APPROPRIATE ENVIRONMENTAL REDUCTION FACTORS FOR FRP

SUMMARY

In order to suggest appropriate reduction factors for FRP, the values proposed by various guidelines were collected and reviewed. A worldwide literature survey was conducted to explore suggested durability factors for various FRP materials and systems. This data was compiled and studied. Much of the reported literature reported that the FRP material used either internally or externally for concrete members degraded due to the attack of various exposure conditions such as freezing, thawing, simulated tidal exposure, alkali and acid attack and Ultraviolet (UV) ray exposure.

BACKGROUND

The "Gap Analysis" (Karbhari et al., 2001) pointed out that research is requisite in areas related to standardization and test methods for various FRP materials and there is a lack of easily accessible data. Furthermore, a Task Group constituted by ACI Sub-Committee 440L (2004) suggested that a literature search be undertaken to obtain and assemble data to better evaluate current guide recommendations to review the appropriateness of current ACI guideline recommendations. Therefore, this study has been initiated to retrieve and compile available data.

This is in response to a vagueness about the supporting data for the environmental reduction factors proposed in the guidelines of ACI, (American code), JSCE (Japanese code), CHBDC (Canadian code), NS3473 (Norwegian code), BISE-EUROCRETE (British code) and FIB Task group 9.3 (European code).

OBJECTIVE

To explore and report appropriate environmental reduction factors that are used for FRP applications in concrete.

COLLECTION OF DATA

The environmental reduction factors reported in this summary were collected from ACI 440.2R-02, ACI 440.1R-03, a Task Group Report on the Environmental Reduction Factors for Internal and External FRP by ACI Sub-Committee 440L, and other worldwide codes. A literature survey was performed for obtaining information regarding the durability of FRP. Technical papers published in various books and journals, were reviewed to retrieve the required information.

DISCUSSIONS

Various values for reduction factors were compared. Table 1 summarizes these values. Also detailed in the table is the median value that is obtained based on data collected from worldwide codes.

TABLE 1: SUMMARY COMPARISON OF THE EXISTING DURABILITY REDUCTION FACTORS

Criteria	Type of fibers used	Highest value used	Median	Lowest value used
Reduction for Environmental Degradation	CFRP	1.0	0.88	0.60
	GFRP	0.80	0.70	0.1375
	AFRP	0.90	0.85	0.31
Reduction for sustained stress	CFRP	1.0	0.95	0.90
	GFRP	1.0	0.9	0.80
	AFRP	1.0	0.85	0.70
Total strength reduction for environmental exposure and sustained stress	CFRP	1.0	0.86	0.60
	GFRP	0.80	0.55	0.30
	AFRP	0.90	0.74	0.42
Creep rupture limits	CFRP	0.55	0.55	0.55
	GFRP	0.22	0.22	0.22
	AFRP	0.30	0.30	0.30
Stress limits for permanent load	CFRP	0.85	0.76	0.44
	GFRP	0.75	0.70	0.14
	AFRP	0.85	0.70	0.16

The literature survey helped in the compilation of data regarding the strength degradation in FRP material used in concrete. Four figures have been developed based on the percentage reduction in the strength of the FRP materials reported in various sources of literature. The classification of data was based on the application of FRP. They are classified as internally bonded, externally bonded and material alone. Figures 1, 2, 3 and 4 are presented below.

