BHARTIYA VIDYA BHAVAN'S,
SARDAR PATEL COLLEGE OF ENGINEERING

(Government Aided-Autonomous Institute)

Bhavan's Campus, Munshi Nagar, Andheri (West),
Mumbai 400 058.

CIVIL ENGINEERING DEPARTMENT

STRUCTURAL ENGINEERING LABORATORIES

TESTING AND CONSULTANCY BROCHURE

BHARTIYA VIDYA BHAVAN'S SARDAR PATEL COLLEGE OF ENGINEERING

Bharatiya Vidya Bhavan's Sardar Patel College of Engineering (SPCE) was established in 1962 as a Government Aided Engineering College. The institute is affiliated to University of Mumbai. In the year 2010, UGC conferred Academic Autonomy to SPCE. Currently SPCE offers 3 UG courses in Electrical, Mechanical and Civil Engineering and 5 PG courses in Structural, Thermal, Machine Design, Construction Management and Power Electronics and Power Systems with total strength of around 1000 students. SPCE also offers Ph.D. in Mechanical, Electrical and Civil Engineering. Civil Engineering Dept. offers very strong consultancy and testing services and contributes voluminously in revenue generation of the Institute.

Over the last 59 years the college has gained an excellent reputation in the field of Technical Education. S.P.C.E. Grade "A" rating engineering college from Govt. of Maharashtra has maintained a proud tradition of excellent academic records. Institute has won an award for outstanding contribution in Industry Institute Partnership in govt. aided college category for the year 2014-15 based on survey for the last three years conferred by SEED, Chennai. The college has produced many graduates and Post-graduate Engineers, many of our past students are now leaders in their professions. S.P.C.E. Alumni can be found in all public and private sector organizations operating in diverse fields, often holding senior and key positions in the organization.

Structural Engineering Laboratories

Engineering Mechanics, Strength of Materials, Concrete Technology, NDT, Structural Dynamics, Computer Centre.

Computing facilities:

Faculty members are provided with computer with printer. Department has three LCD projectors for presentations. A separate computer centre is provided for PG students with latest computers, printers and softwares. All the computers are in Network with internet access.

Major Equipments & Testing facilities available in department

Following testing facilities are available :

The Department undertakes testing of various materials for private and government bodies involved in construction activities. The list of tests available are as follows :

AGGREGATE - COARSE & FINE	
A)	**Physical Tests Coarse Aggregate**
1	Sieve Analysis
2	Specific Gravity
3	Bulk Density
4	Water Absorption
5	Impact Value
6	Crushing Value
7	Abrasion value (Los Angles)
8	Elongation Index
9	Flakiness Index
B)	**Chemical Tests Coarse Aggregate**
1	Soundness by Na_2SO_4
2	Total Deleterious Material
3	Alkali Aggregate Reactivity
4	Water Soluble Chloride Content
5	Water Soluble Sulphate Content
6	pH
C)	**Physical Tests Fine Aggregate**
1	Sieve Analysis
2	Specific Gravity
3	Water Absorption
4	Bulk Density
5	% Finer than 75µ
D)	**Chemical Tests on Fine Aggregate**
1	Soundness by Na_2SO_4
2	Total Deleterious Material
3	Alkali Aggregate Reactivity
4	Organic Impurities
5	Water Soluble Chloride Content
6	Water Soluble Sulphate Content
7	Ph Value
CHEMICAL ADMIXTURE	
A)	**Physical**

1	Workability
2	Setting Time
3	Bleeding
4	Water Content
5	Compressive Strength
6	Flexural Strength
7	Length Change
8	Air Content
B)	**Chemical/Uniformity Test**
1	pH
2	Dry Material
3	Ash Content
4	Chloride Content
5	Relative Density
CEMENT	
A)	**Chemical Tests on Cement**
1	Chemical Analysis (SIO_2, Al_2O_3, Fe2O3, CaO, MgO) (SO_3, Na_2O, K_2O)
2	Loss On Ignition
3	Insoluble Residue
4	Free Lime
B)	**Physical Tests On Cement**
1	Fineness (Blaines, m^2/kg)
2	Setting Time (Minutes)
	Initial
	Final
3	Compressive Strength (Mpa)
	3,7 & 28 Days
4	Soundness
	Le-Chatelier's Expansion (mm)
5	Normal Consistency
6	Specific Gravity
7	Autoclave Expansion (%)
8	Drying Shrinkage, (%)
CONCRETE	
1	Compressive strength of Cubes upto M50
2	Compressive strength of Cubes Above M50
3	Accelerated Curing Test of Cubes
4	Core/Cylinder - Compressive Strength
5	Extraction of Concrete Core
6	Flexural Strength of concrete
7	Splitting tensile strength of concrete cylinder
8	Cement Content
9	Chloride Content
10	Sulphate Content
11	pH
12	Cement : Sand Proportion
CONCRETE DURABILITY TEST	
1	Rapid Chloride Penetration Test (RCPT)
2	Water Permeability of concrete (WP)
3	Initial Surface absorption test (ISAT)
4	Modulus of Elasticity (MOE)
5	Drying Shrinkage

