Jawaharlal Nehru Port Trust (JNPT), Navi Mumbai.

JNPT decided to take up the rehabilation work of the Karal Railway Over Bridge (ROB). It got functional in 1991. There are 36 spansof varying lengths having 37 expansion joints in this bridge and the length is 700m. During the heavy rains in july, 2005 the wearing coat and expansion joints were severly damaged. These damaged coats and joints were subsequently repaired and re-laid. But the bridge was still not working satisfactorily. The vibrations of bridge during the vehicle movement were becoming more and more noticeable. The major observation during the site visit are as follows...

1. Expansion joints were not functioning properly. In the original design there was no provision of appropriate expansion joint.
2. Slab area of expansion joint was found to be damaged severly due to heavy vehicular movement. The gap between two spans has become significant and concrete had deteriorated.
3. The neoprene/elastomeric bearings provided in bridge were inadequate for heavy vehicle movements. They appear to be bulging out and damaged.
4. There was a visible sag in the superstructure in many spans. The typical structural failure cracks in the girders were observed.
5. The new expansion joints could not last long due to excessive vibrations and the poor quality of deck concrete at the end of span.
6. The substructure/piers appeared to be sound.

In view of above observations it seemed that the structural health of the bridge was not very good. The proposed strengthening measures by the consulting team are as follows.

1. Strengthening of girder by steel truss system-
   The girders and slabs are to be strengthened by placing additional steel truss systems which will support the bridge deck/slab/girders with M32 high strength bolts. This was designed to take about 50% of load carrying capacity of girders.

2. Replacement of bearings-
   The existing neoprene/elastomeric bearings should be replaced by new elastomeric bearings. Shore-a-hardness hardness of rubber material used should be 60.

3. Provision of new expansion joints-
   It was recommended to replace the expansion joints with Wabocrete Strip Seal Expansion Joint System. It is a superior joint system which can be rapidly installed in failed expansion joints and also is suitable for heavy vehicle bridges.

4. Carbon fibre wrapping of girder and slab-
   To further increase the structural strength of the bridge, it was recommended to strengthen the bridge using the carbon fibre composite wrapping around the girder and slab. At the bottom of each girder 3 Pre-stressed Carbon Fibre Composites (CFC) laminates i.e. 2- 80/1.4mm and 1- 50/1.4mm was proposed to be placed. The load to

be given to prestressed laminates should be 8-9 tons. The deck slab was also recommended to be strengthen by putting CFC laminates 80/1.4 at 50 mm c/c at the bottom. The properties of required laminates and wrap were specified.

Hence the girders were treated with pre-stress technology which gave a back uplift force to girders at a load of 8-9 tons using CFK laminates and high tensioned non corrosive end anchor plates.
After prestressing of laminates the girders were fully confined with C- Fiber UD-300 & G- Fiber BD-80 as per the specified design for better strength and the ends were locked with fiber anchors to avoid peeling and long lasting.

Instrumentation of Bridge for checking the Efficacy of the proposed rehabilitation measures.

The work of bridge testing before and after strengthening was entrusted to Prof. Abhay Bambole, Structural Engineering Department, Sardar Patel College of Engineering, with guidance of prof. B.N Pandya , Head of Structural Engg. Dept., Sardar Patel College of Engineering.

Testing Scheme

Many tests were carried out before and after the repair work. They are as follows

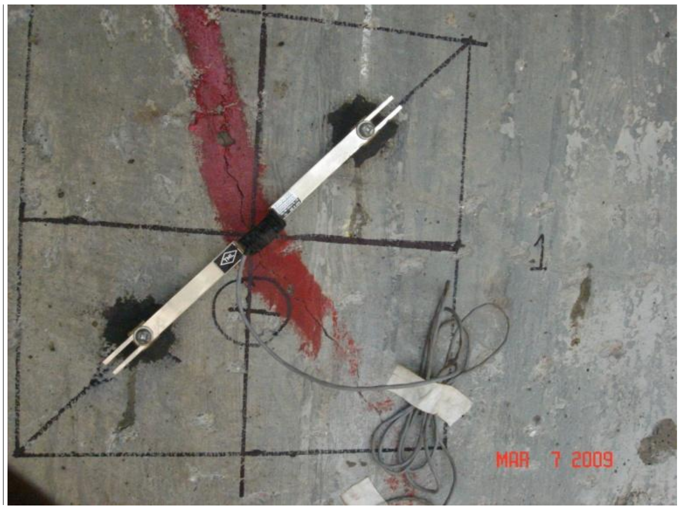
Two types of NDT tests on the superstructure were carried out. It included Rebound Hammer Test and ultrasonic pulse velocity tests (Direct) on the girders.