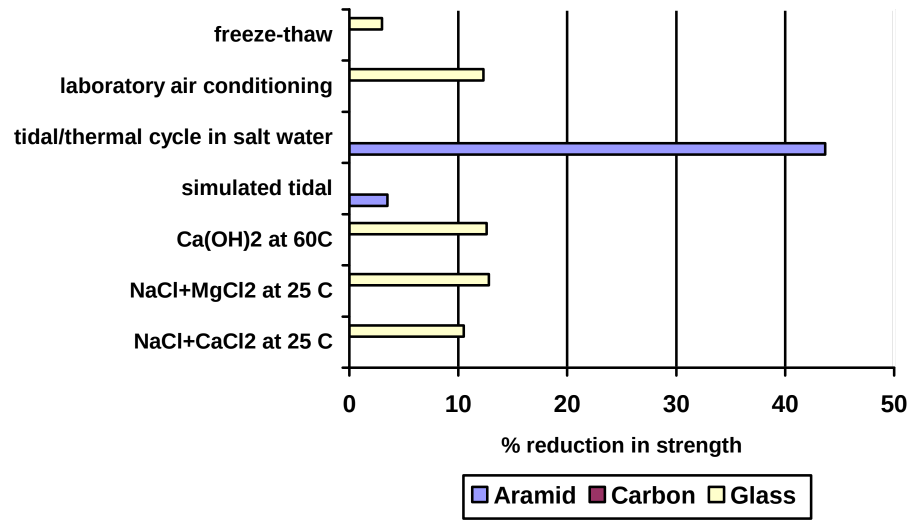

Figure 1. Strength Degradation in Internally bonded FRP

Fig. 1 shows that strength degradation was approximately 10 to 12.5% for internal GFRP bars used in concrete when exposed to alkaline solution where as strength degradation varies from 4% to 45% for two different exposure conditions.

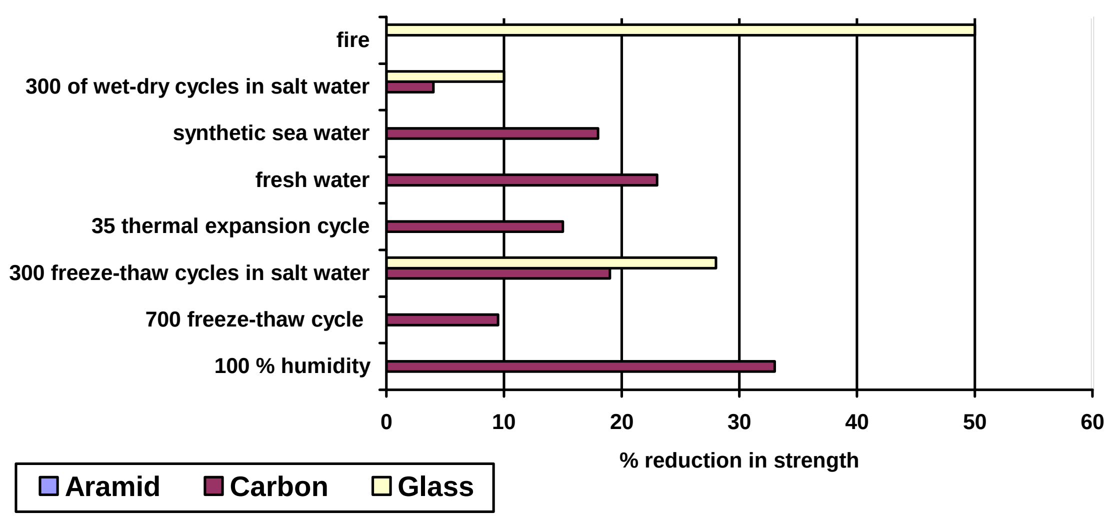

Figure 2. Strength Degradation in Externally bonded FRP

Fig. 2 shows that strength degradation varies from 4% to 19 % for concrete members reinforced with externally bonded carbon fibers under various exposures except to that of fresh water and humidity exposure. Under fresh water and 100% humidity exposures, strength degradation was about 23% and 33% respectively. Similarly, for concrete members with externally bonded glass fibers as reinforcement strength degradation was from 10 to 28% under various exposures. No data was obtained for aramid fibers.

