Rehabilitation for Disaster Mitigation of Bridge

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Abstract:
Every Structure has some lifespan which depends on the certain factors such as its design period, quality control at the time of construction, environmental factors acting on it, the changes in the loads and services of it, regular maintenance of it, etc. The damages in any structure observed may be, severe or mild, in the early stages of its lifespan or later, depends on the same factors mentioned above. A bridge is an important part of the infrastructure which plays a vital role in the transportation system of any country and hence in its development. A bridge is also an important structure in aspects such as it is fast and short transportation route and connecting to the remote places, these significances of the bridge further increases during natural calamity and disaster. As the scale of an important bridges is usually large, failure of it creates a huge disaster to human life and economy. This paper focuses on the bridge disaster-mitigation with the help of Rehabilitation. The topic has been explained with the help of case studies of rehabilitation of some of the important bridges which were damaged. The damages in these bridges were crucial which might lead to their failure. These bridges have been rehabilitated with conventional repair or advanced FRP techniques or both to mitigate their disaster at present as well as in the future.

Keywords: Disaster mitigation, Rehabilitation, Repair, FRP Techniques

Introduction:

Bridges of any country represent its current development. The financial investment done and human life risk depend on any major bridge is huge. Similarly, the dependency of current running finance and human life on any particular bridge is also huge. In general minor damages in bridge becomes severe in no time as the multiple dynamic and static forces applies on the bridge in n number of ways of permutation and combination. So it multiplies the importance of cost and risk factor related to the bridge.

Bridge Inspection is the primary measure for most of the risk mitigation. There are 3 different level of inspection routine, detailed and detailed structural inspection. On the basis of these, we can know the required maintenance and/or rehabilitation to the bridge. As mentioned earlier severity of damages increases faster in the bridges as compared to other structure due to versatile and dynamic forces acts on it, so the minor damages may reduce the life-span of bridge considerably or lead to a major disaster of the bridge. All these consideration makes an inspection, maintenance and rehabilitation (if require) of the bridge mandatory.

Rehabilitation is the process of restoring the structure to service level, once it had and now lost, strengthening consists in endowing the structure with a service level, higher than that initially planned by modifying the structure not necessarily damaged structure. It improves the life of

structure, improved life period gives better return on investment, prevents major deterioration that leads to collapse and ensures safety of users.

Rehabilitation Case Studies of Bridge:

1. Strengthening of 50-Year-Old Central Hinge Bearing of Bridge

1.1 Introduction and background

The Bridge in Bharuch is a balanced cantilever type structure built of prestressed concrete box girders. The deck sections of each main span are connected at mid-span by means of a central hinge, which must ensure that the deck ends at each side of the joint move in unison. This type of bridge is quite popular in many areas due to its ease of construction and overall economy, but suffers from an inherent problem: the hinge points are subjected to sudden and frequent load reversals during the passage of traffic over the bridge, resulting in continual hammering action on the parts of the hinge.

Fig 1. 55-Year-Old Bridge in Bharuch.

1.2 Reason of Strengthening

The common problem of this type of bridge is hinge failure. Hinge exhibit severe fatigue distress in practice due to continuous load reversal. Similarly, central hinge bearing of the Bharuch bridge got damaged as shown in figure 2.

Fig 2. Failed Hinge Connection of Bharuch Bridge

1.3 Strengthening Scheme

The damaged concrete part was repaired by RC Jacketing.

(a) Anti-rust application on exposed Reinforcement (b) Concreting of damaged part

Fig 3. RC Jacketing of Damage Concrete Part

After jacketing of broken connection part of bridge was strengthened with FRP wrap as shown in fig 6. for further increase in capacity to resist the forces like continual hammering action and load reversal. Before application of FRP, reinforcement on both faces of the new concrete were placed as shown in fig 4 and 5. to take reversal forces acting on surface of concrete near central hinge bearing.

(a) Grinding of New Concrete Surface Preparation (b) Marking on New Concrete for Grooving

Fig 4. Surface Preparation for Additional Reinforcement Grooving

Fig 5. Fixing Additional Reinforcement on Concrete surface

Fig 6. FRP Strengthening of Bridge's Hinge Connection Part

2. Girder Strengthening of Dharna River Bridge Nasik, Maharashtra

2.1 Introduction and Background

The PWD Bridge on Dharna River situated 2 km from Ghoti town of Nasik District has been retrofitted in 2017. The reason for strengthening was distress cracks developed in the girder of the bridge.

