Sustainable Solutions in Structural Engineering and Construction
Edited by Chantawarangul, K., Suanpaga, W., Yazdani, S., Vimonsatit, V., and Singh, A.

ISBN: 978-0-9960437-0-0

FLEXURAL PERFORMANCE OF RC BEAMS UNDER TROPICAL CLIMATE EFFECTS

NAUWAL SUKI, MOHD HISBANY MOHD HASHIM, and AFIDAH ABU BAKAR

Faculty of Civil Engineering, Universiti Teknologi MARA, Shah Alam, Malaysia

This study investigates the flexural performance of RC beams under the effects of a tropical climate. Effects from the tropical climate, such as heat and rain throughout the year, may cause deterioration to the surface of concrete. Concrete will gradually erode and may expose the steel inside the beam. If the steel is exposed, it may be oxidized, thus decreasing the strength of the RC structure. To avoid this situation from happening, the Near Surface Mounted (NSM) method of strengthening may be applied as an alternative. Three beams with the size of 125 mm x 300 mm x 1800 mm (width; height; length) were constructed for this study. The first one is a beam without strengthening, while the other two beams were strengthened with CFRP plate horizontally positioned on the tension zones, where one beam is placed under room temperature conditions, while the other is left to endure the conditions of the tropical climate for a period of 6 months. All three beams were then tested under a four-point bending test. Results show that the strengthened beam placed under room temperature conditions has 1% more flexural strength compared to the exposed beam. The exposed beam, however, has 21% more flexural strength compared to the control beam. Thus, NSM is proven to strengthen beams even in a tropical climate.

Keywords: Flexural performance, Reinforced concrete, Beams, Near surface mounted, Carbon fiber-reinforced polymer, Tropical climate effects.

1 INTRODUCTION

Harsh effects from nature may cause deterioration to the concrete surface. Concrete will slowly erode and may expose the steel inside the beam. If the steel is exposed, it will be corroded, thus decreasing the strength of the reinforced concrete (RC) structure. Climate-related deterioration on building surfaces is commonly caused by temperature differences, water and polluted particles brought by wind (Yaldiz 2010).

Strengthening the structures may be unavoidable in order to overcome the effect of environmental deterioration (Mohd. Hashim *et al.* 2013). The Near Surface Mounted (NSM) method of strengthening using Fiber Reinforced Polymer (FRP) can be applied as an alternative. Through this method, grooves are first cut in the concrete cover at the tension zone of an RC beam. After the grooves are produced, the strengthening materials will be attached to the concrete surface using adhesive.

This study focuses on investigating the flexural performance of NSM method for strengthening RC beams with the effects of tropical climate as the FRP-concrete system should be studied in detail especially in the tropical climate region to gain the acceptance in the industry as well as in the economic terms (Hashim *et al.* 2011). The strengthening material used for this method is the Carbon Fiber Reinforced Polymer (CFRP) plate.

2 METHODOLOGY

All the specimens used in this study were design based on BS EN 1992-1-1:2004 and BS EN 1992-1-2:2004. Concrete grade 30 was used to construct all the specimens in this study. The reinforcement steel consists of the main and transverse reinforcement with a tensile strength of 460MPa and 250MPa respectively. The modulus of elasticity for both reinforcement steel is 200GPa. CFRP plate was used as the strengthening material. The plate has a tensile strength of 3000MPa and 165GPa modulus of elasticity. Epoxy adhesive that was used to glue the strengthening material to the concrete surface has a tensile strength of 30MPa and 2GPa modulus of elasticity.

Three beam specimens were constructed with the size of 125mm x 300mm x 1800mm (width; height; length). The first beam is a control beam without any strengthening as shown in Figure 1.

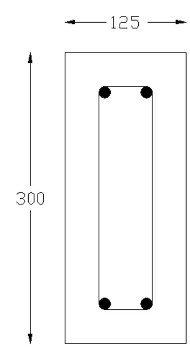


Figure 1. Cross sectional area of control beam (all units are in mm).

The other two beams constructed in this study were strengthened with CFRP plate horizontally positioned on the tension zones as shown in Figure 2(a). One beam was placed under room temperature conditions while the other one was left to endure the conditions of the tropical climate for a period of 6 months. Figure 2(b) shows the groove's dimensions.

