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HYBRID FRP-CONCRETE COLUMN

PROBLEM STATEMENT

In the last ten years, fiber reinforced polymers (FRP) have received considerable attention from the civil engineering community as a viable construction material for repair, rehabilitation, or new construction of the aging infrastructure in various states, especially those subjected to corrosive environments since this material would be useful for minimizing or even eliminating corrosion. A novel application in the form of concrete-filled FRP tubes (CFFT) was initially proposed by the author to the Florida Department of Transportation in 1993. Since then, the feasibility and short-term performance of CFFT piles and columns have been established. Most recently, piles made of precast CFFT were driven into the ground near Tallahassee, Florida to demonstrate the feasibility of the system. However, the long-term time-dependent behavior and the cyclic response of CFFT members have not yet received adequate attention. It is necessary to establish the time-dependent as well as the lateral cyclic response of CFFT, if they are to be used as bridge pier columns or piles. The fundamental issues that need to be addressed are as follows:

- How does the presence of FRP tube affect shrinkage of concrete core?
- Does concrete core shrink away from the FRP tube over time?
- Since both concrete and FRP creep under sustained loads, how does the hybrid system creep over time?
- Is CFFT susceptible to creep rupture during its service life at levels of sustained load normally used for the design of buildings and bridges?
- Can CFFT piles and columns be designed with or without internal steel reinforcement to provide adequate ductility for a safe mode of failure under cyclic lateral loads?

OBJECTIVES

The objectives of this research were as follows:

1. Develop an experimental database for creep and shrinkage of CFFT under axial and flexural loading conditions.
2. Investigate the behavior of CFFT beam-columns, with different levels of fiber reinforcement, and with or without internal steel reinforcement, under constant axial loading and reverse cyclic loading in transverse direction.

FINDINGS AND CONCLUSIONS

A thorough analytical and experimental investigation into the long-term behavior of CFFT beams and columns under sustained loads was carried out. The study resulted in the following findings:

- Shrinkage of concrete core in FRP tube is in the order of 10%-20% of that of exposed concrete. For all practical purposes, the concrete core in CFFT may be considered as sealed with quite negligible shrinkage strains. Moreover, the notion that a concrete core may separate from the FRP tube under the effect of shrinkage is not warranted.

- The current models of the American Concrete Institute (ACI) grossly overestimate creep of concrete core in CFFT columns. The equivalent creep coefficients for the concrete core in CFFT columns may be as low as 22% of that recommended by ACI for a sealed concrete of the same mix proportions and environmental conditions and for the same duration of loading.
- Effect of confinement on creep of concrete core is not as significant as the effect of sealing concrete and the stress re-distribution that occurs between concrete and FRP.
- Creep effects reduce the flexural stiffness of CFFT specimens. However, ultimate strength is not significantly altered.
- Slow rate of loading and short-term creep at 70% of static capacity may cause premature rupture of the FRP tube.
- Fiber analysis of CFFT beam-columns by discretizing the section into filled and hollow FRP tubes can adequately simulate the flexural creep behavior. Moreover, isochronous sustained stress - creep strain curves can be used as constitutive non-linear relationship for creep analysis in flexure.
- Creep rupture life expectancy of CFFT beam-columns with diameter to thickness (*D/t*) ratios of 40 or less is at least 50 years at transverse loads as high as 60% of the static capacity.
- CFFT columns with *D/t* ratios of less than 80 have a creep rupture life expectancy of 75 years at 70% of static capacity under concentric axial loads.

A thorough analytical and experimental investigation was carried out into the cyclic behavior of CFFT beam-columns under constant axial loads and cyclic lateral loads. The findings of the study can be summarized as follows:

- The two types of CFFT beam-columns tested under this study represent two different failure modes; a brittle compression failure for the over-reinforced specimens with thick FRP tube and majority of the fibers in the longitudinal direction, and a ductile tension failure for the under-reinforced specimens with thin FRP tubes and off-axis fibers. The FRP tubes with $\pm 55^{o}$ fiber orientation exhibited significant non-linearity and energy dissipation.
- A moderate amount of internal steel reinforcement in the range of 1%-2% may improve the cyclic response of CFFT members. The improvement is more significant for the under-reinforced FRP tubes. Adding internal steel, especially for members with thick FRP tubes, can be ineffective and may result in premature failure of the system. It is feasible to design CFFT columns with moderate steel reinforcement to be comparable to RC columns under cyclic loading.

BENEFITS

The present study has clearly shown the feasibility of CFFT piles and columns not only under short-term static loading, but also under long-term sustained loading or dynamic and cyclic loading (although it should be noted that this is the case with internal steel reinforcement, as an FRP tube without internal steel reinforcing under monotonic loading exhibits very little nonlinearity). The study emphasizes the importance of proper design of the FRP tube based on the type of applied loading. If effectively utilized, CFFT would be beneficial in protecting bridge pier columns and piles from the corrosive effects of a marine environment.

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