Load Test on Reinforced Concrete Beams Strengthened by Carbon Fibre Laminated Plates—A Case Study

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EXTENDED ABSTRACT

Water Fall Mall is located in Hawally area of Kuwait. It houses three story most modern malls with 20-story residential complex above. At mezzanine level, in three areas with double space, the client wanted to add one more floor with heavy live loads. Figure 1 shows a view of the mall.

Fig 1: Water Fall Mall

Three planted columns were installed such a way that carrying not only the proposed slab but also part of other two stories, resulting in 600 m^2 load area on each column The original beams of 9 m span where columns were planted not designed to carry such additional loads. Due to the floor height and service restrictions, the dimension of the beam could not be increased or strengthen by concrete jacketing or steel plates. Only option was laminated fibre reinforced plates to be so thin that architect would allow. After placing laminated plates under the beam, questions were on its effectiveness with the concrete. Whether laminated plates would work as one entity to resist the new load could not have been resolved theoretically or other lab based experimental methods. Therefore, a load test was suggested.

A total 23,334 thousands sand-cement blocks were placed in four layers over a area of 600^2 for one beam.

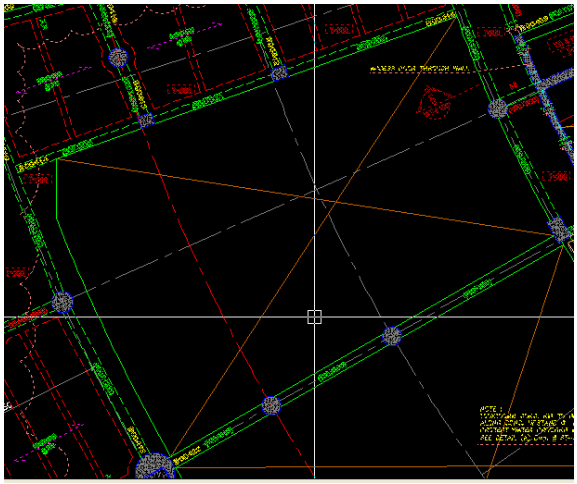

Fig 2: Two Planted Columns

To cover the total three beams about 75,000 sand-cement blocks were placed. Figure 2 shows the plan of floor with planted columns. In two places height of the blocks was 4.8 m due to heavy super imposed loads. All three beams were tested simultaneously.

The following Fig. 3 shows loads next to block walls. In Kuwait it is practiced to use heavy sand-cement blocks as partition walls.

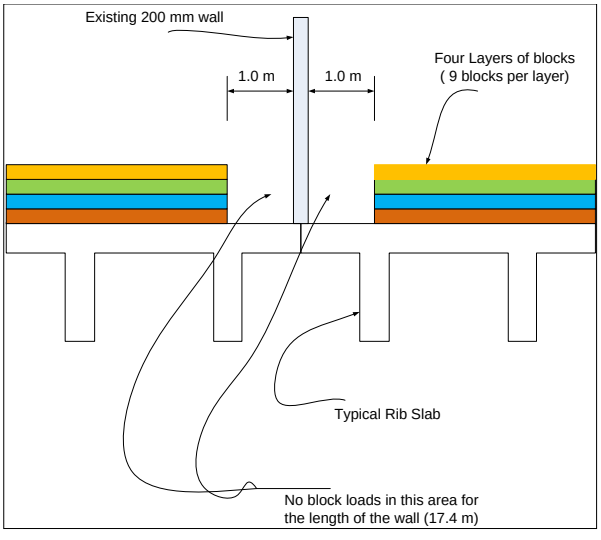

Fig 3: Ribbed Slab with Loads

The slab system with the beams is ribbed type of depth 500 mm and centre to centre span is 750 mm.

Three dial gauges were installed as shown in the following Figure 4.

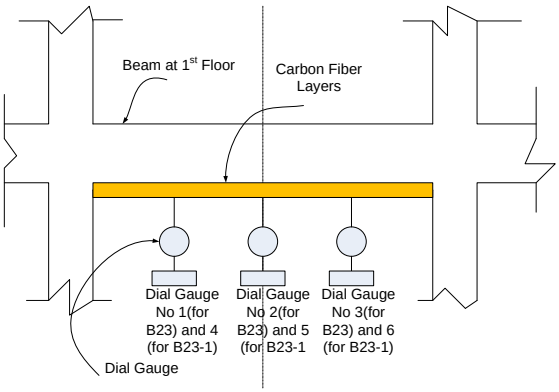

Fig 4: Dial Gauge Location Under Beam

The yellow strip that is seen in Fig 4 is advanced fibre reinforced laminated plates. The following Figure 5 shows the laminated strip under the beam.