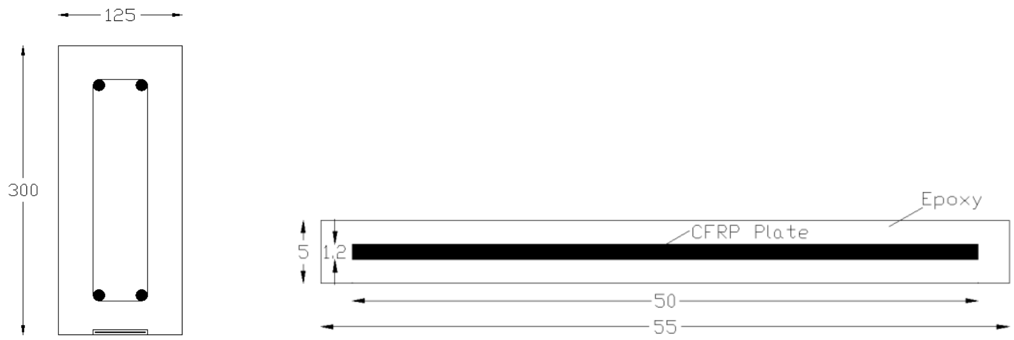
After 28 days, the control beam was tested under a four-point bending test. The other two beams with strengthening material were tested after reaching the period of 6 months.

3 RESULTS AND DISCUSSIONS

3.1 Load-Deflection Behavior

Table 1 shows the data for ultimate load and deflection at near failure. Beam B-02 recorded the highest ultimate load of 93.10kN, followed by beam B-03 and B-01 with 92.55kN and 74.40kN respectively. Although the exposed beam shows reduction by 1% in ultimate load compared to beam B-02, it is still higher compared to the control beam. This indicates that the beam with strengthening can improve flexural performance of RC members even with the harsh effects of tropical climate. Beam B-

02 and B-03 were affected by debonding of CFRP plate on the tension zone causing greater deflection compared to beam B-01. The plotted data for ultimate load versus deflection is shown in Figure 3.



(a) (b)

Figure 2. Cross-sectional area and dimension for horizontal positioning CFRP plate (all units are in mm).

Table 1. Ultimate load and deflection.

Beam Description	Beam ID	Ultimate Load (kN)	Deflection (mm)
Beam without strengthening	B-01	74.40	13.78
Beam strengthened with CFRP Plate (room temperature)	B-02	93.10	16.51
Beam strengthened with CFRP Plate (exposed to tropical climate)	B-03	92.55	18.28

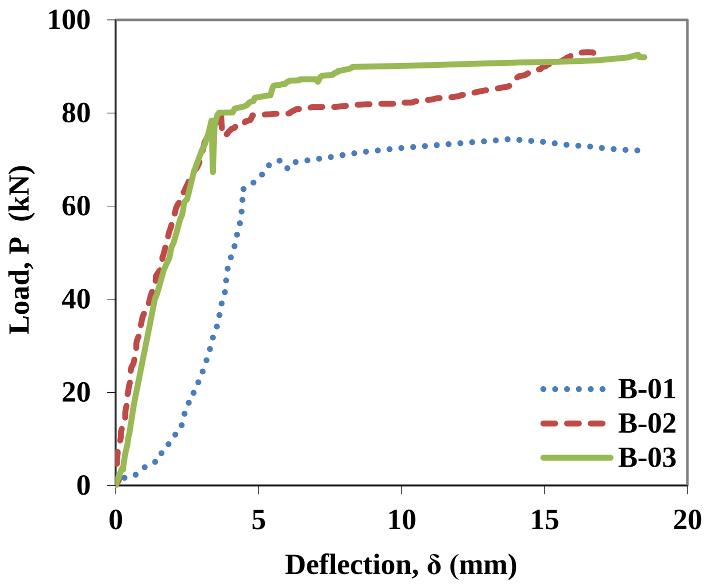


Figure 3. Load versus deflection curves.

3.2 Failure mode and crack pattern

Figure 4 shows the failure mode of beam B-01 which has failed by crushing of concrete at the compression zone. Figure 5 and 6 show the debonding of CFRP plate at the tension zone as the beams failed. The first crack for all three beams occurs at the middle of the beam before developing, and moves towards the support.

