Fatigue Behavior of Heat-Damaged and FRP Repaired Beams

Rami H. Haddad* and Yasmeen T. Obaidat*

* *Civil Engineering Department, Jordan University of Science and Technology, P.O. Box 3030, Irbid, Jordan.*

Summary: Fatigue behavior for heat-damaged and FRP repaired beams was invesitaged using ABAQUS software. Main parameters studeid included heat-damage level and FRP type and configurations. Results showed satisfactory effeciency of FRP composites in regaining fatigue strength espacially when carbon FRP friber was used.

FEM Modelling

A Finite element model (FEM) was developed using ABAQUS software to investigate the impact of repairing heat-damaged beams with Fiber Reinforced Polymer (FRP) composites on their fatigue mechanical behavior. Modelling was conducted on reinforced concrete beams with dimensions of 100 x 200 x 1400 mm. The cyclic behavior of undamaged beams and those, heated to 400-600^{o}C then cooled, was investigated under four-point loading at a fatigue load range of 20-74% with emphasis upon number of cycles to failure, load-deflection response, materials' strain response, and cracking propagation and mode of failure. Continuum material models are used for concrete, steel, and interface along thickness of FRP-concrete bond. The advanced model for concrete plastic damage was used to simulate concrete's behavior. Elastic-plastic model for steel reinforcement and linear elastic model for FRP were adopted. Furthermore, a bond traction separation model was assumed between FRP and concrete.

The FEM was validated using literature data representing mechanical behavior, cracking and failure of undamaged concrete beams under for the specified geometric dimensions and load cycling range conditions. Figure 1 shows a comparison between measured strains in steel as compared to those predicted by the present FEM: the two curves are almost matched over the entire spectrum of cycles considered. The predictions of mid-span deflections for the beams were also in an excellent agreement with experimentally measured ones, as listed in Table 1. Furthermore, the mode of failure observed experimental showed satisfactory agreement with that predicted using the present FEM.

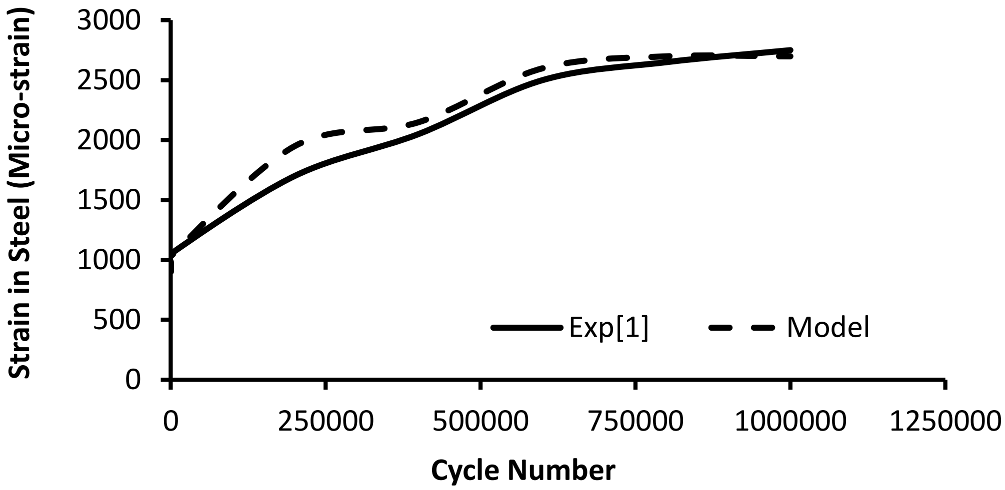

Figure 1. Strain induced in steel reinforcement versus cycle number for control beams, [1].

Predictions by the FEM

FEM predictions were expanded to study fatigue performance of heat-damaged and FRP repaired beam. Primary results showed that cracks were developed during the first few cycles before their width and depth increased with number of cycles. Figure 2 supported the latter argument as strain induced in steel reinforcement was significantly increased with number of cycles. Logically, concrete would experience similar response that is accompanied with crack formation once the ultimate strain capacity had been exceeded followed by crack width and length increase. Strengthening with FRP composites had resulted in less induced fatigue strain in steel reinforcement as compared to that of control beams. Accordingly, the fatigue life would be increased whereas deflection decreased upon the application of FRP composites to concrete beams. As can be induced from Figure 2, repairing with carbon FRP composites is more effective that with glass FRP. In general, repairing heat-damaged beams contributed to extending tangible their fatigue as compared to those without repair.

Table 1. Comparison between FEM predictions of mid-span deflections of control beams and those of literature data.

Number of cycles	Experimental work(mm)	Model(mm)	Reference
20	0.530	0.565	Dong et al.[1].
100000	0.520	0.582	
1000000	0.520	0.581	
1000	4.30	4.61	Parvez et al. [2]
10000	4.50	4.69	
100000	4.90	4.95	

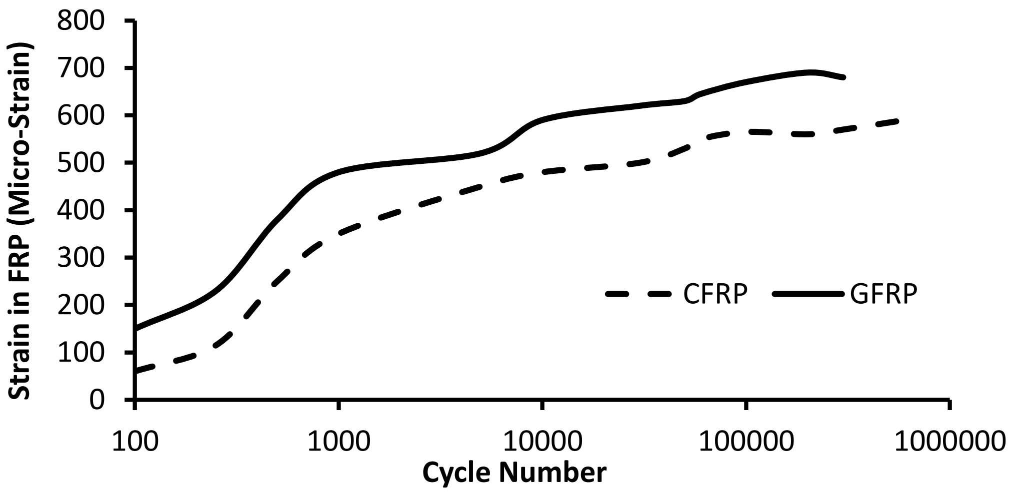

Figure 2. Strain induced in steel reinforcement versus cycle number for control beams strengthened with carbon and glass FRP composites, attached to the beams' tension sides using special epoxies.

Conclusions

Strengthening heat-damaged and undamaged reinforced concrete beams with different configurations of carbon and glass FRP composites had extended the fatigue lives of these beams. The study showed that percentage improvement in fatigue performance of modelled beams is dependent upon heat-damage level as well as the type and configuration of FRP composites, attached as an external reinforcement.

References

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