EARTHQUAKE RESISTANCE OF CONCRETE COLUMNS REINFORCED WITH DUCTILE-HYBRID FIBER REINFORCED POLYMER (DHFRP)

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1 Introduction

In regions of moderate to high seismicity, reinforced concrete (R/C) structures are designed based on their ability to absorb seismic energy. This absorption capacity exists due to the ability of the reinforcement to yield, thereby producing large inelastic strains.

The low-cycle fatigue behavior of a Ductile-Hybrid FRP (DHFRP) bar was investigated by placing the bars in beam-column concrete elements. Unlike most current FRP bars, the DHFRP bar has a behavior that simulates the stress-strain characteristics of conventional steel reinforcement [1, 2]. The DHFRP bar exhibits a tri-linear stress-strain behavior, which shows significant material toughness for all bar sizes. These bars are produced using a combination of both traditional pultrusion and braiding processes simultaneously, creating a 'Braidtrusion' process, and have been produced in a 10-mm diameter prototype size. The bars are a material hybrid of aramid (Kevlar 49) fibers and carbon (Thornel P-55S). The design methodology and manufacturing process is described in [1] and [3]. The energy absorption capacity of the material was demonstrated through the hysteretic load-deflection and moment-rotation behavior of the beam-columns, and through definitions of ductility indices based on displacement, rotation, and curvature. Shown in Figure 1 is the design philosophy of the DHFRP bar showing the carbon unidirectional core yarns and the braided aramid sleeve.

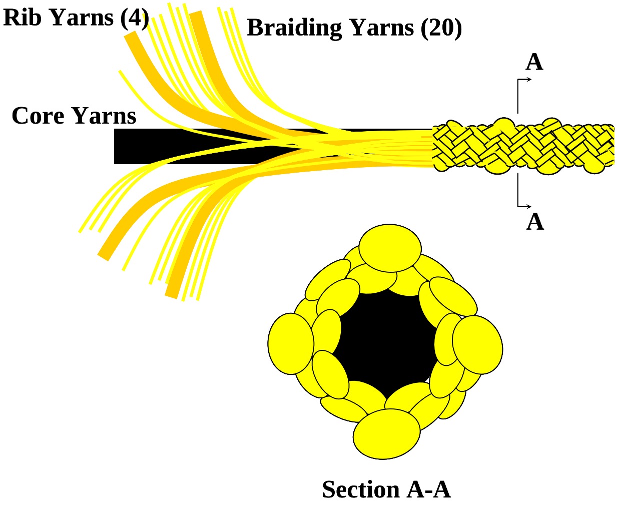

Fig. 1. Design philosophy of DHFRP rebar

2 Results

Testing was conducted on 1/32 and 1/16-scale model bridge piers reinforced with DHFRP. The loading sequence is shown in Figure 2. The samples were subjected to constant axial load with increasing cycles of lateral load through the inelastic range to failure. The reverse cyclic loading behavior of bridge columns reinforced with DHFRP bars was promising. The hysteretic behavior showed significant energy absorption capacity by the DHFRP, especially for large inelastic deformations. Ductility indices of 2.43-4.12 based on displacement, 3.61-5.85 based on rotation, and 3.69-6.08 based on curvature were obtained. This ability to absorb inelastic energy is critical during moderate to severe seismic events and is not typical for FRP materials. Shown in Figure 3 are large inelastic deformations after the development of a plastic hinge at the base of the column. Figure 4 demonstrates the hysteretic behavior and the significant energy absorption demonstrated by DHFRP.

Based on the results of the prototype (1/16-scale) columns, the DHFRP provided sufficient column moment capacity well into the inelastic range, significant displacement ductility, and a stable hysteretic behavior. As the axial load increased, the energy absorption increased, but the hysteresis became more unstable due to increased P-delta moments.

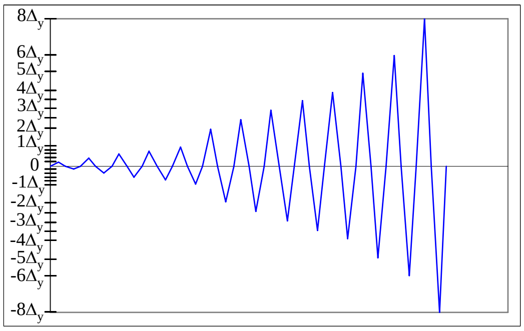

Fig. 2. Loading Sequence for model bridge piers

Fig. 3. Large inelastic deformations of bridge pier samples during testing

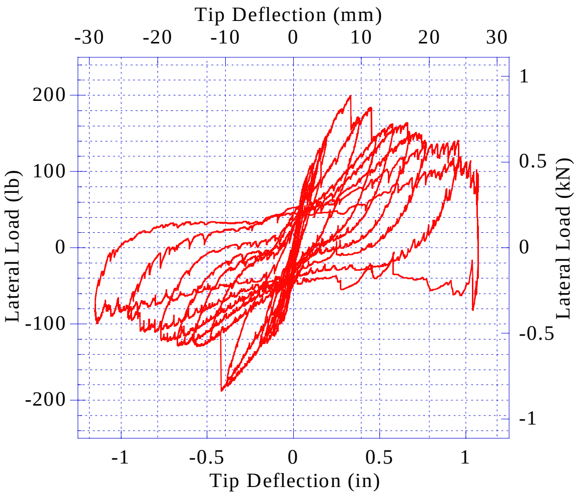

Fig. 4. Hysteresis and energy absorption of DHFRP

References

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