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Rehabilitation of existing Kanchpur bridge using carbon fiber reinforced polymer laminate

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ABSTRACT: Application of Carbon Fiber Reinforcement polymer Laminate (CFRP) for retrofitting old structure in Bangladesh is very rare. This paper presents the successful application of CFRP for retrofitting the existing Kanchpur Bridge. The application Procedure of CFRP has been explained in this paper. The cost comparison of applying CFRP for retrofitting the Kanchpur existing bridge and constructing new Kanchpur Bridge has also been made in the paper.

1 BACKGROUND

Currently, there is an increased demand for the strengthening or rehabilitation of existing reinforced concrete (RC) bridges and buildings. This is mainly due to the ageing, deterioration, increase in loads, corrosion of steel reinforcement or revision in the design codes and knowledge. Higgins et al. (2007) pointed out that the previous design provisions did not have a comprehensive understanding of the behavior of certain structures. Therefore, design code provisions from pre-1970s would be different from current design codes. In addition, construction materials are changing substantially. The American Association for State Highway and Transportation Officials (AASHTO) bridge design provisions did not consider the use of modern deformed reinforcing bars until 1949, and explicit bond specifications for deformed bars were not announced until 1953 (AASHTO, 2002). The knowledge of proper anchorage was unclear. Therefore, many existing structures designed before 1960s have smaller cross-sectional sizes, smaller dimensions for stirrups, wider spaced reinforcement and decreased requirements for flexural bond stresses. This is why older concrete structures become deficient during their service life and require strengthening and repair. While complete replacement of a deficient/deteriorated structure is a desirable option, strengthening/repair is often the more economical one.

While many methods of strengthening structures are available, strengthening by applying CFRP laminate has become popular. For strengthening purposes, application of CFRP laminate is more advantageous than other materials. Teng et al. (2002) pointed out that, there is increased demand for extensive research work to improve the characteristic behavior of FRP materials to establish their application acceptability in RC structures, beams, slabs and columns. In particular, their practical implementations for strengthening civil structures are numerous. Several researchers (Li et al., 2008; Camata et al., 2007; Toutanji et al., 2006; Bencardino et al., 2002) pointed out that most of the pragmatic works consist mainly of the rectangular beams.

Although many research studies (Arduini et al., 1997; Nanni, 1995; Chajes et al., 1994; Saadatmanesh et al., 1991) had been conducted on the strengthening and repairing of simply supported RC beams using external plates, there is little reported work on the behavior of strengthened continuous beams. Especially, works relating to the application of CFRP laminate for strengthening the tension zone of RC beams in the presence of column are very few. In addition, there are few difficulties arise due to the presence of columns and other components such as electric and plumbing lines or HVAC ducts. These columns and components hinder the process of applying CFRP laminate in this region using conventional techniques. Another important point is that, the use of thick steel plates for strengthening will raise the floor level, which might be undesirable.

In Bangladesh, ma be Kanchpur, Meghna and Gumti bridges are the pioneer in which CFRP has been widely used commercially. The application procedure of CFRP in Kanchpur bridge and the cost comparison with respect to new bridge construction has been explained in the following sections.

2 REPAIR METHOD SELECTION

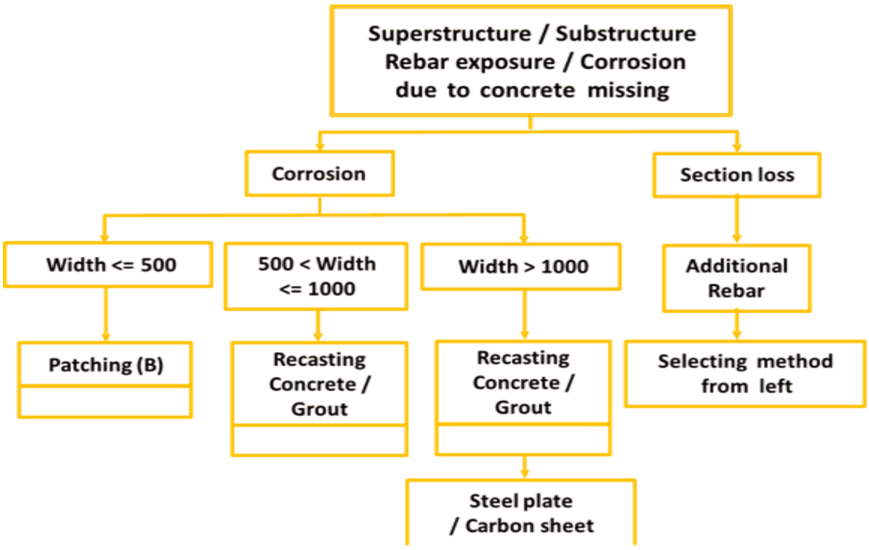

Figure 1. Selection of retrofitting method.

