STUDY ON RETROFITTED GIRDERS AND ITS APPLICATIONS IN BRIDGES

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by

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CHAPTER 6

CONCLUSIONS

6.1 General

Bridges are the most important part of the economy and everyday life of any nation. Most of the bridges that are constructed many years ago are damaged and deteriorated due to aging, an increase in traffic volume, and environmental effects. So it's a real challenge for engineers to rehabilitate the damaged bridge, either vehicle or rail. Different retrofitting techniques have been applied to strengthening and rehabilitate the bridge girder or its part. In the present study an attempt has been made to observe the behavior of FRP laminated girder numerically using ANSYS software. The deformation and stress analysis are carried out for different spans of the girder with the variation of FRP layers. The same methods are applied to retrofit and strengthening real rail bridges and vehicle bridges.

From the present study following significant conclusions can be drawn.

6.2 Concluding remarks

From the study, the following major conclusion can be drawn.

1. The addition of thin FRP composite layers in girder either bottom or side face increase the strength of the girder and decreases the deflection for all considered cases. Without FRP laminate, the deflection sharply increased with the increasing aspect ratio (b/d) of the girder. From Figure 3.23 it may be concluded that the deflection in triple layer laminate girder is decreasing rapidly in higher b/d ratio. i.e if the b/d is more than 1.2 then the reduction in deflection is 335 % than single layered girder.

2. Numerical analysis results of prismatic and I-shaped girder is shown in figure 3.49 and 3.73 which clearly indicates that in 30 meter long prismatic girder wrapped in triple layerd laminates shows 268 % less deformation than single layered girder of same length. While in shorter girder this reduction is almost half and similar reduction is achieved in double layer fibre wrapping. So, it may conclude that the triple-layer composite polymer setup is the most effective in long girders and double layer composite setup for shorter girders. The carbon fibre will be placed in the tension zone of the girder and glass fibre in the shear zone.
3. The Figure 5.49 represents the variation in natural frequency for different fibre layer wrapping obtained in field testing of Rail bridge. The increment in frequency of single layer, double layer and triple layered girder is found 1.69%, 4.5%, and 10.56 %. So, in this modal analysis of rail girder, the variation of magnitude of natural frequency is less when the girder is retrofitted with one layer and double layer FRP composite. Whereas, in the case of triple-layer FRP laminated girder the frequency increases more.
4. The regression analysis shows good relations for static deflection, stress, strain energy and natural frequency for different combinations of fibre layers. This result can be used for designing guidelines for girders retrofitted with FRP composites.
5. An extensive study on retrofitted girders for different spans shows that for span less than 15-meter girder effect of double-layer FRP is prominent. From figure 3.36 it is observed that deflection in triple layered girder is 67 % lower than the single layered beam in the case of constant percentage of steel.
6. With the variation of steel percentage with girder, the results show that in three layer fibre wrapping, the decreasing of strain is more rapidly than the single and double layer fibre wrapping.
7. As the load intensity increases, the triple layer FRP laminated girder shows approximately half deformation than double-layer fibre layer wrapping for constant span and aspect ratio.

8. In the case of a prismatic girder of span 15 meter the maximum deflection for three layer FRP is 2.16 mm while for the single layered girder the deflection 4.17 mm . whereas if the girder length rises up to 30 meter then the deflection in three layer fibre composite girder is 8.04 mm and for single layer it increased to 21.27 mm. so three FRP is more effective for long span girder whereas double layer FRP is better for short span girder.
9. In the case of I-girder if the girder length is 30 meter then the deflection in three layer composite girder is 10.25 mm and for single layer it increased to 21.79 mm, when the carbon fibre is placed in the tension zone and glass fibre is placed in the shear zone of I-girder. The deflection approximately half of single layered girder in the case of longer span.
10. The road bridge at Pusa was damaged due to environmental effects and high vehicle frequency. If the loading condition persists or increases in the future without adequate dilapidated structure, the bridge may become operational or lead to forbidding events. Therefore to ensure safety the adequate strengthening required regularly.
11. As in the Pusa bridge the bottom of the girder is damaged and the side of girder also spalled at several locations. Also, the strength of concrete in the tension zone is comparatively lesser than of shear zone so the strengthening using fibre polymer in this area is essential. In the finite element analysis, the strength of three layer wrapped girder is shown double yielding strain than single-layer wrapping. So it is recommended to three-layer fibre wrapping in the girder having low design steel.
12. The FRP retrofitting technique is used for strengthening of Pusa bridge girder. Before strengthening, the deflection of the girder was 8.55 mm. Two-layer FRP is applied to the girder by proper gluing. The deflection of the girder is reduced to 2.5 mm. As the span of the bridge is 16.5 meter the double layer FRP lamination will be the best option.
13. Before retrofitting the bridge girder, the von misses stress was found 20.68 MPa whereas after strengthening double layer FRP, the stress is reduced to 12.88 MPa.

