Mechanical Behaviour of Adhesive Joint under Tensile and Shear Loading

Xu JIANG
PhD student
TUDelft
Delft, the Netherlands
xu.jiang@tudelft.nl

M.H. KOLSTEIN
Associate Professor
TUDelft
Delft, the Netherlands
M.H.Kolstein@tudelft.nl

F.S.K. BIJLAARD
Professor
TUDelft
Delft, the Netherlands
F.S.K.Bijlaard@tudelft.nl

Summary

Due to various advantages of Fibre-Reinforced Polymer (FRP) decks, the FRP to steel composite bridge system is being increasingly used in new bridge constructions as well as rehabilitation projects for old bridges. This paper focuses on the mechanical behaviours and failure modes of the adhesively-bonded joins between FRP sandwich decks and steel girders. The adhesively-bonded joints were experimentally investigated under tensile and shear loading. Further comparison on failure modes confirmed that the surface pretreatment can improve the bonding quality between FRP composites and adhesive layer, and correspondingly increase the load-carrying capacity of adhesive joints.

Keywords: FRP deck; steel girder; composite bridge; adhesively-bonded joint; tensile and shear loading.

1. Introduction

Fibre Reinforced Polymer (FRP) bridge decks are increasingly implemented in practice for rehabilitation of existing bridges and also for new bridge constructions, which is due to the remarkable advantages of FRP decks: lightweight of bridge superstructures, the ease of installation, minimum traffic disturbing, large tolerance for environmental corrosion, long service life time, as well as low maintenance cost. To be cost-effective, the FRP decks are commonly supported by longitudinal main girders made of either steel, prestressed concrete or FRP composites. Between the FRP decks and steel girders, adhesively bonding technique is usually employed as a preferable connection method, since it can reduce construction time, save weight by eliminating fasteners, introduce more uniform load transfer and provide better long-term performance. This paper experimentally investigated mechanical behaviours and failure modes of adhesively-bonded joints under tensile and shear loading, considering the influence of surface pretreatment on FRP sandwich decks and steel girders.

2. Experiment

Generally. there are three typical stress states for the adhesive joint between FRP decks and steel girders:

1) shear stress τ: due to the composite action between FRP decks and steel girders in the longitudinal direction of bridge, the decks and steel girders tend to bend together to carry the traffic load. Thus, the adhesive joints are under the shear stress condition to transfer the loading from FRP decks to steel beams;

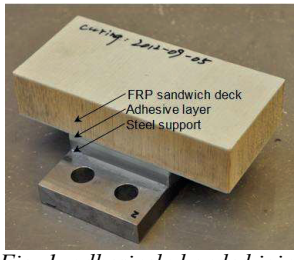


Fig. 1. adhesively bonded joint

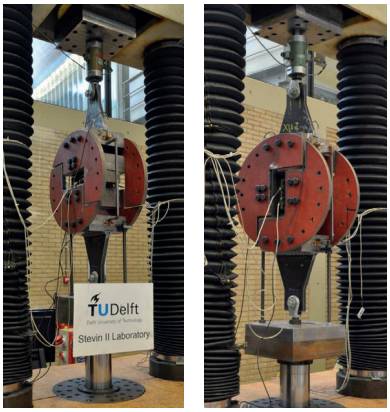
2) tensile stress σ: in the transverse direction of bridge, loading on other traffic lanes causes up-lift forces on adhesive joints, which results in tensile stress;

3) combination of the above two stress states with different ratios of contributions from tensile stress state and shear stress state.

The adhesively-bonded joint between FRP deck and steel girder was extracted for experimental investigation as shown in Fig. 1. Depending on the aforementioned three stress states, a smart loading device was designed for providing tensile loading, shear loading and combination of both simultaneously, as

https://doi.org/10.2749/222137813806501416

shown in Fig. 2. By loading the different angles of circular steel plates, the specific stress-state can be achieved in the adhesive joint, such as pure tension, pure shear and combination of both. In this study, the FRP-to-steel adhesively-bonded joints were experimentally investigated under tensile and shear loading. Six replicated specimens were prepared for each loading condition. Before gluing, three of specimens were pretreated on the surfaces of FRP sandwich deck and steel supports by using sandpapers and acetone. For comparison, the other three specimens were glued without any surface pretreatment. The surface pretreated specimens were indicated as SP-specimens in the following chapters, and un-pretreated specimens were described by UP-specimens.



a) tensile loading b) shear loading

Fig. 2 Experimental set-up

3. Conclusion

In this paper, FRP sandwich deck to steel support adhesively bonded joints were experimentally investigated under both tensile and shear loading condition. The mechanical behaviour of adhesive joint specimens with surface pretreatment (SP) and without surface pretreatment (UP) were compared for these two loading case. All of adhesive joint specimens failed in a sudden and brittle method, expect that a lightly extent of ductility was evident for SP-specimen under tensile loading. The surface pretreatment dominated the failure modes and ultimate failure load of adhesive joint, but not the stiffness of adhesive joints. For tensile loading condition, the failure mode was moved from the adhesion failure between FRP laminates and adhesive layer (UP-specimen) to FRP delamination (SP-specimen). As listed in Table 1, the ultimate failure load of UP-specimens was 16.05kN, which was increased to 17.62kN by the surface pretreatment. The test results also indicated that the through-thickness strength of FRP laminates was a little higher than bonding strength of the adhesive-adherend between FRP laminates and adhesive layer. For shear loading condition, the failure mode was moved from adhesion failure between adhesive layer and steel support (UP-specimen) to adhesive failure in the adhesive layer (SP-specimen). The ultimate failure load of UP-specimens was only 21.9 kN, which was less than one-third of that of SP-specimens (70kN). Therefore, sufficient surface pretreatment on FRP sandwich decks and steel girders must be satisfied in practice, to improve the mechanical performance of the adhesively bonded joints under tensile and shear loading. It would be perfect if the quality of surface pretreatment can be evaluated, of instance, by measuring the surface roughness. Furthermore, it can be found that the strength of adhesive joints under tensile loading was lower than that under shear loading (26.7% lower for UP-specimens and 74.8% for SP-specimens). It indicates that the failure of adhesive joint was initiated more easily by the through-thickness stress. Further research will be followed by the tensile-shear interacted loading conditions and Finite Element modelling will be employed to understand the stress-strain distribution throughout the adhesive joint, since it is not possible to track the strain distribution in such a small scale test. The failure criterion of adhesive joints is expected to be drawn, which can be employed to predict the strength of adhesive connection between FRP decks and steel girder under other combination of shear and tensile loads.

Table 1. Ultimate failure loads of adhesive joints

Tensile loading					
Specimen	UP-01	UP-02	UP-03	Average	Deviation
Failure load (kN)	15.69	16.43	16.04	16.05	2.37%
Specimen	SP-01	SP-02	SP-03	Average	Deviation
Failure load (kN)	19.37	17.93	15.57	17.62	11.63%
Shear loading					
Specimen	UP-01	UP-02	UP-03	Average	Deviation
Failure load (kN)	18.1	25.0	22.7	21.9	17.5%
Specimen	SP-01	SP-02	SP-03	Average	Deviation
Failure load (kN)	76.4	51.2	82.4	70.0	26.9%