6	Moisture Movement
7	Water Absorption (WA)
8	Rapid Chloride Migration Test (RCMT)
9	Chloride Diffusion Test
CONCRETE MIX DESIGN	
1	Grade of Concrete M10 To M50 and Above
2	Concrete design mix verification for Any Grade
3	Additional trial to arrive at economical mix on demand
FLYASH	
A)	Lime Reactivity (LR)
B)	**Physical Test**
1	Fineness by Blaine's
2	Particles Retained on 45 Micron
3	Compressive Strength @ 28 days
4	Soundness by Autoclave
5	Specific Gravity
C)	**Chemical Testing**
1	SiO2 %
2	Magnesium Oxide
3	Loss of Ignition %
4	Total Chlorides %
5	Alumina(Al2O3)
6	Ferric Oxide (Fe2O3)
7	Sulphuric Anhydride(SO3)
8	Available Alkalis %
9	$SiO2 + Al_2O_3 + Fe2O3$ %
GGBS	
A)	**Physical Test as per ASTM Code**
1	Slag Activity Index (7 & 28 Days)
2	Finess by Retain on 45 Micron
B)	**Physical Test as per IS Code**
1	Slag Activity Index (7 & 28 Days)
2	Finess by Blains
3	Density/Specific Gravity
C)	**Chemical Test**
1	Magnesia Content
2	Magnesium Oxide
3	Sulphide Sulphur
4	Sulphate
5	Insoluble Residue
6	Chloride Content
7	Loss On Ignition
8	$(Cao+Mgo+1/3Al_2O_3)/SiO_2+2/3Al_2O_3$
9	$(Cao+Mgo+Al_2O_3)/SiO_2$
10	$(Cao+CaS+1/2Mgo+Al_2O_3)/SiO_2+MnO$
D)	**Glass Content of GGBS**
1	Glass Content
MICRO SILICA	
A)	**Micro silica Physical as per ASTM**
1	Percent retained on 45 Micron
2	Accelerated Pozzolanic Strength
3	Bulk Density
B)	**Micro silica Physical as per IS**
1	Percent retained on 45 Micron

3	Bulk Density
4	Compressive Strength @ 7 days
C)	**Micro Silica Chemical**
1	SiO2
2	Moisture
3	LOI
4	Alkali
5	Chloride
STEEL / METALS	
C)	**Couplers / Spliced Joints**
1	Ultimate Tensile Strength & % Elongation
i)	Bar 6 mm to 16 mm
ii)	20mm
iii)	25mm
iv)	32mm
2	Coupler Grade Confirmation
D)	**Fusion Bonded Epoxy Coated Bar.**
1	Continuity of Coating
2	Adhesion of coating
3	Thickness of coating
F)	**Reinforcement Steel / TMT bars**
1	**Complete Physical Properties (Tensile, Bend & Rebend)**
a.	Bar 6 mm to 16 mm
b.	20mm
c.	25mm
d.	32mm
2	**Tensile Strength**
a.	Bar 6 mm to 16 mm
b.	20mm
c.	25mm
d.	32mm
3	**Bend Test**
a.	Bar 6 mm to 16 mm
b.	20mm
c.	25mm
d.	32mm
4	**Rebend Test**
a.	Bar 6 mm to 16 mm
b.	20mm
c.	25mm
d.	32mm
5	Chemical Analysis (C,S & P)
6	Chemical Analysis (Upto CE)
5	**Weight per meter of bars**
a.	Bar 6 mm to 16 mm
b.	20mm
c.	25mm
d.	32mm

1. Strength of Materials & Material Testing laboratory

Facilities available: 100 T Universal Testing Machine, 40T Universal Testing Machine, Impact Testing machine, Hardness testing machines, Torsion testing

machine, Abrasion testing machine, Temperature controlled Oven, 40 T Capacity loading frame, 30T capacity hydraulic jack, 30 channel strain measuring equipment, Deflection measuring and crack width measuring sensors, EL sensors for tilt measurement, Dial gauges, Proving rings etc.

