

Endurance Characteristic Curves Testing

- To reliably extend service life beyond 50-75 years
 - We need to update time/cycles to rupture curves with new FRP bars
 - ACI 440.3R-B.8 creep rupture failure due to deformation from a constant load on different size and type of FRP bars for a given environment with linear regression to a million hours for creep rupture strength (LSM)

Table 1 - Creep rupture stress limits, ACI 440.1R-15 (Table 7.4.1)

Fiber type	GFRP	AFRP	CFRP
Creep rupture stress limit $f_{fs,sus}$	$0.20f_{fu}$	$0.30f_{fu}$	$0.55f_{fu}$

$$f_{fc} = C_c f_{fu} = C_c C_E f_{fu}^* = 0.14 f_{fu}^*$$

Adapted from ACI 440.1R-15

- C_c parameter for creep, C_E environmental
- CL confidence limit for guaranteed strength
- Need low cost test method for supplier product acceptance
- Cause-and-effect, correlation

Parameter	CSA S806	Proposed	ACI 440	AASHTO	Proposed
C_c	0.25		0.20	0.20	0.25
C_E	0.85		0.70	0.70	0.70
ffu* CL	95%		99.7%	99.7%	99.7%
$C_c \times C_E$	0.21		0.14	0.14	0.18
Example:					
1000 Mpa					
50 MPa std	2		3	3	3
ffu* guar	900		850	850	850
ffu design	189		119	119	149

Endurance Characteristic Curves Testing

- To reliably extend service life beyond 50-75 years
 - ACI 440.3R-B.7 tensile fatigue life, the number of repeated to million loading cycles to fail the FRP bar for a given load and environment (S-N curves) separate parameter C_f
 - Dr. Nanni on endurance curves and limits on FRP rebar

Critical Design Parameters

	AASHTO -18 2 nd Ed.	AASHTO -09 1 st Ed.	ACI 440. 1R-15	CSA-14	
f_{fu}^*	99.73	99.73	99.73	95.0	Percentile grntd. strength
Φ_C	0.75	0.65	0.65	0.75	Res. Fact. concr. failure
Φ_T	0.55	0.55	0.55	0.55	Res. Fact. FRP. failure
Φ_S	0.75	0.75	0.75	0.75	Res. Fact. shear failure
C_E	0.70	0.70	0.70	1.0	<i>Env. knock-down</i>
C_C	0.25	0.20	0.20	0.25	<i>Creep knock-down</i>
C_f	0.25	0.20	0.20	0.25	<i>Fatigue knock-down</i>
k_b	1.2	1.4	1.4	1.0	<i>Bond coeff.</i>
w	0.028	0.020	0.028	0.020	Crack width
$C_{c, stirrups}$ [in.]	1.5	1.5	2.0*	1.5	<i>Clear cover</i>
$C_{c, primary}$ [in.]	2.0	2.0	2.5*	1.5	<i>Clear cover</i>
$C_{c, slab}$ [in.]	1.0	0.75	2.0*	1.5	<i>Clear cover</i>

* ACI 440.5-08 Table 3.1

