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Structural Health Monitoring and Strengthening Of Bridges

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Abstract: This paper presents one bridge which were either rehabilitated or strengthened by using FRP composites. The resulting structure was then tested for the effect after using FRP composites for Rehabilitation and strengthening. In this paper, Structural Health Monitoring basics are covered and need for SHM in future in or India scenario. Use of FRP composites in Rehabilitation and Strengthening of structures is becoming increasingly popular and is opening new possibilities in construction and rehabilitation of structures.

Keywords : Rehabilitation, Structural Health Monitoring, Bridge Strengthening, Repair

1. INTRODUCTION

In the recent years, rapid deterioration of exiting bridge structures has become a serious technical and economical problem in many countries, including highly developed ones. Therefore, bridge rehabilitation is one of the most important tasks in civil engineering. Bridge rehabilitation process should be preceded by assessment and evaluation of the structure to determine its actual technical condition and to select the proper rehabilitation techniques and materials. The reasons leading to deterioration of the existing bridge are more or less same in every country.

a) Increase in traffic flows and weight of vehicles, especially their axle loads, compared to the period when the bridges have been designed and constructed.
b) Harmful influence of environmental pollution, especially atmospheric ones, on the performance of structural materials,
c) Low quality structural material as well as bridge equipment elements, such as expansion joint, waterproofing etc.

2. SCOPE OF WORK

The focus of this present work is to study the effectiveness of the bridge rehabilitation with respect to different aspect such as strain measurement, vibration measurement, deflection measurement, temperature measurement etc. The project contains one case study which are as follows.

Rehabilitation and Testing of Karal Rail Over Bridge at JNPT, Navi Mumbai

3. AIMS AND OBJECTIVES

The aims and objectives of "Rehabilitation and structural health monitoring of bridge superstructure" dissertation are as follows:

1) To study strengthening techniques of bridge rehabilitation.
2) To study the effectiveness of the FRP material and external pre-stressing in the field of bridge rehabilitation.

3) To study the different type of damages in concrete structure.

4) To study the behavior of the bridge before and after strengthening.

5) To develop a 24 x 7 bridge monitoring system for deflection, vibration and strain measurements for vehicular loading.

4. CASE STUDY

Port at Nhava-Sheva, Navi Mumbai is managed by Jawaharlal Nehru Port Trust (JNPT). This port is one of the busiest port and handles about 70% of container traffic of whole INDIA has constructed Rail over bridge at Karal for efficient traffic flow. The construction of this bridge was completed and opened for traffic since 1991. This bridge consists of 36 spans of varying lengths with 37 expansion joints. The total length of bridge is 700 m.

Upon critical inspection and the comparison of the design load versus the strength of the girders of the Karal ROB, 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 centre and diagonal cracks at the end) which prove the structural inadequacy of the girders and
3. Presence of visible sag in the superstructure, it confirms that the superstructure may not be quite adequate to resist the increased vehicular traffic load on the Karal ROB in recent years.

5. SCHEME FOR STRENGTHENING THE BRIDGE

1. The girders and slab of the bridge have been strengthened by placing the additional steel truss system along the two main girders in each lane (i.e. along the girder 2, 3, 6 and 7 are to be placed in each span of and 1, 4, 5 and 8 remain as it is). The truss system is supported by bridge deck/slab and cross girders using the M32 high strength bolts. This truss system is designed to take about 50% of the load carrying capacity of the existing girders. [8, 10,12,13,14-20]

Connection of truss over main beam

Pre-stressing Mechanism in Truss

2. The bearings provided in the bridge between girders and piers were damaged and were insufficient to take the increased load. Elastomeric bearings have thickness around 75mm and it become 25mm because of heavy traffic load. It is suggested to replace all the existing neoprene/elastomeric bearings with the new elastomeric bearings as shown in Figure 6.4.

Replacement of damaged Bearings with new

3. It is also recommended to replace the expansion joints of the bridge with the Wabocrete Strip Seal Expansion Joint System.

4. It is recommended to strengthen the RCC girder beams with FRP Carbon laminates.

5. In order to further improve the structural strength of the bridge, it is recommended that the fiber reinforced plastic composites wrapping around the girder.

6. To check the strength of FRP wrapping and steel truss different types of measurements have been taken before and after the strengthening.

Groove for carbon Fibre composites laminates

Carbon fibre wrapping

6. TEST SCHEME AND INSTRUMENTATION

The various measurements to ascertain strengthening effect has been presented below.

1. Measurement of strain, deflection and vibration of three spans of the Rail Over Bridge of JNPT at the identified locations under the static and rolling load before rehabilitation/retrofitting.
2. Measurement of strain, deflection and vibration of the three spans of the Rail Over Bridge of JNPT at the same identified locations under the same static and rolling load after retrofitting.

