behaviour of the headed shear stud and failure modes have been investigated.Fig.1 shows a comparison of the capacities of shear connection obtained experimentally and numerically. It can be seen that good agreement has been achieved between both results for most of the push-out tests.

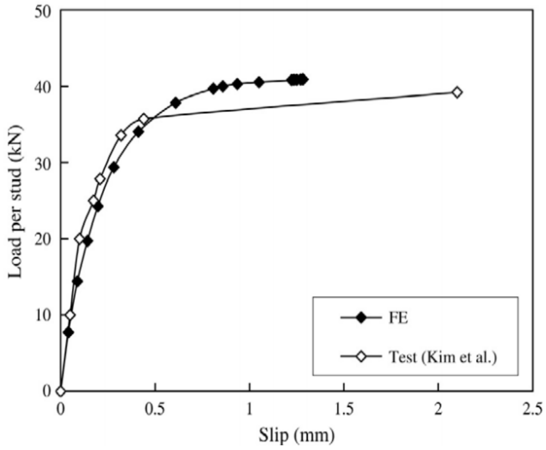


Fig.1Effect of concrete strength on the load–slip behaviour

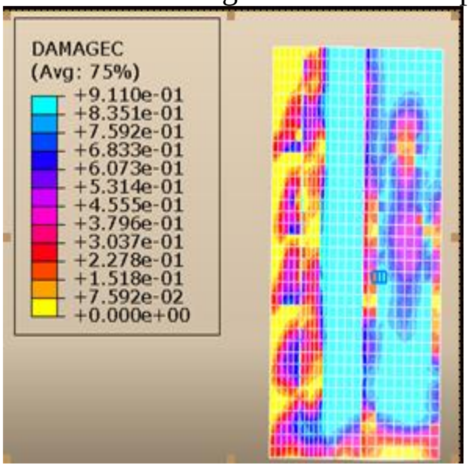


Fig.2. Stress contours of push-out specimen

The failure mode observed experimentally for specimen SP1 was compared with that predicted numerically. The failure mode was a combination of concrete conical failure and stud shearing as observed experimentally and confirmed numerically. Fig. 2 shows the stress contour at failure of specimen obtained using the finite element model.

4. Conclusion

Accurate nonlinear finite element models have been developed to investigate the behaviour of shear connection in composite beams with profiled steel sheeting perpendicular to the steel beam. The models take into account the nonlinearmaterial properties of the concrete, steel beam, profiled steel sheeting, reinforcement bars and headed stud shear connectors. The capacity of shear connection, load–slip behaviour of headed stud and failure modes were predicted from the finite element analysis and compared well with experimental results. An extensive parametric study of 44 push-out specimens with different profiled steel sheeting geometries, headed shear stud diameters and heights as well as concrete strengths was performed using the finite element models. The comparison of shear connection capacities obtained from the finite element analysis and the design rules specified in the American Specification, British Standard and European Code have shown that, the American and British specifications overestimated the capacity of shear connection with a maximum value of 27% and 25%, respectively. The design rules specified in the European Code were generally conservative, except for some cases that overestimated thecapacity of shear connection with a maximum value of 11%.

Acknowledgements

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