Sr No.	Name of Equipment		Description
1.	Universal Testing Machine	 	To carry out test on steel and concrete
2.	Impact Testing Machine		To carry out Impact Test on Brass, Copper and Mild Steel by Charpy Impact Test and Izod Impact test.

3.	Hardness Testing Machine		To calculate the Brinell Hardness no. and Rockwell Hardness no. for Mild Steel, Copper and Brass.
4.	Deflection Test		To measure deflection of simply supported beams of different materials.
5.	Torsion Testing Machine		For determining the modulus of rupture in torsion for mild steel and cast iron.

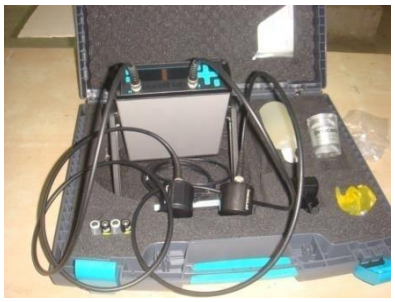
6.	Oven		
7.	Tile Abrasion Testing Machine		To carry out Abrasion Test on tile.

2. Concrete Technology & NDT laboratory

Facilities available: 200 T Compression Testing Machine, 200T Automatic compression Testing Machine, Mortar mixing machine, Mortar vibrators, Flow table, Vicat apparatus, VB compacting machine, Weighing balances, Curing tank, Table vibrator, Accelerated curing Tank, UPV measuring instrument, Digital Test Hammers etc.

Sr. No.	Name of machine	Image	Information
1	**Compression Testing Machine**		**Used for compression tests on concrete cubes, bricks, timber, paver blocks**

2	**Compression Testing Machine**		**Used for compression tests on concrete cubes.**
3	**Compression Testing Machine**		**Used for compression tests on concrete cubes.**
4	**Digital weighing scale**		**Used for weighing materials upto 100kg**
5	**Vee-Bee Consistometer**		**Used for testing the workability of concrete mix**
6	**Flow table**		**Used for flow table test to determine consistency of fresh concrete.**

8	**Mortar cube vibrating machine**		**Used for compaction of mortar cubes by vibration**
9	**Ultra sonic pulse velocity apparatus**		**Used for ultrasonic pulse velocity test on concrete**
10	**Concrete mixer**		**Used for concrete mixing.**
11	**Compacting factor apparatus**		**Used to test compaction factor for concrete**
12	**Vibrating table**		**Used for compaction of concrete.**

13	**Vicat's apparatus**		**Used for testing consistency, initial setting time and final setting time of cement.**
14	**Le Chateliers apparatus**		**Used for testing soundness of cement**
15	**Shaker**		**Used for sieve analysis of aggregates**
16	**Universal Testing machine**		**Used for tension test on rebars, flexural strength test on timber, concrete pavement b**
16	**Universal Testing machine**		**Used for tension test on rebars, flexural strength test on timber, concrete pavement b**
17	**Oven**		**Used for oven drying materials such as tiles, bricks, timber, concrete**

3. Dynamics Laboratory

Facilities available: Shake Table with 1 Ton capacity servo-hydraulic shaker, Vibration sensors, Four channel charge amplifier, 'OROS' 8 channel vibration recorder and analyzer, 'System 7000' 24 channel data acquisition system for dynamic strain and deflection measurements, long distance laser based static and dynamic displacement measuring system etc.

