Development of Fully Prefabricated Steel-UHPC Composite Deck System

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1. Introduction

Infrastructure construction, especially the reconstruction of congested lanes, requires huge workspace, resulting in the serious long-term disruption on the normal service. Long-term construction introduces obvious negative external effects, i.e. time consuming and costly city transportation, business disturbance in the construction area etc. (Culmo 2009). There is a clear and strong demand in the accelerated construction technology in the urban area (Ralls 2008).

Prefabricated bridge is one available approach to achieve accelerated construction. The industrial produced structural elements are friendly to environment and expected with better quality control. A novel fully-prefabricated steel-UHPC composite deck is proposed for completely eliminating the on-site wet construction, as shown in Fig. 1. The composite bolting-welding joint is the key structure of the prefabricated deck system. Two sets of specimens are designed for the deep investigation on the mechanical performance of this composite deck. The strain distributions, crack development and load-deflection curves are obtained. On the basis of physical test, a sophisticated numerical model is built in ABAQUS, which presents satisfactory accuracy. The influences of some important design parameters are discussed through supplementary parametric analyses. Finally, the design suggestions are provided according the test and analysis results.

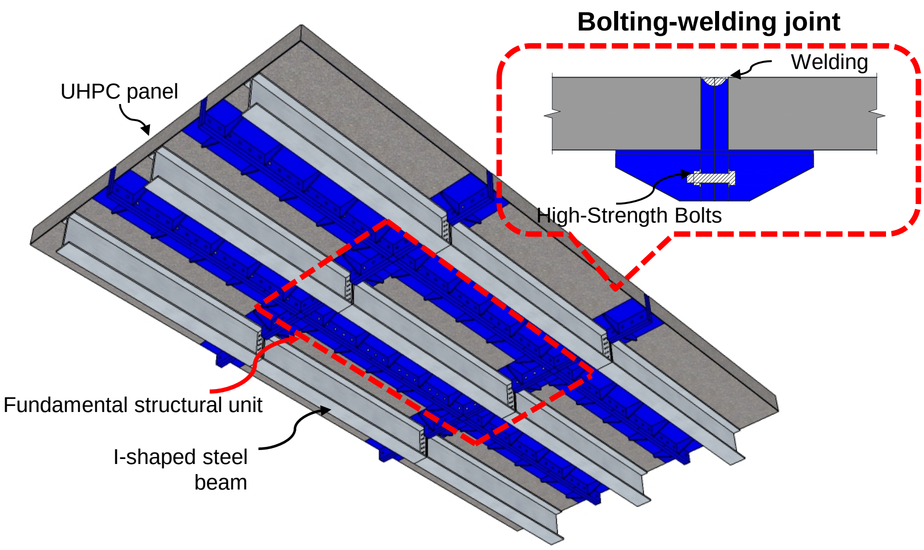

Fig. 1 Structure of the fully-prefabricated steel-UHPC composite deck system

2. Test program

Totally two sets of specimens were designed and tested, called Set P (Passive) and Set A (Active) respectively. The fundamental difference between Set P and Set A is the configurations at the steel-UHPC interface for crack resistance. In Set P, several studs were welded on the vertical steel plate to prevent the separation between steel plate and UHPC panel under negative moment. Alternatively, for the specimens in every Set A component, four pre-tension (PT) rebars with the diameter of 18 mm were used to enhance crack resistance of the steel-UHPC interface. One end of the PT-rebar was tapped and the screw nut was placed in the thick plate for anchorage. The other end is embedded in the UHPC layer.

Classic four-point bending test was conducted to obtain the crack development, strain distribution and load-deflection curves of the specimens. According to the test, Set A presented evident advantages on the crack resistance performance, which had a quite large initial cracking stress and nominal tensile stress in post-cracking stage.

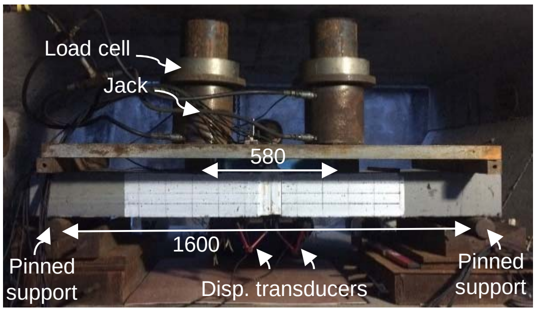

Fig. 2 Specimen and loading setup

The crack development is shown in Fig. 3. Set A presented more satisfactory crack resistance With PT-rebar, the initial cracking stress was evidently enhanced. But the pretension rebar could not significantly enhance the post-cracking

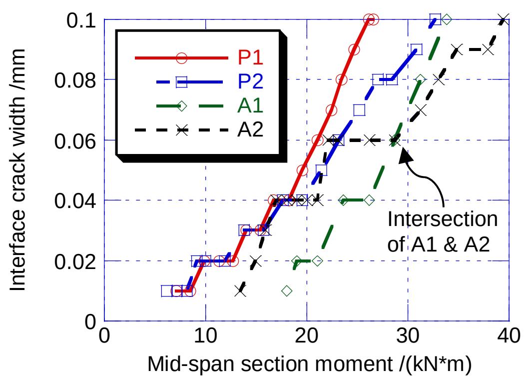

Fig. 3 Crack development at the steel-UHPC interface

3. Finite element analysis

To supply the physical test, finite element analysis was built in ABAQUS, which could well reproduce the load-deflection curves and crack development of the bolting-welding joint.

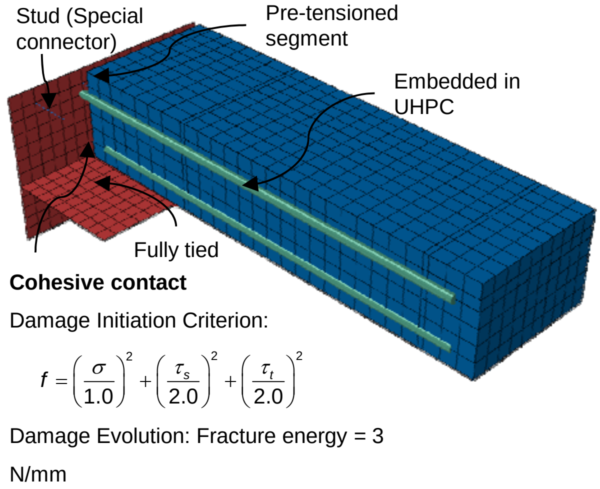

Fig. 4 Numerical model in ABAQUS

With the numerical model, the effect of pretension fore and height of the stiffener were investigated. According to the results of parametric analysis, the regression formula of estimating the initial cracking stress was derived.

$$\sigma_{\text{initial}} = 8.4\left(a\frac{F_{\text{p}}}{65}+b\frac{h_s}{109}+c\right) \tag{3-1}$$

where F_{p} was the pretension force in one rebar, h_{s} is the height of stiffener; a (=0.4466), b (=0.06361) and c (=0.5616) were the coefficients for regression.

4. Conclusion

Employing PT-rebar could evidently improve the initial cracking stress, but hardly improve the nominal stress in seriously cracking stage.

Based on parametric study, the initial cracking stress is more sensitive with the pretension force, while increasing the stiffener height could evidently improve the nominal tensile stress in seriously cracking stage.

5. Reference

Culmo M P. Prefabricated composite bridges in the United States including total bridge prefabrication [C]//Workshop on Composite Bridges with Prefabricated Deck Elements. 2009.

Ralls M L. Benefits and costs of prefabricated bridges [J]. Accelerated Bridge Construction Study. Salt, 2008.