Fig 7. Dharna River Bridge at Ghoti, Nasik

2.2 Strengthening Scheme

The 17 m span of bridge was strengthened using composite FRP Technique. One layer of 430 GSM carbon fiber with U-wrap and fiber anchor at 500 mm center to center spacing for increasing its shear strength capacity throughout span. One Prestressed laminate and two non-prestressed laminate at bottom face of the girder were applied throughout the length to increase girder's flexural capacity as shown in figure 8 and 9.

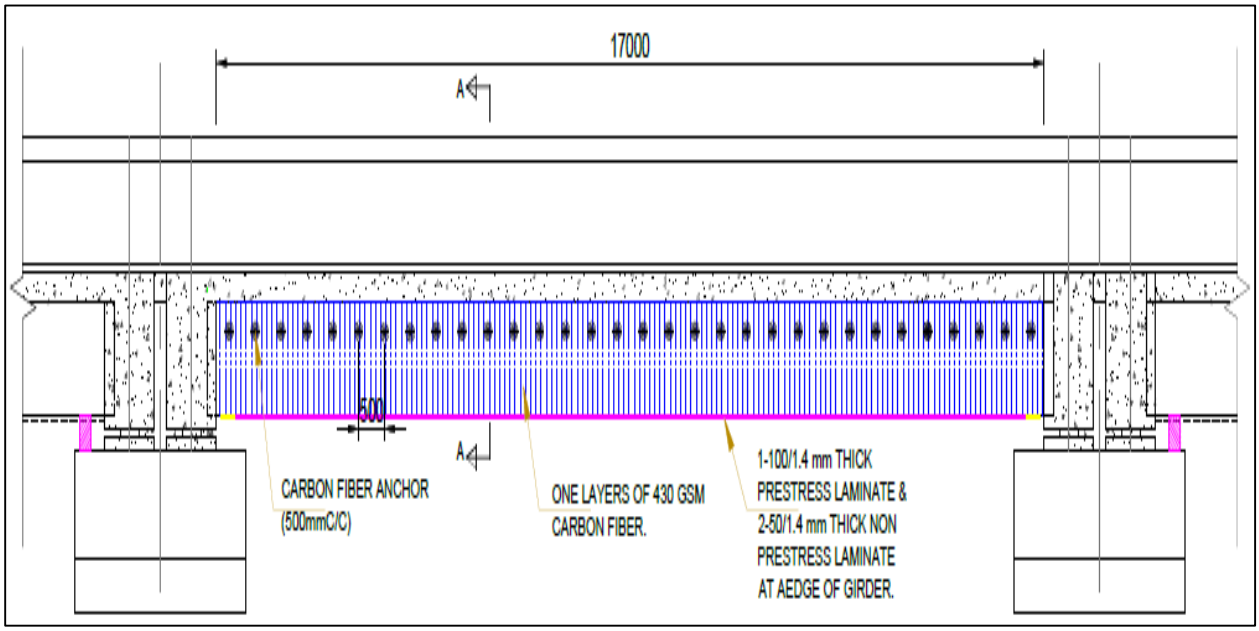

Fig 8. Side Elevation of Bridge

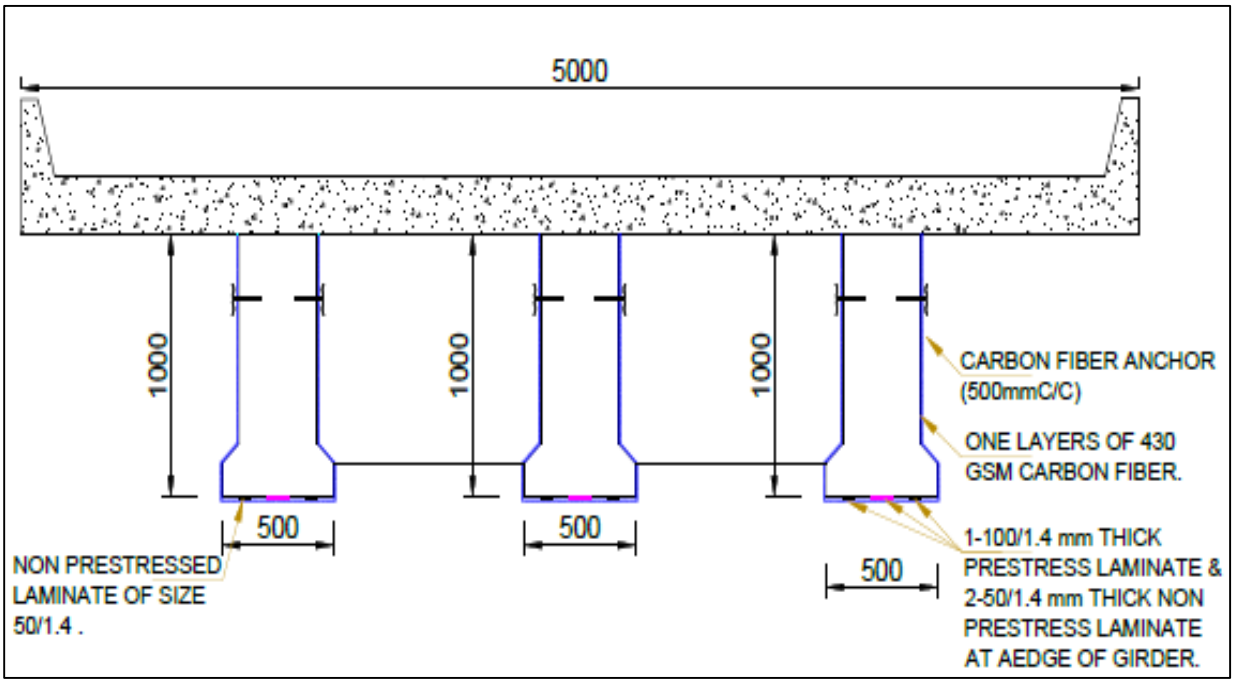

Fig 9. Section A-A

2.3 Post-strengthening Test on Bridge

To evaluate the effectiveness of the FRP strengthening done, NDT test has been carried out. Deflection and frequency has been measured for actual load acting on the bridge. These test were carried out when the bridge is serving the actual traffic. The NDT test result shown that there is reduction in deflection and increment in frequency has been developed in strengthened girder of bridge as compared to un strengthened bridge. On the basis of these result we can easily comment that stiffness of the strengthened girders got increase. The FRP wrapping will arrest the further distress in girder and will increase the life of the bridge.

3. Diaphragm Wall Strengthening of Box Girder Bridge at Boisar, Mumbai

3.1 Introduction and Background

The bridge is post-tensioned box girder bridge situated at Boisar, Mumbai. Multiple vertical cracks have been developed in the diaphragm wall of girder as shown in following figure 10 and 11.