Besides this, to estimate condition of concrete in existing structure, Rebound hammer tests and Ultrasonic Pulse Velocity (UPV) tests were also proposed before strengthening.

7. NDT ON SUPERSTRUCTURE

1) Testing of Bridge girder using UPV (Ultrasonic Pulse velocity) test to obtain quality of concrete. All the girders will be tested at minimum 3 locations on each under direct transmission. (Figure 6.6 (a))
2) Testing of Bridge girder using Rebound hammer to estimate the characteristic strength of the girder. All the girders have been tested at minimum 12 locations (6 locations on each face of the girder.(Figure 6.6 (b))

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Table 1
Rebound Hammer Test Results of RCC Girder Beams
(DIGI Schmidt 2000 Rebound Hammer)

Sr. no	Location	Avg. fck in MPa
Bay 1		
1	Girder Beam 1	59.5
2	Girder Beam 2	55.3
3	Girder Beam 3	53.1
4	Girder Beam 4	58.2
5	Girder Beam 5	60.5
6	Girder Beam 6	53.4

[13,10,12]

Table 2
Result of Ultrasonic Pulse Velocity Measurements of RCC Girder Beams

Sr. No.	Location	Pulse Velocity in Km/Sec	Concrete Quality
1	Girder Beam 1	3.57	Good
2	Girder Beam 2	4.11	Good
3	Girder Beam 3	4.22	Good
4	Girder Beam 4	4.36	Good
5	Girder Beam 5	4.17	Good

[13,10,12]

Table 3

Average Central Deflection (mm)

	Span-1	Span 2
Before strengthening	5.38 mm	5.18 mm
After strengthening	3.93 mm	3.65 mm
Reduction in defection	1.46 mm	1.53 mm
% reduction in deflection	-27.10%	-29.50%

[2, 13, 10]

Table 4

Average Flexural Strain (με)

	Span 1	Span 2
Before strengthening	450 με	407 με
After strengthening	198 με	188 με
Reduction in Flexural Strain	262 με	219 με
% Reduction in Flexural Strain	-58.20%	-53.80%

[2,5,13,10]

Table 5

Crack Width of Diagonal Cracks near Support
(Change in change width over a gauge length of 200mm in με)

	Span 1	Span 2
Before strengthening	80 με	90 με
After strengthening	42 με	28 με
Reduction in Shear Strain	38 με	52 με
% Reduction in Shear Strain	47.5 (%)	57.8 (%)

[2, 5, 13, 10]

Table 6

Average Acceleration (mm/s^2)

	Span 1	Span 2
Before strengthening	21.38 mm/s^2	35.91 mm/s^2
After strengthening	11.43 mm/s^2	15.93 mm/s^2
Reduction in Acceleration	9.95 mm/s^2	19.98 mm/s^2
% Reduction in Acceleration	46.5 (%)	55.6 (%)

[2,3,7,5,13,10}

8. CONCLUSIONS

1. Central defections obtained under standard loads indicate significant improvement in the flexural stiffness of the RCC girder beams after rehabilitation and effectiveness of the pre-stressed steel truss straitening system. Reduction in deflection of all the two spans indicates that the flexural strengthening system (FRP laminate and Pre-stressed steel truss system) is effective in sharing the vehicular loads. An average of 26% reduction in the deflection of bridge superstructure under standard loads has been observed.

2. Flexural strains measured under standard loads indicate significant improvement in the flexural stiffness of the RCC girder beams after rehabilitation and effectiveness of the pre-stressed steel truss straitening system. Reduction in flexural strain of all the three spans indicates that the flexural strengthening system (FRP laminate and Pre-stressed steel truss system) is effective in sharing the vehicular loads. An average of 53% reduction in the flexural strain in RCC girder beams under standard loads has been observed.

3. Change in the width of the diagonal shear cracks on the RCC girder beams near the support have been measured before and after strengthening with the help of omega type strain gage based transducer. An average of 56.8% reduction in the shear strain in RCC girder beams under standard loads has been observed. Reduction in the shear strain after rehabilitation indicates significant enhancement in the shear stiffness as a result of FRP wrap and Steel truss system.

4. Reduction in the vibration of the superstructure was envisaged due to rehabilitation of RCC girder beams and strengthening with steel truss system. An average reduction of 8.5% in fundamental frequency of vibration is achieved. In addition to this, the amplitude of acceleration has been reduced by 50%. The increase in fundamental frequency of vibration and reduction in amplitude of acceleration indicate that the significant improvement in the overall stiffness of the structure.

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