FULL-RANGE BEHAVIOR OF FRP-TO-CONCRETE BONDED JOINTS WITH END ANCHORAGE

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Introduction

Researchers have indicated that an effective application of FRP laminates to the concrete or steel structures is not possible until a fundamental understanding of the mechanics and failure mechanisms of the retrofit system is available. Of the available closed-form analytical studies, Täljsten [1] analytically obtained the expression for the ultimate load using a linear ascending bond-slip model. Yuan et al [2-6] developed equations for the ultimate load, the interfacial shear stress distribution and the effective bond length for various interfacial bond-slip models.

All above analytical solutions of FRP-to-concrete bonded joints considered only the joints with free end. Mechanical anchors can be installed at the plate ends to delay or prevent plate-end debonding failure. Although a series of tests on FRP-plated beams with end U strip anchorage were conducted, no analytical solution has been presented which is capable of predicting the entire debonding propagation process. This paper attempts to get a closed-form analytical solution of the model. Such an analytical solution can also be used to study debonding failure in shear strengthening.

Theoretical Analysis

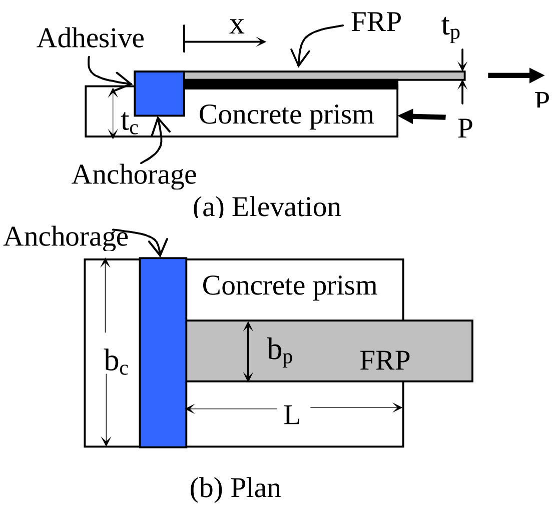


Figure 1. Pull-push shear test of a single-lap plate-to-concrete bonded joints with end anchorage

Figure 1 shows a single-lap pull-push test of a plate-to-concrete bonded joint, in which the width and thickness of each of the three components (plate, adhesive layer and concrete prism) are constant along the length. The width and thickness of the plate are denoted by b_p and t_p respectively, those of the concrete prism by b_c and t_c respectively, and the bonded length of the plate (i.e. bond length) is denoted by L. The Young's modulus of the plate and concrete are E_p and E_c respectively.