To measure the effect of rehabilitation on the superstructure following

- Deflection measurements at the centre of the superstructures, before and after strengthening, by using linear potentiometer of "Sakae Japan" make, which were installed at the center of all three spans at 4 girder positions(1,3,5 and 7). Readings were taken by using standard loaded vehicles positioned to induce maximum deflection.

- To measure Flexural strains, before and after strengthening, foil type PL-60 TML Japan Make electrical strain gauges were mounted at the two girders(1 and 5) in all three spans. Readings were taken by using standard loaded vehicles positioned to induce bending moment.

- To measure the shear strains, Before and after strengthening, foil type electrical strain gauges mounted on the side faces of the two girders near the support oriented at an angle of 45 deg to the beam axis in all the three spans. Measurements were done with the help of standard loaded vehicles positioned to induce maximum shear.
- To measure the change in crack width omega type displacement transducers were mounted on the side face of four girders oriented perpendicular to the diagonal shear cracks. Measurements were done with the help of standard loaded vehicles positioned to induce maximum shear.



- To measure the change in frequency of vibration, before and after strengthening, of the girder piezoelectric accelerometers of B & K Denmark Make were mounted at the centre of the four girders on the bottom face in the mid span positions. Measurements were done with the help of standard loaded vehicle moving at constant velocity of 25 kmph.

Results of the tests conducted

	Span 1	Span 2	Span 3
Before strengthening	5.38 mm	5.18 mm	5.08 mm
After strengthening	3.93 mm	3.65 mm	3.95 mm
Reduction in defection	1.46 mm (27.1%)	1.53 mm (29.5%)	1.13 mm (22.2%)

Table 1 Average Central Deflection (mm)

	Span 1	Span 2	Span 3
Before strengthening	450 με	407 με	311 με
After strengthening	198 με	188 με	160 με
Reduction in Flexural Strain	262 με (58.2%)	219 με (53.8%)	151 με (48.5%)

Table 2- Average flexural strain (με)

	Span 1	Span 2	Span 3
Before strengthening	80 με	90 με	72 με
After strengthening	42 με	28 με	15 με
Reduction in Shear Strain	38 με 47.5 (%)	52 με 57.8 (%)	47 με 65.3(%)

Table 3- Average change in crack width (με) for a gauge length of 200mm

	Span 1	Span 2	Span 3
Before strengthening	21.38 mm/s^2	35.91 mm/s^2	85.92 mm/s^2
After strengthening	11.43 mm/s^2	15.93 mm/s^2	42.06 mm/s^2
Reduction in Acceleration	9.95 mm/s^2 46.5 (%)	19.98 mm/s^2 55.6 (%)	43.86 mm/s^2 51.0 (%)

Table 4- Average Acceleration (mm/s^2)

	Span 1	Span 2	Span 3
Before strengthening	5.301 Hz	5.344 Hz	5.520 Hz
After strengthening	5.737 Hz	5.964 Hz	5.833 Hz
Increase in Fundamental Frequency	0.436 Hz 8.2 (%)	0.620 Hz 11.6 (%)	0.313 Hz 5.7 (%)

Table 25- Natural Frequency of Vibration (Hz)

<u>Conclusion of the tests Conducted.</u>

1. The NDT test results i.e the Rebound hammer test and the ultrasonic pulse velocity test concluded that the concrete is in sound condition.
2. 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. The average reduction in central deflection for loading condition inducing maximum deflection for each of the span is presented in the Table 21.

   Reduction in deflection 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 26% reduction in the deflection of bridge superstructure under standard loads has been observed.

3. 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. The average reduction in flexural strain for loading condition inducing maximum bending moment for each of the span is presented in the Table 22.

   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.

4. 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. The average reduction in shear strain over a gage length of 200mm under loading condition inducing maximum shear force each of the span is presented in the Table 23.

   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.

5. Reduction in the vibration of the superstructure was envisaged due to rehabilitation of RCC girder beams and strengthening with steel truss system. Vibration measured at the mid-span of girders has been presented in the Tables 24 and 25.

   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.