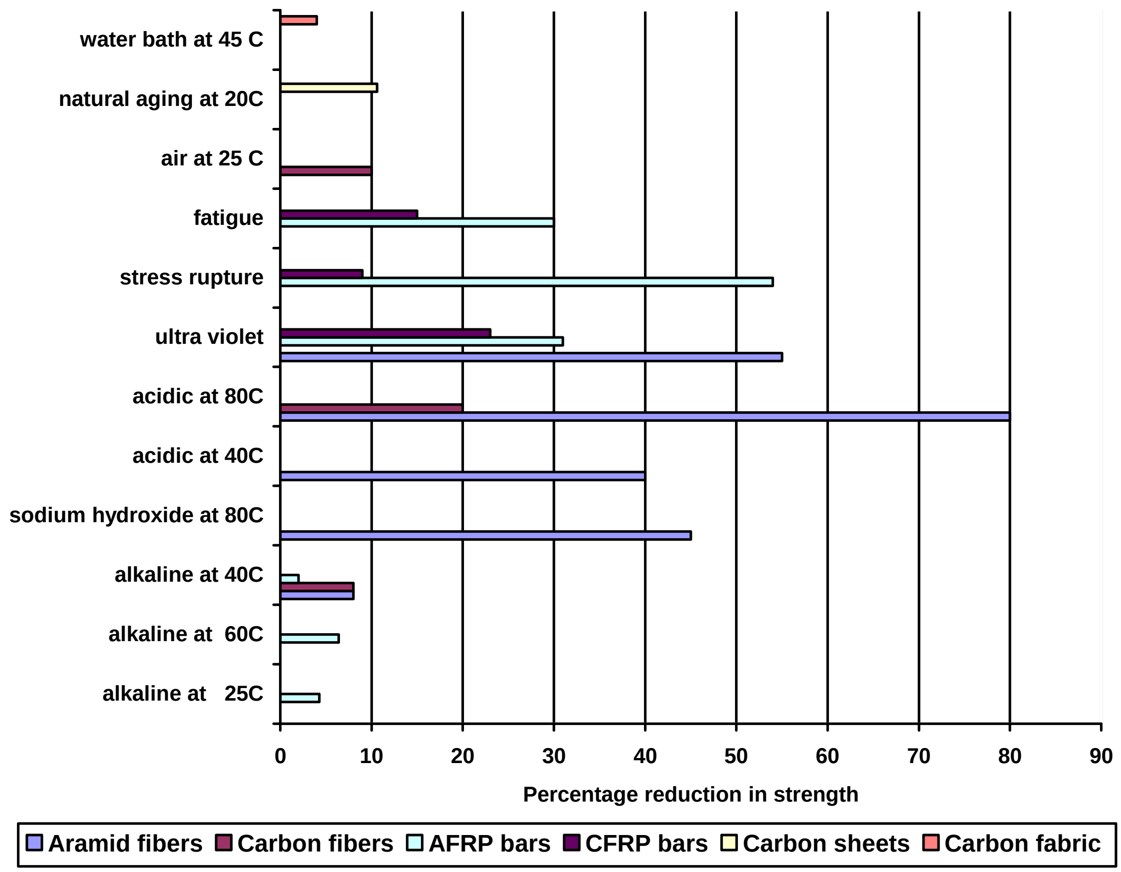

Figure 3. Strength Degradation of FRP material alone

In Fig. 3, it is shown that the strength degradation is different in acidic exposure at different temperatures for aramid fibers. In alkaline solution, AFRP bars retained more strength than Aramid fibers. Maximum degradation for CFRP bars is due to UV exposure according to this graph and this percentage degradation is 23%.