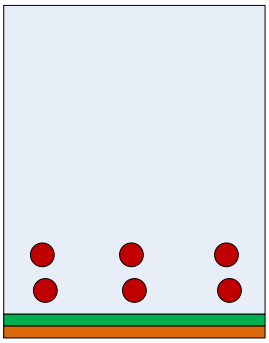

Fig. 5: Beam with Laminated Strips

Two layers of laminated carbon plates were installed. Each layer has nine plates of size 1.4 mm thickness, and 100 mm width. Tensile strength of the carbon plate used is fy = 2420 MPa, and Young's Modulus = 1600 GPa. Figure 6 shows the placement of laminated carbon plate at the end of the beam.

Fig 6: Carbon Fibre Plate at Beam

Resin of type epoxy and hardener type Plolyamide Amine were used with 2:1 ratio, respectively.
Reference ACI 318M-08 has been used in load scheme and strength evaluations process. Flexure cracks of width less than 1 mm developed within the middle third of the beam. The depth of the cracks were within 2 mm. One can identify as surface cracks. Flexure cracks initiated just before the carbon laminated plates, 16 mm from the surface of the bottom of the concrete. The following Fig 7 shows vertical flexure cracks and their locations.

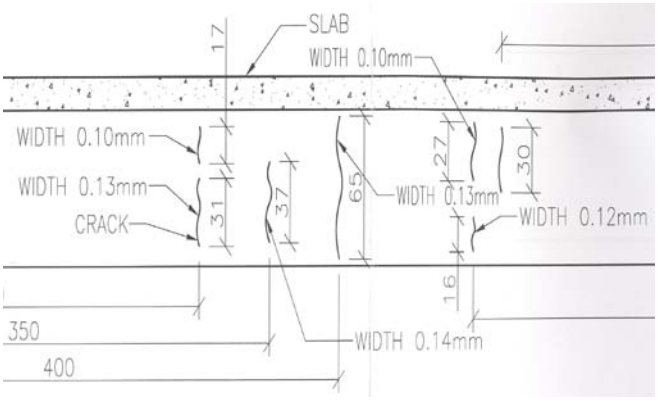

Fig 7: Cracks on Beams at 100% Loading (after 24 hours)

Figure 8 shows deflection versus load stage.

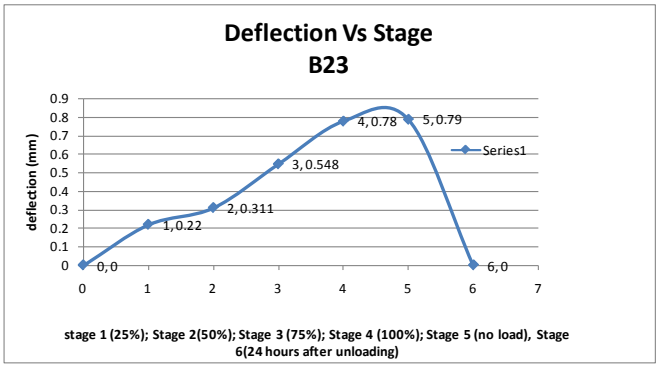

Fig. 8: Load-Deflection Curve at the Center of the Beam

Fig 8 shows load stage 25%, 50%, 75%, 100% and 100% (after 24 hours) load vs deflection vatiations. Normally, creep effects are noticeable (up to 25% permanent deflection) for the case of traditional reinforced concrete. However, combination of carbon fibre plates with the traditional reinforced concrete beams, such creep or permanent deflection was not observed.

CONCLUSION

Three beams of span 9000mm were loaded with 75,000 sand-cement blocks. Deflection, cracks, spallinging, or distress were observed. No permanent deflection was found in the beams.

REFERENCES

American Concrete Institute, ACI 318M-08, Detroit, Michigan, USA.