ACI 440-F anchorage task group: Updating paragraphs that refer to anchorage systems on 440.2R

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Sections

Section 1.2 Scope and limitations

Section 10.1.1 Failure modes (flexural strengthening)

Section 10.2.4 Flexural strengthening of concave soffits

Section 11.4 FRP Contribution to shear strength

Section 13.1.1 FRP Debonding

Section 13.1.2 FRP end peeling

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Section 1.2 Scope and limitations

CURRENT TEXT	PROPOSED CHANGES
Section 1.2-Scope and limitations Some research has been conducted on various methods of anchoring FRP strengthening systems (by mechanical or other means). It is important to recognize, however, that methods of anchoring these systems are highly problematic due to the brittle, anisotropic nature of composite materials. Any proposed method of anchorage should be heavily scrutinized before field implementation.	Research has been conducted on various methods of anchoring FRP strengthening systems (U-wraps, mechanical fasteners, fiber anchors, and NSM rods). Because no anchorage design guidelines are currently available, the performance of any anchorage system should be substantiated through representative physical testing that includes the specific anchorage system, installation procedure, surface preparation, and expected environmental conditions.

Section 10.1.1 Failure modes (flexural strengthening)

Section 10.1.1 Failure modes (flexural strengthening) Transverse clamping with FRP layers improves bond behavior relative to that predicted by Eq. (10-2). Provision of transverse clamping FRP U-wraps along the length of the flexural FRP reinforcement has been observed to result in increased FRP strain at debonding. An improvement of up to 30% increase in debonding strain has been observed (CECS-146 (2003)). Further research is needed to understand the influence of transverse FRP on the debonding strain of longitudinal FRP.	Anchorage systems such as U-wraps, mechanical fasteners, fiber anchors, and NSM rods have been proven successful at delaying, and sometimes preventing, debonding failure (Kalfat et al. 2013, Grelle and Sneed 2013). Numerical and experimental studies have shown that these anchorage systems can increase the strain of the flexural FRP to higher values at the onset of debonding, and up to the level of tensile rupture (Lee et al. 2010).

Section 10.2.4 Flexural strengthening of concave soffits

CURRENT TEXT	PROPOSED CHANGES
Section 10.2.4 Flexural strengthening of concave soffits Alternately, anchor systems such as FRP anchors or U-wraps should be installed to prevent delamination (Eshwar et al. 2003).	Alternately, anchorage systems such as U-wraps, mechanical fasteners, or fiber anchors should be installed to prevent delamination (Eshwar et al. 2003).

Section 11.4 FRP Contribution to shear strength

CURRENT TEXT	PROPOSED CHANGES
Section 11.4 FRP Contribution to shear strength Mechanical anchorages can be used at termination points to develop larger tensile forces (Khalifa et al. 1999). The effectiveness of such mechanical anchorages, along with the level of tensile stress they can develop, should be substantiated through representative physical testing. In no case, however, should the effective strain in FRP laminates exceed 0.004	Anchorage details have been used to develop higher strains in bonded U-wraps used in shear strengthening applications. Anchorage systems include mechanical fasteners, FRP patches, U-wrap extensions (or embedment), fiber anchors, and NSM rods (Kalfat et al. 2013, Grelle and Sneed 2013). Properly anchored U-wraps can be designed to fail by FRP rupture (NCHRP-678 2011). In no case, however, should the effective strain in FRP laminates exceed 0.75 ε_{fu}

Section 13.1.1 FRP Debonding

Section 13.1.1 FRP debonding Mechanical anchorages can be effective in increasing stress transfer (Khalifa et al. 1999), although their efficacy is believed to result from their ability to resist the tensile normal stresses rather than in enhancing the interfacial shear capacity (Quattlebaum et al. 2005). Limited data suggest a modest increase in FRP strain at debonding can be achieved with the provision of transverse anchoring FRP wraps (Reed et al. 2005). The performance of any anchorage system should be substantiated through testing.	Anchorage systems have been proven successful at delaying, and sometimes preventing, debonding failure (Kalfat et al. 2013, Grelle and Sneed 2013). Numerical and experimental studies have shown that these systems can increase the strain of the flexural FRP to higher values at the onset of debonding, and up to the level of tensile rupture (Lee et. al 2010). A few studies have proposed analytical models to predict the behavior of specific anchor systems (Kim and Smith 2010), however no published anchorage design guidelines are currently available; thus the performance of any anchorage system should be substantiated through representative physical testing.

Section 13.1.2 FRP end peeling

CURRENT TEXT	PROPOSED CHANGES
Section 13.1.2 FRP end peeling The tensile concrete cover splitting failure mode is controlled, in part, by the level of stress at the termination point of the FRP. In general, the FRP end peeling failure mode can be mitigated by using anchorage (transverse FRP stirrups), by minimizing the stress at the FRP curtailment by locating the curtailment as close to the region of zero moment as possible, or by both. When the factored shear force at the termination point is greater than 2/3 the concrete shear strength (Vu > 0.67Vc), the FRP laminates should be anchored with transverse reinforcement to prevent the concrete cover layer from splitting. The area of the transverse clamping FRP U-wrap reinforcement $A_{f,anchor}$ can be determined in accordance with Eq. (13-1) (Reed et al. 2005) $A_{fanchor} = \frac{(A_f f_{fu})_{longitudinal}}{(E_f \kappa_v \varepsilon_{fu})_{anchor}}$ (13-1)	The tensile concrete cover splitting failure mode is controlled, in part, by the level of stress at the termination point of the FRP. In general, the FRP end peeling failure mode can be mitigated by using anchorage (U-wraps, mechanical fasteners, or fiber anchors), by minimizing the stress at the FRP curtailment by locating the curtailment as close to the region of zero moment as possible, or by both. When the factored shear force at the termination point is greater than 2/3 the concrete shear strength (Vu > 0.67Vc), the FRP laminates should be anchored with transverse reinforcement to prevent the concrete cover layer from splitting. The area of the transverse clamping FRP U-wrap reinforcement $A_{f,anchor}$ can be determined in accordance with Eq. (13-1) (Reed et al. 2005) $A_{fanchor} = \frac{(A_f f_{fu})_{longitudinal}}{(E_f \kappa_v \varepsilon_{fu})_{anchor}}$ (13-1)

Cited References

Literature Review

Next steps

- Ballot this document at 440-F
- Ballot revised 440.2R document at 440 Main