SECONDARY REINFORCEMENT FOR FRP REINFORCED CONCRETE

SUMMARY

Previous work at UMR conducted by Koenigsfeld and Myers on Secondary Reinforcement examined three areas 1.) Early-age tensile characteristic of slabs subjected to environmental conditions; 2.) Later-age tensile test and 3.) Crack control of panels tested in flexure. This study proposed to examine early and later-age crack development on restrained panel systems. Panel or slab systems that have a high level of end restraint are the most susceptible to crack formation due to temperature and shrinkage behavior. A schematic of the test set-up is shown in Fig. 1.

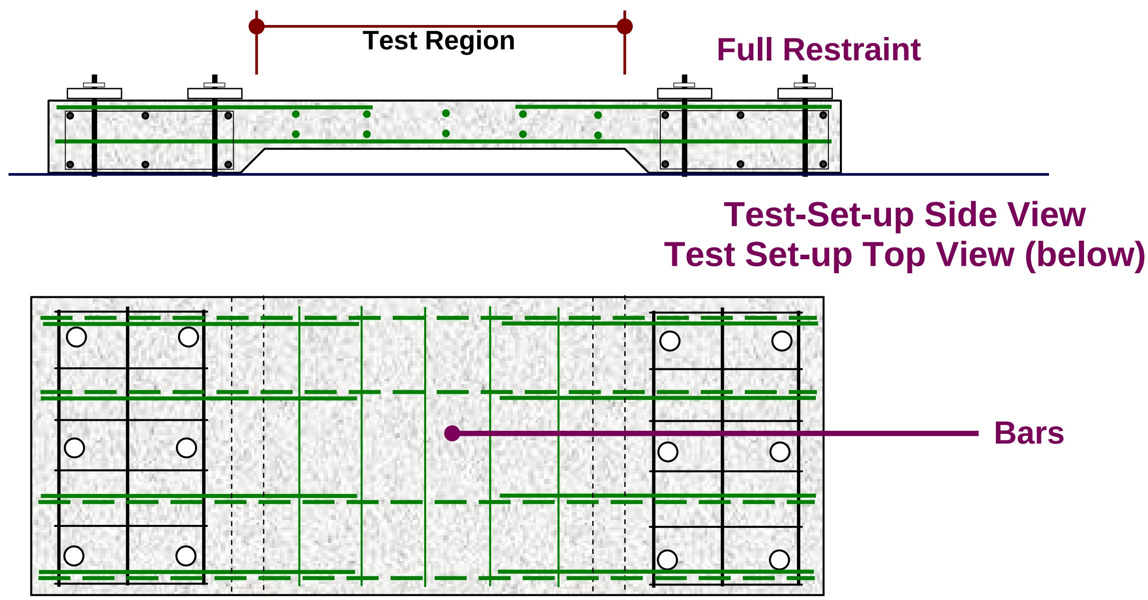

Figure 1. Test Set-Up for Restrained Panel Tests

"REQUESTED NO-COST TIME EXTENSION TO INDUSTRY SPONSOR"

BACKGROUND

Controlling the width and pattern of concrete cracks are important for two primary reasons; durability and aesthetic appearance. Due to rebar corrosion accelerating the deterioration of concrete bridge decks, emphasis has been placed on conserving the service life of structures through adequate crack control. Volume changes due to shrinkage and temperature alone can produce tensile stresses large enough to produce cracks if subjected to sufficient restraint. Reinforcement can not prevent cracks, yet with proper design crack widths are smaller and less likely to contribute to durability problems. Limitations and problems associated with epoxy-coated rebar have led to efforts of trying nonmetallic rebar, such as glass fiber-reinforced polymers (GFRP). Currently, ACI 440.1R-03 "Guide for the Design and Construction of Concrete Reinforced with FRP Bars" requires in many applications a secondary reinforcement ratio that is significantly larger than the primary reinforcement ratio based on flexural requirements be used. The current minimum reinforcement ratio guideline for shrinkage and temperature has no experimental validation and is considered to be excessive by many experts.

OBJECTIVE

The objective of this proposed work is to investigate the development of an empirical secondary reinforcement ratio for FRP based on experimental tests performed at the University of Missouri-Rolla (UMR) and to investigate possible standard test methods for secondary reinforcement that includes boundary restraint.

EXPERIMENTAL PROGRAM

This study contains one primary phase which examines early-age and later-age crack development of various reinforcement ratios on the formation of shrinkage / temperature and flexural cracks. A series of slab panels were cast with varying reinforcement ratios using GFRP bars. Each series included control panels that are reinforced with mild steel to serve as a benchmark. In series one only FRP bar was studied as the primary reinforcement. In series two FRP bars plus random fibers will be used (not yet initiated) to investigate the effectiveness of random fibers combined with FRP bars. To successfully develop an end restraint system the structural floor in the UMR SERL High-Bay Laboratory was used. A schematic is illustrated in Fig. 1 and Fig. 4. Five test panels were cast in Series 1 with varying levels of reinforcement. The panels were cast monolithically with the end supports to develop as close as possible a fixed-fixed end restraint. Table 1 illustrates the test matrix was fabricated in Series 1.

Table 1. Series 1 Test Matrix

Slab #	Reinforcement Type	Reinforcement Ratio (%)
1	Steel	0.18%
2	GFRP	0.22%
3	GFRP	0.33%
4	GFRP	0.44%
5	GFRP	0.56%

Figs. 2, 3 and 4 illustrate the Panel Series 1 during the stages of fabrication and prior to testing.

Figure 2. Series 1 Prior to Casting

Figure 3. Series 1 Specimen Casting

Figure 4. Series 1 Prior to Testing

Figure 5 illustrates a representative panel during later age testing.

Figure 5. Panel during Later-age Testing

RESULTS AND DISCUSSION

Prior to later age testing as shown in Fig. 5, the panels were studied for plastic shrinkage crack formation prior to final set, drying shrinkage cracking during curing and the presence of thermal gradient.

A standard MoDOT bridge deck mix was used to be representative of a deck application that resulted in compressive strength gain as shown in Table 2. The compressive strength development was quite higher than is required (4,000 psi) per MoDOT specifications. In combination with the end restraint, the FRP reinforced concrete panels did not exhibit any significant cracking due to the shrinking of the panels irrespective of the reinf. ratio.

Table 2. Compressive Strength Development

Test Age	Compr. Strength (psi)
1 day	2,320
3 day	4,090
7 day	5,150
14 day	5,970
28 day	6,630
Thermal Gradient	7,860
Flexural Testing	8,200

A temperature increase of 70 °F was achieved at the top of the center of the panel when subjected to high temperature (heat lamps) in an environmental chamber. That temperature increase induced a thermal gradient of 36°F throughout the depth of the panel which exceeded AASHTO specification model gradients. The later-age testing (flexural loading) is currently in process.

In light of the limited cracking that resulted several modifications are planned in the subsequent series of early-age tests including the mix design.

INTERIUM CONCLUSIONS

No significant conclusions are drawn at this time as testing of the panels are in progress.

EXPLANATION FOR NO COST EXTENTION

A no cost extension was requested for the following reasons:

1. Unexpected difficulties in panel crack development at early age due to concrete quality in first series of RC panels.

2. Timeline receipt of research funding and associated delays in the start date of the GRA (Jan. 2005).

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