Shake table

(Model No. SH-01-1010,Capacity -1 T. Table size-1200x1200,Table acceleration-1 g,Actuator stroke 150mm,Height=417mm,Width=1900mm,Depth=1095mm,Weight-1T)

‘OROS’ 8 channel vibration recorder and analyzer

‘System 7000’ 24 channel data acquisition system

Strain Indicator

Switching and Balancing Unit for strain gauges

Omega type displacement Transducer for crack width measurement

Displacement sensor

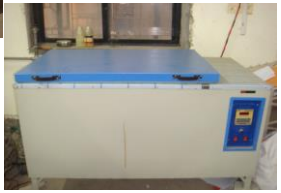
EQUIPMENT PROCURED UNDER TEQIP PROJECT

Sr. No.	Name of the Equipment	Important Technical specifications	Equipment useful for	Equipment Photographs
1	Adjustable and sighting Telescope for existing PSM laser based displacement sensor	Adjustable base- 360 degrees rotational and +/- 40 degrees vertical Sighting telescope range - 500 M	It helps in aiming laser displacement sensor Type PSM accurately on target	
2	a) Hand held Vibration Meter - 1 No b) Accelerometers - 5 Nos	a) Hand held Digital Vibration meter for measuring vibration levels in three modes b) High sensitivity ICP accelerometers, Sensitivity - 100 mv/g, Freq range - 1 to 4 kHz including low noise cables	a) For preliminary investigation of vibration levels b) Additional inputs directly to existing vibration analyser for vibration measurements	 
3	a) Load cells - 3 Nos b) Electronic weighing balance - 2 Nos	a) Load cells with Digital indicators one each for 10 T, 25 T for compression and 40 T capacity for both compression and Tension, Safe overload: 20% of rated capacity complete b) Electronic weighing balance -	a) For measuring different loads (replacement to old proving rings), with digital indication b) For proper weighing of material for concrete mixing	 
4	Compression Testing Machine with digital load and pace rate indicator	Capacity - 3000 kN, Least count - 1 kN, Pace rate indication - 0.1 to 20 kN/sec, Four column high stiffnes welded frame, suitable for testing cubes up to 200 mm and cylinders of 160 x 320 mm, with spacer blocks of 50 mm, 100 mm and 200 mm	For testing high strength concrete cubes and cylinders	

5	a) Function Generator - One b) Solid state true RMS AC Voltmeter / Multimeter	a) 10 MHz Function Generator with digital display of frequency and amplitude for sine, squre, triangular, pulse and DC generation in different ranges and amplitude settings, Freq resolution - 0.1 Hz, Output - 10 V p-p, Accuracy- ± 2% of setting, Freq rang	a) Replacement to the old function generator, which is used in vibration exciter system b) For measuring AC voltages	 
6	Ultrasonic Pulse Velocity Concrete Tester - One	UPV Concrete Tester which is light, portable, rugged and simple to operate having highly visible display (auto ranging transit time display up to 9999 μsec), working on rechargable battery and 240 V AC 50/60 Hz power supply with two 54-kHz transducers, ne	For measuring ultrasonic pulse velocity in concrete structural components for assessing quality of concrete	
7	Battery powered Digital Storage Oscilloscope	Battery Powered digital storage oscilloscope, Tektronix Type TPS2012B, 100 Mhz, having two fully isolated channels and standard accessories.	For monitoring vibration signals	
8	Air Compressor	Two stage, air cooled Air Compressor, Maximum pressure - 175 psi, Displacement - 8.6 CFM, Air receiver capacity - 300 l, slow running speed and low noise, fitted with necessary valves, relay, pressure gauge, safety valve etc.	For providing air cushion to the existing vibration table system and for	

9	Vibrating wire strain gauges with data logger - one set	Four nos. Vibrating wire strain gauges of 125 mm gauge length with data logger,	Used for continuous monitoring of static and quasi-static strains in structures for prolonged period.	
10	Concrete Test Hammer Type N	'Silver schmidt' concrete test hammer, type N, which is impact direction independent Range - 10-100 N/ sq mm, Impact energy - 2.207Nm, Hammer mass-115 g, Display - 17 x 71 pixels, max number of impacts to be stored - 99, with necessary software and acces	for Non Destructive Testing of concrete structures	
11	a) Advanceed Half Cell Potential Survey System - one b) Advanced system for determining resonant frequency of material, young's modulus and Poissions ratio - one c) Chloride field test system - on	a) The system should have specially shaped porous ceramic tip to allow half cell to take readings in vertical, horizontal or inverted position. It should have fully integrated data acquisition and analysis unit for rapid analysis of data in the fieldwith	a) This system is useful to quickly identify areas of probable rebar corrosion in concrete for even large structures b) This system is useful for determining Young's Modulus, Poission's Ratio and resonant frequency of conc	  