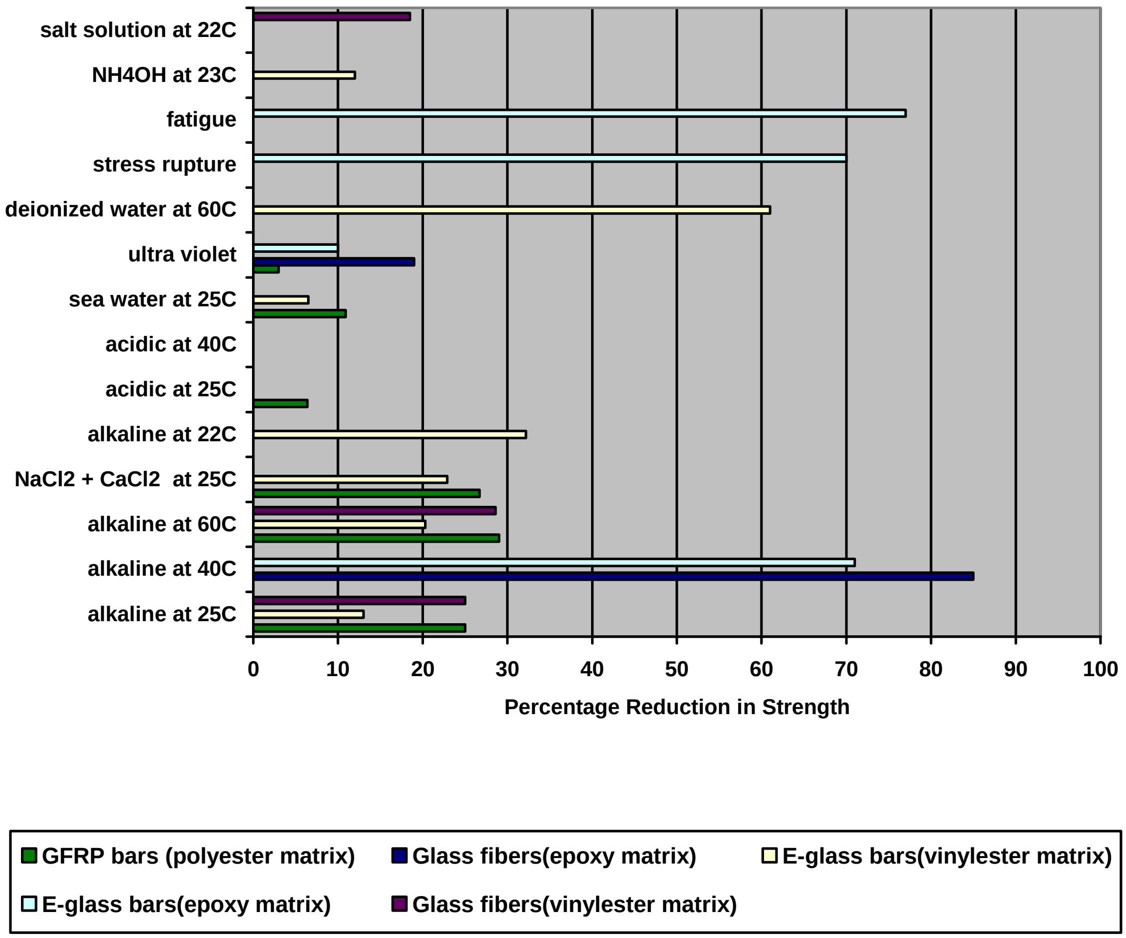

Fig 4 Strength Degradation of Glass FRP alone

Percentage reduction in strength is about 85% for glass fibers exposed to alkaline solution at 40°C but it is less for glass bars. Minimum strength degradation was when exposed to Ultra violet rays.

CONCLUSION

Laboratory studies showed that there is strength degradation in all FRP materials applied in concrete. 100% humidity and fresh water exposure is the largest enemy to carbon fibers. When exposed to all other conditions the degradation was below 20%. In case of aramid fibers, the degradation varied from 45% to 80% under different exposures. Finally, the glass fibers were found to be degraded more when exposed to alkaline solution at a temperature of 80C than in all the other conditions.

Some of the values obtained in the aforementioned figures approximately match the values proposed by various guidelines; however, there was insufficient literature that provided the strength degradation due to the synergistic effect for all these different exposures. Moreover, no data is available to conclude over the creep rupture limits.

It is apparent that the link between laboratory and filed related studies is greatly lacking. Therefore, field data needs to be compiled and compared with the laboratory studies to examine if these reduction factors should be eliminated, reduced, or increased.

SOURCE OF ADDITIONAL INFORMATION

Additional information is available in the final detailed project report which includes durability related data sheets on recent laboratory studies.

CONTACT

Thara Viswanath
Graduate Research Assistant
Dept. of Civil, Architectural and Envir. Engineering
The University of Missouri-Rolla
E-mail: tv98f@umr.edu

John J. Myers, Ph.D., P.E.
Assistant Professor of Civil, Arch. & Envir. Engineering
Architectural Engineering Program Coordinator
Dept. of Civil, Architectural and Envir. Engineering
The University of Missouri-Rolla
325 Butler-Carlton Hall
Rolla, Missouri 65409-0030
(V) 573-341-6618
(F) 573-341-6215
Email: jmyers@umr.edu