Structural optimization of a composite steel and concrete connection through FE analysis and testing

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Summary

The increasing ratio between labour cost and the cost of construction materials is urging for the development of construction techniques requiring the smallest number of skilled workers and the optimization of building schedule in order to minimize the overall building time. Composite decks and floors are becoming increasingly widespread due to their structural effectiveness that allows for the optimization of the mechanical properties of the coupled materials and for the possibility of achieving a simplified detailing with a limited number of structural elements involved in the structural response.

In the paper, FEM analysis and test setup of a newly developed moment resisting connection between a centrifuged high strength concrete pre-fabricated column and a composite steel and concrete beam will be presented. The connection proposed allows for a sustainable construction process based on modern construction technologies which are suitable for creating improved structures for buildings in urban areas.

Keywords: Composite steel and concrete connections, construction, experimental based analysis, FE analysis, structural optimization.

1. Main features of the joint

The joint proposed has the purpose to achieve a moment resisting connection between prefabricated column and partially prefabricated composite steel and concrete beam. The main goals of the connection are summarized in: minimization of tolerance problems, minimization of installation time, no need for skilled labour during erection, high bearing capacity, overall quality of structural components, sustainable construction process. In the paper, the composite connection presented will allow for the achievement of frame structures with centrifuged pre-fabricated high strength concrete columns with egg-shaped cross section and composite partially prefabricated steel and concrete type beams (fig 1a). The need for the use of a high strength centrifuged concrete derives from the always increasing requirements coming from architects and designers to have low impact structures with minimum cross section and increased spans. This has also an economic consequence in terms of availability of living spaces and therefore of value of the building. The typical cross sections of the structural members and detail of the connection are given in figure 1b.

2. Finite element analysis and test setup

A 3D finite element models of the column was initially created with the use of 61726 brick elements in order to investigate the local stress distribution. This was done prior to the implementation of the whole joint in order to deal just with vertical loads. The software used for the analysis is Strand 7. A preliminary structural optimization, carried out through a manual procedure, was implemented in order to remove material from the horizontal steel plates where allowed by

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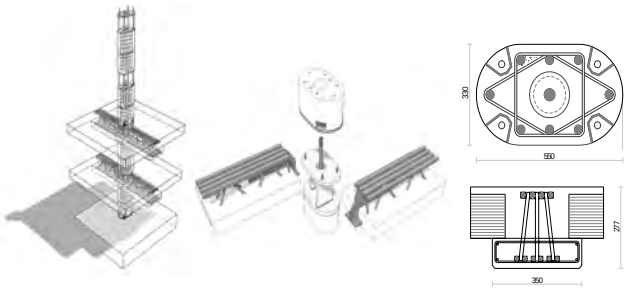


(a) (b)

Fig. 1: Global view of the connection proposed

stress distribution.

The following assumptions were made in the model: eight-nodes brick elements were used to implement all models; the base of the models were considered as fixed while loads were uniformly applied at the top; Poisson's ratio of the concrete was held constant and equal to 0.20.

Different thickness of both vertical and horizontal plates was implemented and vertical ultimate load was therefore determined for the different columns. The results found show peaks of stress locally exceeding the mechanical properties of both steel and concrete for the maximum load specified (fig.2).

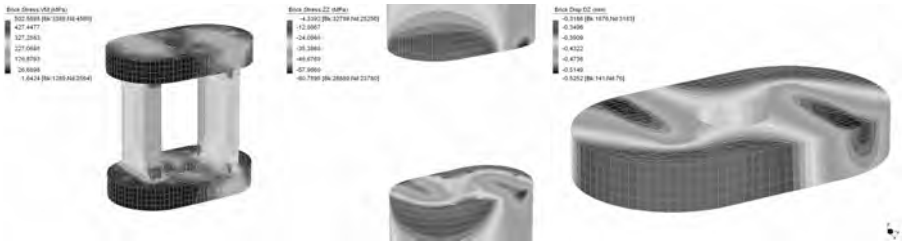
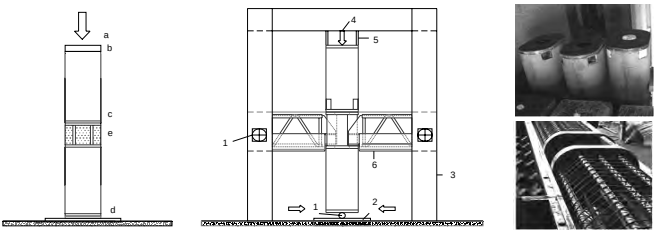


Fig. 2: Column 4: N = 5000kN. Stress level in steel, concrete and vertical displacement in horizontal plates from FE analysis



A campaign of experimental tests on full scale specimens is scheduled in order to assess the real response of the joint both under vertical loads and cyclic loads. Test will be carried out at Tongji University (fig 3).

Fig. 3: Test setup both for monotonic and cyclic loading tests.

3. Conclusions

The connection proposed aims to achieve easy and fast erection of partially prefabricated frame structures with architectural value. Sustainability of the construction process, meant as the maximization of result with minimum impact, is one of the goals of the research.

Further research is required in order to carry out an extensive experimental campaign whose results will be used for the final optimization of the connection both towards vertical static loads and cyclic loads.