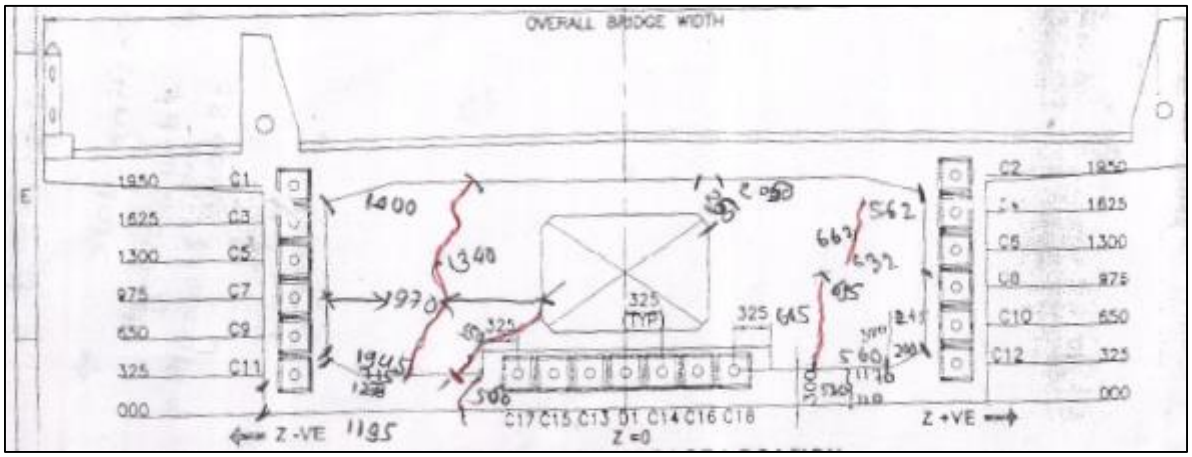

Fig 10. Cracks Marked in Drawing at Diaphragm Wall of Pier Side

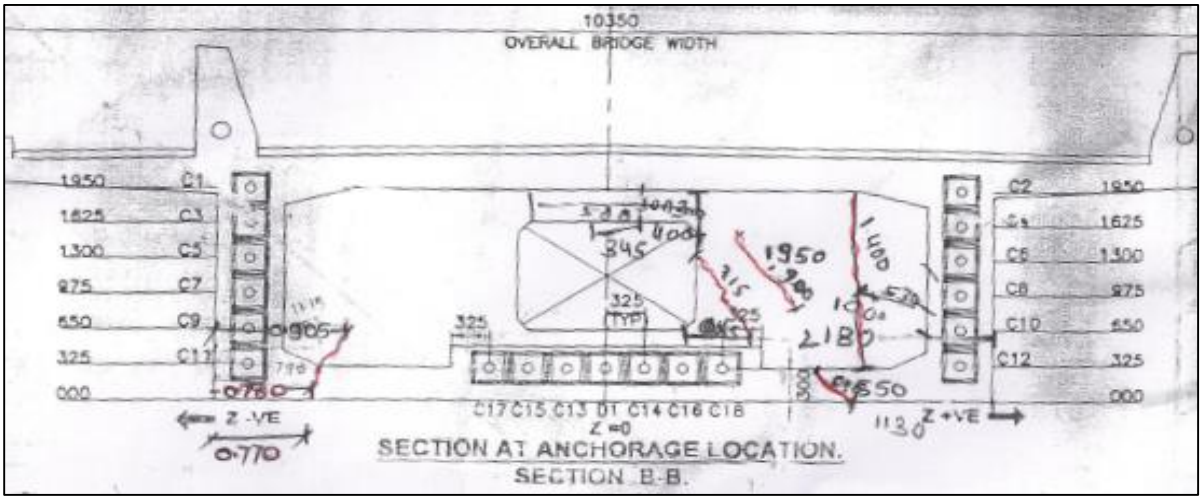

Fig 11. Cracks Marked in Drawing at Diaphragm Wall of Abutment Side

3.2 Strengthening Scheme

Since the cracks were vertical hence laminate was provided in horizontal direction which would cross the cracks and arrest them. The cracks were mainly inclined and vertical due to flexural and shear stresses induced in the diaphragm wall which were being resisted by the horizontal reinforcement provided on both faces of diaphragm wall.

It was decided to double the tensile strength of diaphragm wall in horizontal direction. Hence 2.4 mm thick 20 mm wide laminates in horizontal direction on both faces by making grooves in the diaphragm wall was provided as shown in fig 12 and 13. One layer of 430 GSM carbon fibre wrap was provided as shown in fig 14 to further enhance the strength of concrete of diaphragm wall by partly confining it. It was provided to increase the shear strength of the section and de-bonding strength of laminates by delaying de-bonding.

Fig 12. Grooving and Primer Application

Fig 13. Laminate Fixing and Application of Putty

Fig 14. Application of FRP to Increase Strength

4. Deck Slab Strengthening of ROB, Gwalior.

4.1 Introduction and Background

The deck slab portion of ROB at Gwalior was distressed. From the top side slab as shown in fig 15 it was observed that small portion of deck slab was settled. The bottom face of deck slab shown in fig 16 cleared the severity of damage as major part of concrete was fallen down and reinforcement has been exposed. These damages could be reason for major failure or disaster in the bridge.

Fig 15. Distress Portion of Deck Slab

Fig 16. Bottom Side view of Distressed Deck Slab

4.2 Strengthening Scheme

This damage was repaired with the help of conventional repair. The concrete portion of damaged area of deck slab was removed including some surrounding part of deck slab, then all the steps of conventional repair with micro concrete were followed. Bonding agent were used for proper of bonding of old and new concrete as shown in fig 17 so the load should be transfer properly from new repair patch of slab to old structure part of bridge.

(a)

(b)

(c)

Fig 17. (a) Removal of Damaged Concrete (b) Micro -concreting with Bonding Agent (c) Curing of Conrete

Summary:

- Rehabilitation of different types of bridges for different types of damages were explained in this paper.
- Rehabilitation type and steps depend majorly on the type of the failure occurred in the bridges.
- Conventional repair or advanced techniques of repair or both in synergy can be used for rehabilitation of bridge.

Conclusion:

- In many instances bridges are very forgiving structures and can tolerate delayed maintenance without any real consequence. However, there are also issues of structural significance that need to be rehabilitate in order to prevent catastrophic consequences.
- The investment into rehabilitation of the bridge can be considerable and this investment should be based on risk and value. However, the ratio of initial investment of cost and resources to the life span of bridge justifies the total investment. Similarly, the ratio of rehabilitation investment to the increase in the life span, safety and initial investment and resources of the bridge justifies the rehabilitation.

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