12	Rapid Chloride Permeability Test apparatus with provision for tests on 4 specimen simultaneously.	Each RCPT cell should be as per ASTM c 1202-05 for holding concrete specimen of 100 mm diameter and 50 mm thick with necessary rubber gaskets andwashers etc. Instrument is having automatic Data Acquisition unit and regulated DC current of 60 volts and nec	Useful for Rapid Permeability Test of concrete specimen.	
13	Sets of experimental set-ups for Engineering Mechanics Laboratory with necessary work Panels	Apparatus sets for following experiments 1) Equilibrium of forces containing necessary pulleys, weight hangers, weights, cord, rings magnetic protractor etc. 2) Bell crank Lever containing necessary pulle	These sets are useful for 1) For experiments in concurrent and non concurrent coplaner forces and angles. 2) experiments on principles of moment, bell crank lever etc. 3) Experiments in beams with different conditions and their deflectio	 

14	Noise level meter with FFT analysis software	Integrating sound level meter with single channel FFT analysis of sound or Vibration containing 1) Type 2250-G4 with BZ-7230 FFT Analysis software 2) IEPE Accelerometer TEDS 10 mv/g, side connector, insulated base 3) Cable low noise, 10-32 UNF(M) to triax	Useful for on sight analysis of sound or vibration signals	
15	a) Cement Autoclave b) Accelerated curing tank	a) Inside chamber dimensions - 15 cm dia x 50 cm height, suitable for operation on single phase AC power supply, consisting of rustproof S.S. pressure vessel, microprocessor based PID controller for accurately controlling the temperature and pressure	a) Used for estimating delayed expansion of Portland cement caused by hydration of CaO and MgO b) Accelerated curing tank enables the long term strength of concrete after 1 year in as little as 14 days. Thus accelerate	 

16	a) Core cutting and Grinding machine b) table vibrator c) Heat of hydration apparatus	a) Suitable for cutting and Grinding cylindrical rock or concrete specimen up to 100 mm size with 200 mm dia diamond cutter, sample holding device, protection shield etc b) Table size 1 M x 1 M, frequency variable from 3600 to 2600 vibratio	a) This machine is used for cutting and grinding rock or concrete cores so that both of its surfaces are parallel which can be tested in machine. b) Table vibrator is used for compacting concrete in the moulds by vibrating them	  
17	Longitudinal Compressometer	Suitable for use with concrete cylinder of size 152 x 305 mm consisting of two annular cast aluminium frames with clamping screws, stainless steel pivot rod, tensioning spring and digital dial gauge with resolution of 0.0025 mm.	a) Used for determination of modulus of elasticity of concrete using 15 cm dia x 30 cm high cement concrete cylinders subjected to compressive loads	

Major Projects Undertaken:

Apart from the routine testing of various types of construction materials, the department undertakes special tests as under:

- Concrete mix design including higher grade concrete using accelerated curing technique
- Testing of paver blocks
- Polymer modified mortar – specimen preparation and testing
- Load tests on beams and slabs including manhole covers
- Rebound Hammer and Ultrasonic Pulse Velocity test on Concrete
- Calibration of Compression testing Machines
- Chloride and sulphate content of cement mortar and concrete
- Permeability test of cement mortar and concrete

Major Consultancy Projects Undertaken:

Proof checking of steel and RCC designs of various types of structures viz., commercial and residential buildings, bridge structures, reservoirs, swimming pools.

- Design of machine foundations.
- Analysis and design of structures using STAAD/ETABS
- Stability assessment of dilapidated building in Mumbai western suburbs and Mira Bhayander Municipal council area.
- Instrumentation to bridge over Ganga river at Patna during external prestressing of bridge girders.
- Assessment of dynamic characteristics of vibration damper at Nasik.

