INFLUENCE OF MECHANICAL PROPERTIES AND OTHER CHARACTERISTICS ON THE DURABILITY STUDY OF FRP MATERIALS

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Introduction

To ensure effective and efficient utilization of FRP materials for strengthening and repair of different parts of the infrastructure, several criteria must be met. These include mechanical properties (e.g. short and long term strength), interactive structural properties (e.g., bond to concrete, anchorage), physical properties (e.g. thermal expansion) and durability (e.g., resistance against physico-chemical attack etc.). Among all these items, it is now well established that the long-term durability of FRP composites is the single most important factor needed for their successful application as repair materials or reinforcement for concrete (Alsayed *et al.* 2002; Almusallam *et al.* 2002, Al-Salloum 2001).

On the other hand, factors such as volume of FRP, type of fiber, fiber orientation, type of resin, dimensional effects, method of manufacturing, and quality control during manufacturing play major roles in establishing product characteristics. Under such circumstances it is difficult to distinguish between the variation due to the above factors and those due to the environmental and loading effects (durability effect). Unless the variations in the engineering characteristics due to the foresaid factors are limited to some tolerable values, the results of the durability study will be meaningless. Therefore, it is reasonable to say that durability study must be carried using only materials that have steady engineering characteristics before being subjected to environmental and/or loading variations. In addition, some other factors such as type of application, level and ease of application and consistency of the available data with the actual test results should also be considered in the screening test for the durability study.

Experimental Program

The present study was a part of the funded research project. The objective of the project was to evaluate the durability of the composite sheet system (CFRP sheets, GFRP sheets and the counterpart epoxy for each type of sheets) for external strengthening of the infrastructure in Saudi Arabia. For this purpose, an extensive screening test program was conducted to determine the composite system with the least variation in the instantaneous mechanical properties, the lowest complication in utilization and the best consistency between the data sheet properties and the corresponding measured properties. Therefore, a total of six types of composite system were considered in this study. A weight factor for each property was considered in the evaluation process. Based on the results of the screening tests the composite system(s) to be used for the durability study was selected. The tests considered in carrying out the screening tests on the FRP sheets and the counter part epoxy are shown in Tables 1 and 2, respectively.

Table 1 Tests carried out on FRP sheets

Test Type	ASTM STANDARD
Tensile Test Peak Strain Modulus of Elasticity	ASTM D 3039/D 3039M-00
Shear Strength	ASTM D 5868-01
Flexural Strength Flexural modulus of	ASTM C 1341-00
Pull-Out	ASTM D 4541-95

Table 2 Tests carried out on epoxy

Test Type	ASTM
Glass transition temp. (°C)	ASTM D 3418-00
Moisture absorption (%)	---
Flexural strength (MPa)	ASTM D 790-00
Flexural modulus of elasticity	
Tensile strength (MPa)	ASTM D 638-00
Tensile modulus of elasticity	
Tensile strain at Break	

Test Results

In addition to the mechanical properties, the weight factors play a paramount role in defining the best candidates for the durability study. Of particular concern is the fact that these weight factors are function of the type of application and the service and environmental conditions that the FRP system will be exposed to. Moreover, when enough data is available, the coefficient of variation (COV) of the different parameters can be used in evaluating the screening test results.

In this study six types of composite systems were investigated. For each type of tests, 10 samples were considered. However, due to the space limitations, the results for three types of GFRP composites system are presented in Table 3.

Based on the results, composite system type 2 was found to be the best candidate for the durability study.

Conclusions

To assure the long term performance of the composite system, a methodology for defining the best candidate materials for the durability study is suggested in this paper.

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References

Alsayed S.H., Alhozaimy, A.M., Al-Salloum, Y.A., Almusallam, T.H., "Durability of the New Generation of GFRP Rebars Under Severe Environments," *Second Int. Conf. on Durability of Composite for Construction*, Montreal, Quebec, Canada, May 29-31, 2002.

Almusallam, T.H., Al-Salloum, Y.A., Alsayed, S.H. and Alhozaimy, A.M., "Tensile Strength of GFRP Bars in Concrete Beams Under Sustained Loads at Different Environments," *Second Int. Conf. on Durability of FRP Composites for Construction*, Mont., Canada, May 29-31, 2002.

Al-Salloum, Y.A., Almusallam, T.H. and Alsayed, S.H., "Effect of Hot-Dry Weather on Performance of RC Beams Externally Strengthened with GFRP heets," *Third Int. Conference on Concrete Under Severe Conditions: Environment & Loading*, Vancouver, Canada, June 18-20, 2001.

Table 3 Results of the screening tests

Standard Test	**Importance Factor (Out of 3)**	***GFRP***					
		Type 1		Type 2		Type 3	
FRP SYSTEM		Points	Total	Points	Total	Points	Total
Tensile stress	3	1.00	3.00	0.64	1.93	0.30	0.91
Tensile strain	3	1.00	3.00	0.78	2.33	0.79	2.36
Tensile modulus of elasticity	3	1.00	3.00	0.80	2.40	0.37	1.10
Shear strength	1	0.77	0.77	0.45	0.45	1.00	1.00
Flexural strength	1	1.00	1.00	0.41	0.41	0.19	0.19
Flexural strain	1	0.72	0.72	0.56	0.56	1.00	1.00
Flexural modulus of elasticity	1	1.00	1.00	0.50	0.50	0.15	0.15
Pull-out strength	2	0.63	1.26	0.43	0.86	1.00	2.00
Adhesive		Points	Total	Points	Total	Points	Total
Glass transition temperature	3	1.00	3.00	0.99	2.97	0.63	1.88
Moisture resistance	2	0.99	1.98	0.49	0.98	1.00	2.00
Flexural stress	1	0.59	0.59	1.00	1.00	0.52	0.52
Flexural strain	1	1.00	1.00	0.78	0.78	0.61	0.61
Flexural modulus of elasticity	1	1.00	1.00	0.72	0.72	0.88	0.88
Tensile stress	3	0.87	2.60	1.00	3.00	0.72	2.16
Tensile strain	3	1.00	3.00	0.98	2.94	0.66	1.98
Tensile modulus of elasticity	3	0.64	1.92	1.00	3.00	0.85	2.54
Easiness of application	3	0.20	0.60	1.00	3.00	0.80	2.40
Easiness of preparation	3	0.20	0.60	1.00	3.00	0.80	2.40
Consistency with available	3	0.85	2.55	1.00	3.00	0.85	2.55
Total		**32.57**		**33.81**		**28.62**	