Repair & Retrofitting of National Highway Bridge By Using Carbon Fiber Reinforced Composites - A Case Study

Dr. Mangesh Joshi¹, Sagar Patil², Manish Yadav³
¹CEO, ²Structural Design Engineer, ³Project In-charge (Execution)
Sanrachana Structural Strengthening Pvt. Ltd. (SSSPL), Thane, India

Abstract: Presently in India, numbers of bridges are structurally deficient and are restricted to the lighter traffic loads and/or lower speed. Due to the lack of proper maintenance and overloading bridges are showing distress which may cause sudden bridge failure that can lead to losses of lives and economy both. Such bridges are needed to be rehabilitated or reconstructed. However for bridge retrofitting traffic diversion traffic management becomes major issue as conventional bridge repairs methods are bulky and time consuming. The modern FRP composite materials are promising for its high efficiency and shorter shut down period of structure. One such Bridge near Phagwara, Punjab is successfully rehabilitated using these modern techniques. It was more than 50 year old design for 45R loading. As per present loading this bridge need to sustain 70R loading. The most significant advantage of using FRPC in rehabilitation and retrofitting of the bridges is that bridge can be strengthened to the desired level without increasing the dead load of the structure. The structural performance of the particular strengthened structure was very satisfactory under the actual load test and it successfully met all the structural requirements with generous safety margin. The paper presents the evolution of the structural strengthening system, its application at site and details of load test conducted.

Introduction

The NH-1 Panipat-Jalandhar Toll Road Project is the biggest among the National Highway development project (NHDP). The project consists of six-lanes of 291 km of the existing four lane NH1 road from Panipat to Jalandhar from Km 96.000 to Km 387.100.

On this project, structural cracks were observed on the major bridge near Phagwara which connect Jalandhar and Phagwara city. It was decided jointly by concessionaire and consultant that this bridge has to be rehabilitated and accordingly Authority approved the repair and rehabilitation work.

Bridge consist of 8 spans having 7 girders. The total length of the bridge is 216m. The plan area of the carriageway is 27m X 7.5m. The bridge was functionally designed for IRC 45R loading. As per the revised recommendations of IRC and prevailing practices, the bridge is now required to sustain IRC Class 70 R loading.

Upon critical inspection and the comparison of the design load versus the strength of the girders of bridge, it was observed that:

1. The girders provided in the bridge are not adequate to resist the design vehicle load as per revised IRC recommendation,
2. Occurrence of the structural cracks in the girders (i.e. vertical crack in the center) which prove the strength inadequacy of the girders (photo no. 2).
3. Loss of pre-stressing in cross diaphragms beam shows that each girder of bridge superstructure is behaving independently.

In view of the above, there was an immediate need for repair & rehabilitation of super structure. Based on the design and analytical solution it was decided that bridge will be rehabilitate with carbon fiber and Pre-stressed carbon fiber laminate with 4 to 5Ton pre-stressing force. The actual work of retrofitting was carried out by Specialized contractor Sanrachana Structural Strengthening Pvt. Ltd.

Methodology of Rehabilitation

Step by step methodology is explained as below

Step 1: Application for pre-stress laminate at bottom of girder up to full length

Step 2: Application for non-pre-stress laminate at bottom of girder upto 20m length

Step 3: Application for single no of 500mm wide 600 GSM UD carbon fiber strips upto 20m length
Step 4: Application for 4 nos of 500mm wide 600 GSM UD carbon fiber strips at center 8m length

Step 5: Application for 600 GSM UD carbon fiber wrap in vertical direction

Step 6: Application for 415 (+45/45) glass fiber wrap in vertical direction (in span 5 and Span 8)

Site Execution Photos

Photo 1: Initial Cracks
Photo 2: Initial Cracks

Photo 3: Initial Cracks
Photo 4: Sand Blasting on Girder

Photo 5: Before and After sand Blasting
Photo 6: Crack Opening

Photo 7: Crack Opening
Photo 8: Nozzle Fixing

Photo 9: Nozzle cleaning by Blower
Photo 10: Grouting

Photo 11: Prestress Laminate – 100X1.4mm
Photo 12: Prestress and non prestress Laminate

Photo 13: Fiber Wrapping Process
Photo 14: 20m Length Carbon fiber wrapping

Photo 15: 600 GSM Carbon Fiber on girder
Photo 16: Final view of carbon Fiber
Rapid Bridge Load Test

The various measurements (As per IRC-SP-51-1999) to ascertain strengthening effect has been presented below.

1. Measurement of deflection of the Bridge at the identified locations under the static loading.
2. To assess the effect of rehabilitation work on the bridge.
3. To submit the report on the experimental studies.
4. To check the percentage recovery of deflection after removal of load.

Test Procedure

The load test procedure of the Chehru Bridge will be tested for static load condition. Load test procedure involve following point.

1. Two Standard vehicle having distance of 3.1 meter between front and middle axle and 1.4 meter between two rear axles and weighing 35 Ton (average weight) were used for loading (As shown in Photo No.1)
2. Two vehicles of 35T was kept at the center of the span for generating maximum deflection or Maximum bending moment. Position of the vehicle was place in such a manner that it will generate maximum deflection. Front wheel of the vehicle will be 18.68 from the support.
3. Before placing the vehicle, three deflection sensors were placed at bottom of span no. 5. One sensor was placed at the center and two sensors were at L/4 (both the side) from the support.
4. Initial reading of the sensor was noted. Once the vehicle placed at the loading position, pre-final reading was taken.
5. After 24hr. final reading was recorded.
6. After removal of the load, recovery of span was monitor for 24 hr.
7. Once recovery was recorded for 24 hr. sensor and data acquisition system was maintain for another 24hr to check the variation due to temperature.

As per IRC:SP 51-1999 clause 5.2, Minimum percentage recovery of deflection at 24hr. after removal of load for prestressed concrete is 85%. Due to temperature, deflection in the

Load Vs Deflection

Superimposing of Loading and Unloading of Sensor 1

Load (ton)

Deflection

-5

0

5

10

15

0

20

40

60

80

Loading

Series 3
sensor remain unchanged so graph and correction due to temperature in the deflection reading is not considered.

Conclusion

Major NH Bridge was successfully retrofitted using modern FRP Composite. Post Tensioned Carbon fiber laminates can be used effectively to optimize the use of composite. Full scale load test was successfully carried out with generous margins

Acknowledgement: