THE EXPERIMENTAL MODELING OF GFRP CONFINED CONCRETE CYLINDERS SUBJECTED TO AXIAL LOADS

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INTRODUCTION

Seismic repair, rehabilitation and strengthening of existing structures have become a major part of construction activities. It is now well known that both strength and ductility of concrete compressive members can be greatly improved by using glass fiber reinforced polymer (GFRP) sheets. The objectives of this study are to investigate the effects of three parameters on the stress-strain behavior of GFRP confined concrete. The parameters studied in this research included unconfined concrete core strength, number of layers of GFRP and the fiber orientation in the laminate structure. The confinement and ductility effectiveness along with energy absorption capacity are studied based on the experimental results. Due to recent increase in the application of high performance concrete structures, compressive behavior of high strength concrete columns externally confined by FRP jackets are focused. Although many confinement models have been developed in order to predict the response of confined concrete, their applications are limited providing different degrees of prediction accuracy. In this paper, three confinement models with the applicability of predicting complete stress-strain response of FRP confined concrete are evaluated and discussed according to the experimental results.

EXPERIMENTAL PROGRAM

The experimental program consisted of axial compressive tests on plain concrete and GFRP confined concrete cylinders. A total of 14 GFRP confined and 6 unconfined control concrete cylinders with a diameter of 150 mm and a height of 300 mm were tested. The effect of unconfined concrete core strength was examined by using three target strengths of 10, 20 and 40 MPa. The low, normal and high strength concrete cylinders were wrapped with one layer of GFRP sheet with 0º fiber orientation with respect to the hoop direction. The effect of number of layers of GFRP sheet was studied by using three different numbers of layers. The 20 MPa concrete cylinders were confined with 1, 2 and 4 layers of GFRP sheet with 0º fiber orientation with respect to the hoop direction. The effect of fiber orientation was examined by wrapping the 20 MPa concrete cylinders with 2 layers of GFRP sheet and three different ply configurations, including 0º/0º, 0º/90º and -45º/+45º.

EXPERIMENTAL RESULTS AND COMPARISON WITH CONFINEMNET MODELS

The experiments indicated that the increase in the compressive strength of GFRP confined specimens compared to the unconfined specimens was 103%, 36% and 25% for concrete cores with the strength of 10, 20 and 40 MPa, respectively. The maximum strain or ductility of GFRP confined specimens compared to the unconfined specimens showed 671%, 509% and 54% increase for low, normal and high strength concrete cores, respectively. The same trend was also observed for the absorbed energy where 1407%, 1026% and 82% increase was found for low, normal and high strength concrete cores, respectively. As the unconfined concrete strength increases, the confinement effectiveness decreases. The GFRP wrapped cylinders with the least concrete core strength show the maximum increase in confined strength. The results also reflect the reduction of ductility effectiveness of GFRP wraps in high strength concrete.

The experiments indicated that any increase in GFRP jacket thickness caused an increase in both maximum stress and strain and also in the absorbed energy of the strengthened specimens. The increase in the jacket thickness from 1 layer to 2 layers and 4 layers translated 36%, 121% and 231% strength increase compared to the unconfined specimens. The same trend existed when the ductility increased by 509%, 752% and 1104% and absorbed energy increased by 11, 22 and 42 times.

The sample with 0º/0º jacket is sufficiently confined and the second part of the stress-strain curve is ascending, while this ascending part shifts to a plateau in two other cases. This different behavior resulted in 121%, 752% and 2200% increase compared to the unconfined specimens in maximum stress, maximum strain and energy absorption capacity, for the specimens confined with 0º/0º GFRP jacket, respectively. This increase was 54%, 357% and 900% for the 0º/90º ply configuration and 26%, 626% and 1300% for the -45º/+45º ply configuration, respectively. The 0º/90º jacket provided a higher confined strength than the jacket with -45º/+45º ply configuration. However, the ultimate confined strain and the absorbed energy for the specimens with -45º/+45º jacket were higher than the specimens with 0º/90º jacket.

Three models are chosen for comparison with the experimental results, including the model by Toutanji, the model by Spoelstra and Monti and the model by Fam and Rizkalla.

CONCLUSIONS

- Confined specimens with low to medium strength concrete show bilinear stress-strain responses. Confining low to medium strength concrete cylinders leads to significant enhancement in strength and ductility.
- The confined high strength concrete shows a strain softening response and very little ductility when it reaches the unconfined concrete strength level and no distinct post peak behavior is observed. For the case of confined high strength concrete, the response is quite similar to that of unconfined concrete. For high strength concrete, little improvement in strength can be achieved due to the confinement, but no significant improvement in ductility is expected.
- For new construction with FRP tubes, it is more effective and economical to use low or medium strength concrete instead of high strength concrete.
- The confinement effectiveness, the ductility effectiveness and the energy absorption capacity reduce with increase in the unconfined concrete strength.
- The ratio of confinement effectiveness and ductility effectiveness reach to a relatively same level in case of confining high strength concrete.
- The confinement effectiveness, the ductility effectiveness and the energy absorption capacity proportionally improve with the increase in the number of GFRP layers.
- The sample with 0º/0º jacket is sufficiently confined and the second part of the stress-strain curve is ascending. The second part of the stress-strain response shifts to a plateau in the case of confined specimens with 0º/90º and -45º/+45º ply configuration.
- The 0º/90º jacket provided a higher confined strength than the jacket with -45º/+45º ply configuration.
- The ultimate confined strain and the absorbed energy for the specimens with -45º/+45º jacket were higher than the specimens with 0º/90º jacket.
- The confinement models show different degrees of accuracy in predicting the confined concrete behavior. For medium concrete strength, the confinement models provided a better prediction of stress-strain response in case of the higher number of layers of GFRP.
- Confinement models failed to predict stress-strain response of confined high strength concrete.
- The confinement models provided a relatively good prediction of the peak confined strength, but they overestimated the ultimate confined strain for different types of concrete strengths and GFRP jacket thicknesses.