ABSTRACT

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Abstract（Doctor）

Title of Thesis	Structural design on strengthening multi-bolted connections in pultruded glass fiber reinforced polymer (PGFRP) using multi-directional fiber sheets

Infrastructures that have been rapidly expanding in recent years are now reaching a critical age, with widespread signs of deterioration and inadequate functionality. Therefore, designing effective methods for rehabilitating, rebuilding, and maintaining civil infrastructure is essential for sustainable development. Fortunately, glass fiber-reinforced polymer (GFRP) composites have emerged as an excellent material for renewing existing structures. In recent decades, numerous research projects have been conducted to investigate the reinforcement behavior for connections in GFRP structures. However, the main focus of previous studies has been limited to strengthening based on the original material connections in GFRP. This research program aims to investigate a novel and promising method of strengthening bolted connections in GFRP, using multidirectional fiber sheets. The primary advantage of this method is its simplified application, cost-effectiveness, and high effectiveness.

Firstly, a brief introduction to pultruded GFRP (PGFRP) as a material and manufacturing process was presented. The first experiment was conducted a series of experiments to consider the effects of GFS on strengthening PGFRP multi bolted connections. In this study, three varieties of multi-directional Glass Fiber Sheets (GFS) were employed for strengthening purposes, namely: 0°/90° GFS, ±45° GFS, and chopped strand mat (CSM) GFS, all of which were produced using the Vacuum Transfer Molding technique. The findings of this investigation reveal that all three types of GFS exhibit a marked ability to enhance the maximum failure loads of Pultruded GFRP connections. Furthermore, the impact of all GFS

variants on the reinforcement process was observed to be directly proportional to increases in the ratios of end distances to bolt diameter (*e/d)* or the number of bolts (*n*). In nearly all instances, 0°/90° GFSs outperformed ±45° GFSs and CSM GFSs in terms of the extent of the reinforcement effect achieved.

A subsequent experiment was conducted to evaluate the bonding capability of Pultruded GFRP. This experiment was necessitated by the observation that the specimens with the highest connection strength in the previous experiment had experienced debonding failure. In light of a sequence of material tests, a set of equations were posited with the aim of accurately predicting the failure modes and ultimate loads of multi-bolted PGFRP connections fortified with multi-directional GFS.

The third experiment investigates the influence of bolt tightening force in connection strength. A similar series as non-tightening force were designed and tested under apply a 21N.m torque load. The outcomes of the connection testing evince that the employment of GFS for strengthening purposes continues to be efficacious, even when deployed under diverse conditions of bolted PGFRP connection. While there was an increase in the maximum load for all specimen types in comparison to the untightened state, the effectiveness of the system, as measured by the ratio of the maximum loads before and after reinforcement with GFSs, exhibited a slight decrement.

The final investigation involved determining failure behavior and strengthening effectiveness in beam-to-column multi bolted connection. Full scales experiments were implemented to investigate behavior and effectiveness of beam-to-column connection with and without strengthened by GFS. The experimental findings did not align with the expected outcomes, owing to unforeseen circumstances in the design of the auxiliary steel components in the beam. Although the adoption of GFS served to enhance the reinforcement of the column, it nevertheless suffered damage before the onset of failure observed in the beam's profile. Consequently, a revision was put forward, which entailed altering the connection of the cleats, with the objective of aligning with the primary objective of the experiment, which was to investigate the behavior of the beam.

To summarize, the all-encompassing research program detailed herein suggests that the use of multi-directional GFS constitutes an effective approach for enhancing the structural aptitude of civil engineering constructions. Specifically, the incorporation of GFS sheets enhances the load-bearing capacity and overall performance of pultruded PGFRP connections. The findings and formulae proposed in this study possess practical implications for promoting the adoption of cutting-edge materials such as FRPs within the civil engineering industry. Nonetheless, certain pertinent issues remain, which the author has identified as prospective areas for future investigation.