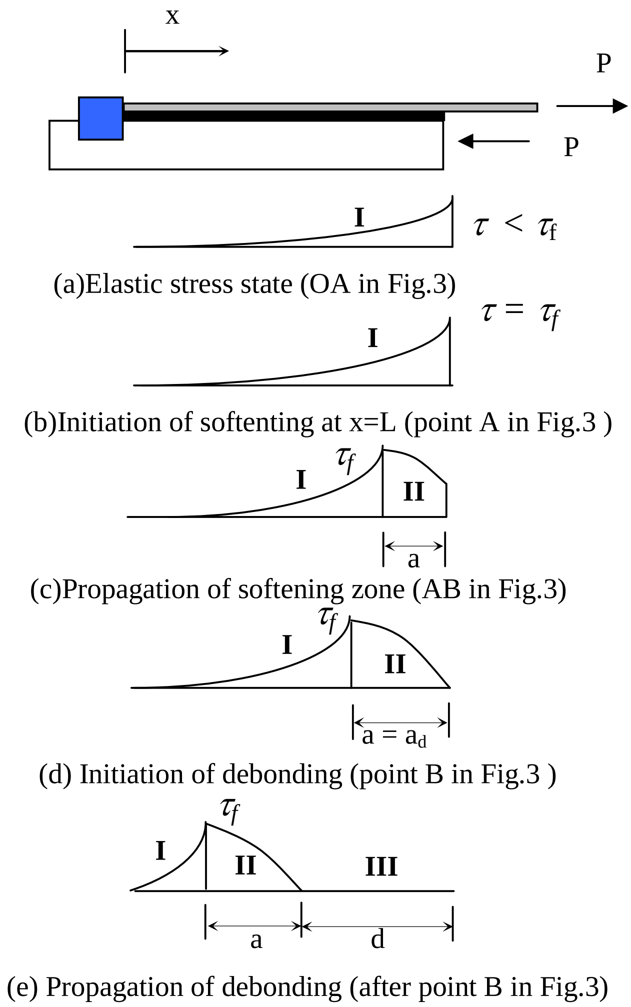


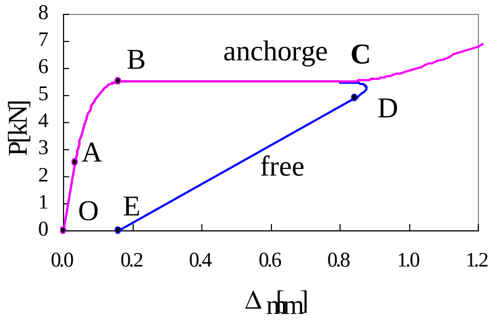
Figure 2. Interfacial shear stress distribution and propagation of debonding for bonded joints

With the bi-linear interfacial bond-slip model, the governing equation can be obtained and solved to find the shear stress distribution and propagation of debonding (Figure 2) along the interface and the load-displacement response of the bonded joint. The solution of equations can be get stage by stage.

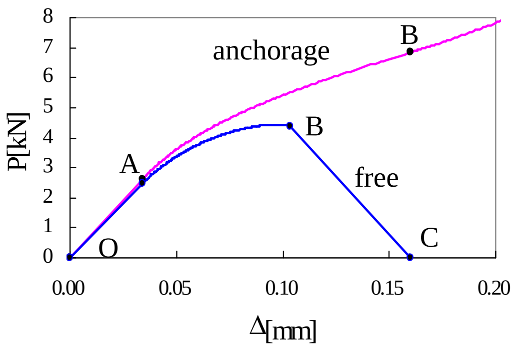
Comparison of Load-Displacement Curves of Bonded Joints with End Free and Anchorage

The author of the paper studied also the behavior of FRP-to-concrete bonded joints with free end [2-6]. In that case, the normal stress of the plate is zero ar the free end (x=0). When the bonded length is longer than the characteristic softening length a_u, the interface will experience Elastic, Elastic-Softening, Elastic-Softening-Debonding and Softening-Debonding stage until the interface debonding. When the bonded length is shorter than a_u, the interface will experience Elastic, Elastic-Softening and Softening stage until the interface debonding. But for the end anchorage model in the paper, bonded length doesn't influence the failure processes. The interface always experiences Elastic, Elastic-Softening and Elastic-Softening-Debonding stage until the FRP ruptures.

The load-displacement curves of FRP-to-concrete bonded joints with end free and anchorage are showed in Figure 3 for comparison.



(a) L=190mm



(b) L=30mm

Figure 3. Comparison between the load-displacement curves of bonded joints with end free and anchorage

Conclusions

This paper presents an analytical solution, in which the realistic bi-linear local bond-slip law and end anchorage boundary conditions are employed. Expressions for the interfacial shear stress distribution and load-displacement response are derived for different loading stages. The analytical solution of FRP-to-concrete bonded joints with end anchorage is compared with that of the joints with free end. Based on the results and discussions presented in the paper, the following conclusions may be drawn:

(a) The load-displacement behavior of a bonded joint features a linear elastic stage, a softening stage, and a debonding propagation stage;

(b) Bonded length doesn't influence the failure processes for anchorage model. The interface always experiences Elastic, Elastic-Softening and Elastic-Softening-Debonding stage until the FRP ruptures;

(b) If the end of FRP plate is anchored reliablly, the final failure mode will change from interfacial debonding to FRP rupture.

Acknowledgments

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