14. The real time field test was carried out by moving a loaded truck, and maximum deflection was measured 3.32mm. Maximum deflection in all girders is within the permissible limit of L/1500 as prescribed in IRC SP: 37 for the girder length of 16.5 m. Full recovery was measured after the removal of loads in all spans in two truck-loaded conditions. After removing load, the Minimum recovery in girders was 95.1% and 91.8% respectively, which is more than 75% as prescribed in IRC 51 for RCC Bridge.
15. Two rail bridge at Ratlam was reported damaged of span length 13.67 meter and 19.67 meter for bridge no 114 and bridge no 54 respectively. It was required to strengthening the bridge so that high speed trains can run on it. The modeling of the deteriorated girder was carried out to find out the suitable strengthening scheme.
16. The real-time field test was carried out by running WAGON 7, and maximum deformation was measured in the span and found 4.5 mm in bridge no 114, and the maximum deflection in bridge no 54 is found 3.65 mm experimentally. The natural frequency in the bridge no 114 and 54 before strengthening was found 9.79 Hz and 9.34 Hz, respectively.
17. A suitable strengthening scheme was proposed based on experimental and numerical analysis of the girder. For the bridge, no 54 the two-layer carbon fibers were used in tension zone and two-layer glass fibre layers in shear. As the bridge no 114 has a longer span, three layer glass and three-layer carbon fibre in a similar pattern were applied.
18. Real-time testing of the bridge was carried out for one layer, two-layer and three-layer FRP lamination. The deflection was measured for each cases by running the WAGON 7 locomotive over the bridge for static and dynamic loading condition. In the dynamic loading the speed of train was varied from 20KMPH to 100 KMPH. the deflection is reduced by 8.31 % and in double layer wrapping this decrement in deflection was recorded as 16.16 percentage and in the three layer wrapping deflection reduced by 28.36 % compared to unstrengthened girder for bridge no 114.

19. For the shorter span bridge, no 54 the maximum deflection reduction after the single layer fibre lamination is reduced by 12.37 percent. In double layer wrapping, this decrement in deflection was recorded as 56.81 percentage.
20. The static deformation of the retrofitted girder was less compared to the dynamic loading conditions. The recovery rate in the high speed WAGON load is higher than the static load condition after strengthening by proposed scheme. In the girders designed to operate high speed vehicles required high shear stress capacity. In the longer girder, if glass fiber in provided in shear, the natural frequency increased by a satisfactory amount. For the speed of train up to 100 KMPH, the proposed scheme is most suitable.
21. The natural frequency of longer girders is higher than of short span I-girder for the proposed scheme of strengthening. It is observed that the increment in natural frequency was higher in dynamic loading compared to static loading.
22. The overall conclusion is that FRP composite strengthening is the better option for bridges.

6.3 Future Scope of Study

In this research, damage analysis and strengthening scheme for long and short girder has been investigated. During the present study following area of research may be suggested:

1 Reduction in ductility of the beam caused by the gluing of the plate.

2 Predicting the limiting load that causes the concrete layer between the longitudinal to reinforce and plate to fail.

3 In hot regions or a fire outbreak case, multilayer composite fiber's thermal capacity needs to investigate.

4 The method of applying fiber-reinforced polymer in the cambered area of a structure or its applicability in a cambered beam where shotcrete is not possible.