3 MATERIAL, TOOL/EQUIPMENT

Following material, equipment/tools were used for Carbon fiber sheet application for Kanchpur existing bridge: CFRP, Epoxy primer, Epoxy putty, Epoxy resin adhesive, Abrasive Sand blaster, Air compressor, Disc grinder, Portable generator, Paint Roller/ Brush

4 WORK FLOW OF CARBON FIBER SHEET BONDING

The workflow of applying CFRP in Kanchpur bridge has been explained in the following figure.

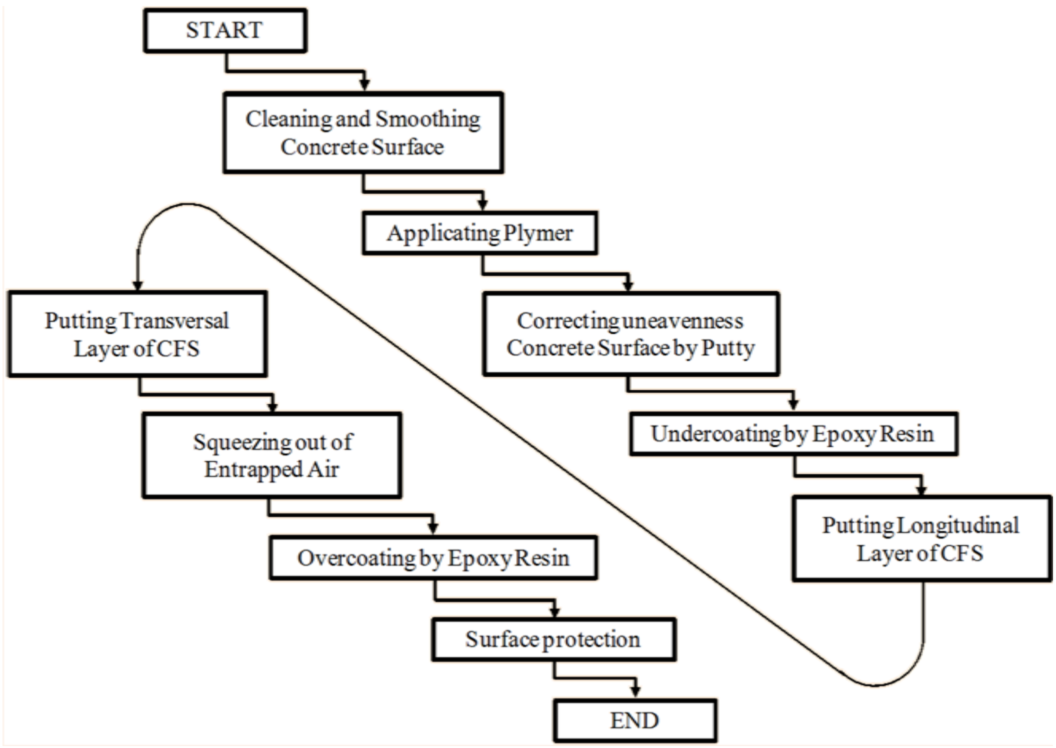

Figure 2. Work flow of applying CFRP.

Systematical procedure of applying CFRP in Kanchpur bridge has been explained in the following sections.

4.1 *Surface Preparation*

- Concrete surface were cleaned and smoothened by disc grinder or abrasive sandblasting , and free from moisture.
- Cracks were sealed or waterproofed.
- Cracks larger than 0.3mm were injected epoxy.

(a)

(b)

Figure 3. Surface preparation.

Figure 4. Adjustment of unevenness with putty.

Figure 5. Adjustment of unevenness with putty.

4.2 *Adjustment of Unevenness with Putty*

- Any concave, pores, gaps on the concrete surface were smoothened using epoxy putty using trowel or spatula.
- Application timing primer shows tack-free.
- Allowable unevenness 1 mm/m.

4.3 *Application of Epoxy Resin for Undercoat*

- Application timing epoxy putty shows tack-free.
- Surface of primer resin and epoxy putty tack-free, and no dust and clay.
- Time interval of longer than 3 days after the primer and putty application coated surface should be roughened with sandpaper and cleaned.
- Application rate 0.5kg/m^2.

4.4 *Putting Longitudinal Layer of CFS*

- Alignment CFS strips were aligned on the adhesive coated concrete surface.
- Application of CFS were pressed the CFS by using plastic roller starting from the center toward the edge to squeeze out entrapped air before the epoxy resin sets.
- Stick the CFS in the longitudinal direction lapse of 20~30 minutes after the epoxy resin application.
- When lapping of two CFS is required, a lap length of not less than 20 cm were provided.

Figure 6. Putting longitudinal layer of CFS.

Figure 7. Putting Transversal Layer of CFS.

4.5 *Putting Transversal Layer of CFS*

- Alignment to be aligned CFS strips on the adhesive coated concrete surface.
- Application of CFS at right angles to each other in same manner as the longitudinal direction.

4.6 *Squeezing of Strip to Entrapped Air*

- Squeezing entrapped air squeezed out the strips using the roller, before the adhesive sets.
- Do not apply the roller against the direction of the placed CFS to avoid damaging the material.

Figure 8. Squeezing of strip to entrapped air.