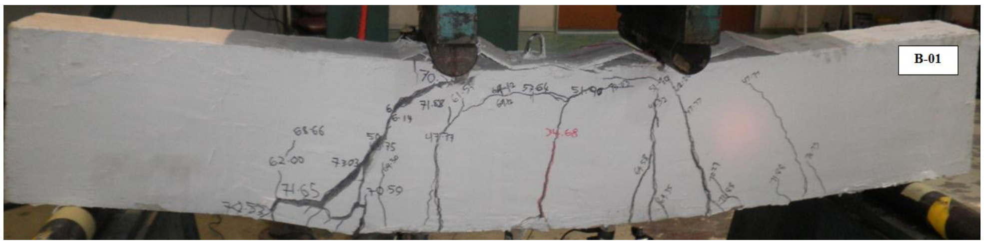


Figure 4. Failure mode of the control beam.

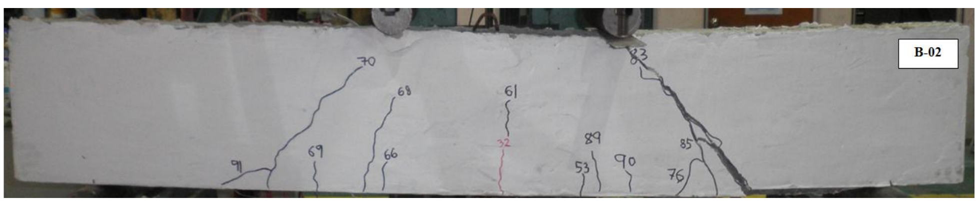


Figure 5. Failure mode of beam placed in room temperature condition.

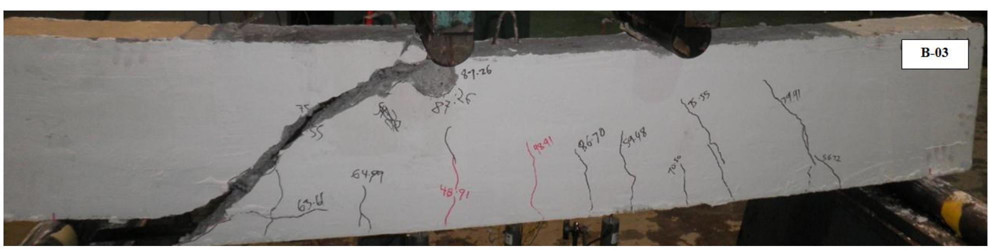


Figure 6. Failure mode of beam exposed to the tropical climate.

Table 2 tabulates the data related to cracks. First crack load for all three beams occur at a load of between 34% to 52% of the ultimate load. Beam B-01 recorded the highest number of cracks formed, followed by beam B-03 and B-02.

Table 2. Crack details.

Beam ID	First Crack Load (kN)	Total Number of Cracks	Largest Crack Width (mm)
B-01	34.68	27	11
B-02	32.00	12	10
B-03	48.91	14	16

4 CONCLUSIONS

Results show that the strengthened beam placed under room temperature conditions has 1% more flexural strength compared to the exposed beam. The exposed beam, however, has 21% more flexural strength compared to the control beam. The beam which has been exposed to tropical climate effects shows an increased number of cracks formed, compared to the beam placed in room temperature condition, by 15%. It can be concluded that the cracking behavior can be affected by nature. However, NSM has demonstrated its ability to strengthen beams in the long term even with the effects of a tropical climate.

References

BS EN 1992-1-1:2004, Eurocode 2: Design of Concrete Structures (Part 1-1: General Rules and Rules for Building), CEN, April 16, 2004.

BS EN 1992-1-2:2004, Eurocode 2: Design of Concrete Structures (Part 1-2: General Rules – Structural Fire Design), CEN, July 8, 2005.

Hashim, M. H. M., Sam, A. R. M. and Hussin, M. W., The Future of External Application of Fibre Reinforced Polymer in Civil Infrastructure for Tropical Climates Region, *International Journal of Mechanical and Materials Engineering* (IJMEE), 6(2), 147-159, 2011.

Mohd. Hashim, M. H., Mohd. Sam, A. R., Hussin, M. W. and Mohd Arshad, M. F., Structural Performance and Ductility of Fiber Reinforced Polymer Concrete Bonding System under Tropical Climates, *Jurnal Teknologi*, 61(3), 21-29, 2013.

Yaldiz, E., Climate Effects on Monumental Buildings, *Conference on Water Observation and Information System for Decision Support* (BALWOIS 2010), Macedonia 2010.