4.7 *Over Coating by Epoxy Resin / Surface Protection*

- Applied quantity of Over Coating Epoxy Resin 0.2kg/m^2.
- Fire protection fire proof protection coating were applied to the finished surface.

5 DETAILS OF CFRP USED FOR KANCHPUR BRIDGE

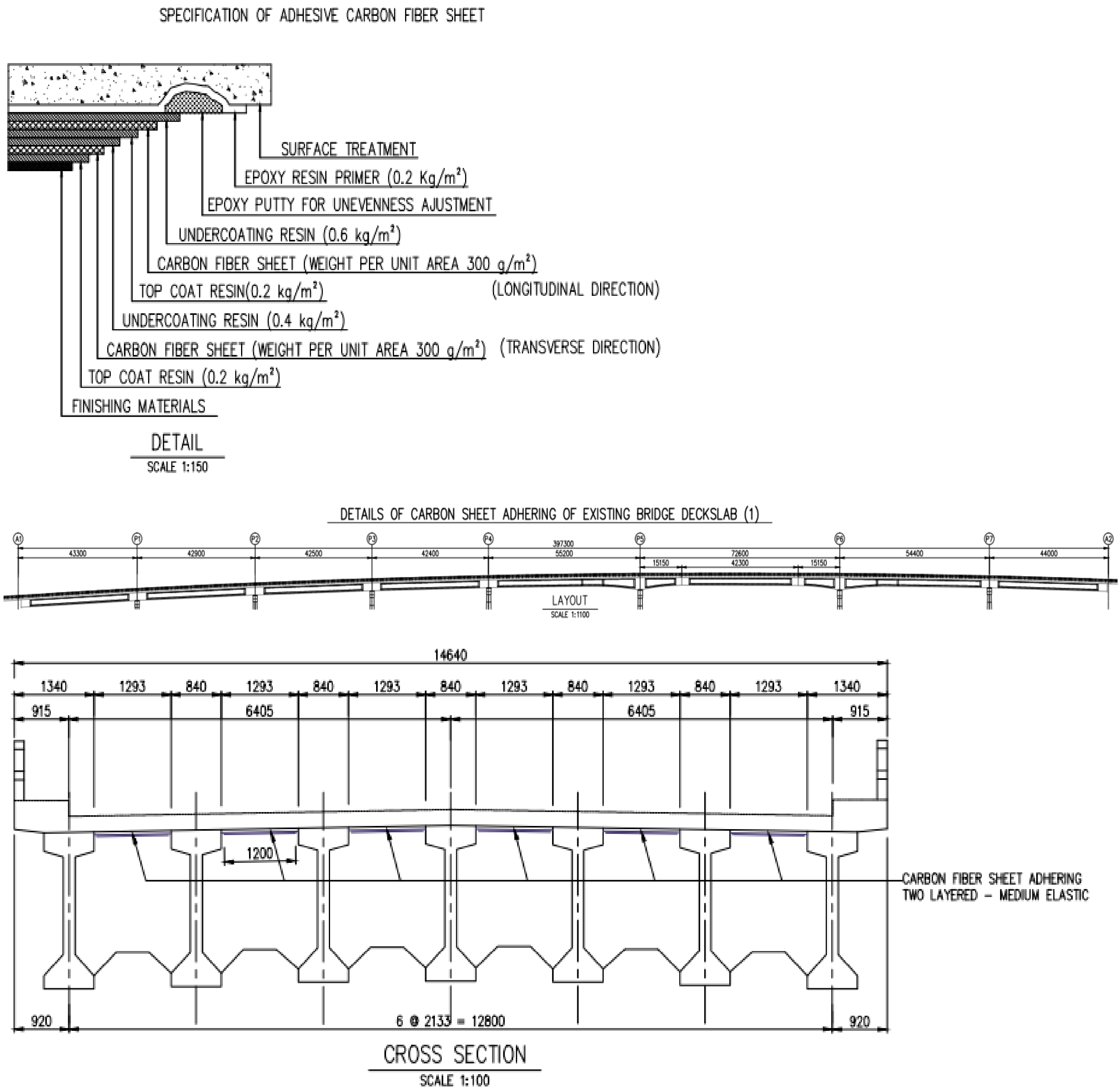

Figure 9. Details of CFRP used for Kanchpur bridge.

Figure 10. Bridge deck slab before applying CFRP.

Figure 11. Bridge deck slab after applying CFRP.

6 COST COMPARISONS

On an average the construction cost of one square feet Kanchpur, Meghna and Gumti 2nd bridge was about 5 Lac BDT. On the other hand, the retrofitting cost of one square feet Kanchpur, Meghna and Gumti old bridge was about 74 thousand BDT, 1 Lac BDT and 1.5 Lac BDT for applying 1, 2~5 and 4~7 layers of CFRP respectively. It was also shown by Rahman (2012) that the strengthened structure can withstand double load compared to that of unstrengthened structure.

7 CONCLUSIONS

From the discussion it is clear that a huge amount of budget can be saved by retrofitting old structures compared with new construction. Specially, countries like Bangladesh will be extremely benefitted it this technology is commercially applied.

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