BREIF DESCRIPTION OF MAJOR PROJECTS COMPLETED & ONGOING

1. INSTRUMENTATION OF GANGA BRIDGE AT PATNA ON NH-19

INTRODUCTION:

The bridge across river Ganga called Mahatma Gandhi Setu is situated on National Highway No. 19 in the state of Bihar. This bridge is vital link between North Bihar and South Bihar and is near Patna city, the capital of Bihar state. This is the longest river bridge in Asia. There are two carriageways, each comprising of two standard lanes. The upstream carriageway was constructed and opened to traffic in 1982 and the downstream carriageway was opened to the traffic after five years i.e. in 1987. The two carriageways are structurally separated with longitudinal joint however these are supported on a common pier and foundation system. The superstructure was mostly

constructed using pre-cast segmental construction. This Ganga Bridge or Mahatma Gandhi Setu, spans across Ganga River near Patna, capital city of Bihar state. At other end of the bridge i.e. North end, there is a town called Hajipur. There are two carriageways, each comprising of two standard lanes and a footpath. The Superstructure is in pre-stressed concrete and is constructed by cantilever method using pre-cast segments. It is rigidly connected with the pier and extends by about 60.5 M on either side of the pier. Each 'T' arm is therefore of nominal length of 121 M. There are in all 45 'T' arms and the total length of the bridge is 5445 M. The section is a box girder with varying depths from 8 M at the pier to about 2.2 M at the tip of the cantilever. The tips of the cantilever are connected by means of steel plunger bearings serving as load transfer mechanism

It was observed by the Public Works Department (PWD) of Bihar that most spans are suffering from distress such as excessive sagging of the cantilevers on account of creep and other losses of pre-stress. At certain points, the joints between two segments have also opened out, clearly indicating reduction in applied pre-stress. Due to drooping of the cantilevers, the hinge bearings are also not functioning well and in some cases the plunger bearings are damaged and holding bolts broken. Thus stability of the structure is threatened due to these distresses.

In order to restore the structural integrity of the superstructure, the Public Works Department of Bihar has decided to strengthen affected spans by external pre-stressing for which strengthening program was chalked out. These spans were to be strengthened by applying additional pre-stress, with external cables placed inside the box. Assessment of additional pre-stress was based on the estimate of likely time dependent losses like creep and shrinkage. To check the effectiveness of external pre-stressing, PWD desired to have measurements of strains and deflections during pre-stressing of these spans. They also desired that a reputed institution should associate with M/s FPCC Ltd. for carrying out these measurements during pre-stressing of these spans.

For this purpose M/s FPCC approached Department of Structural Engineering, Sardar Patel College of Engineering (SPCE), Mumbai. This Department of SPCE has adequate facility and expertise to arrange for such measurements and evaluation. The proposal was put up to the Principal of the college by Head of structural Engineering Department and was approved The scope of work involved the various activities like planning of the instrumentation scheme, installation of sensors and instruments inside the box girder, periodic measurements during the various stages of pre-stressing and processing of data to give the strains and deflections. The work of instrumentation and measurements during strengthening of these spans was carried. The work was started in 2005 in phases & presently the last 11^{th} span work is going on.

Objectives

The purpose of the instrumentation was to check the efficacy of the external pre-stressing. It is envisaged that due to external pre-stress, compressive strains shall be further induced in the box section. Besides, there would be lifting of the cantilever tips due to application of the force. Measurements of all these parameters were recorded

after pre-stressing of each pair of cables. To measure all these effects the instrumentation proposed is described in following paragraphs.

It was decided to plan instrumentation for following measurements.

a) Temperature measurements
b) Deflection measurements and
c) Strain measurements

INSTRUMENTS USED:

The following instruments and strain gauges were used for measuring strains.

1. Digital Strain Indicator (Photo-05)

Manufactured by: 'VISHAY' Micro-Measurements, USA

Type	: Model P-3 strain indicator and recorder
Range	: ± 31,000 micro-strains at GF=2.00
Accuracy	: ± 0.1% of reading ±3 counts
Input circuit	: 60 to 2000 ohms, half, quarter or full bridge Internal dummy gauges provided for wheat-stone bridge completion.
Gauge factor	: Adjustable from 0.5 to 9.900
Power	: 2 x 1.5V Battery Cells

2. Switching Units

Manufactured by: HBM, Germany

Type: UMK-10

Capacity: 4 full bridges plus 10 channels half or quarter bridges
plus open position

External Circuits: Accepts quarter, half or full bridge
or any combination

Input Bridge Resistance: 50 to 2000 ohms

Switching Repeatability: Better than 1 μ /m

Following equipment was used for measuring deflections of the bridge.

1. Auto Levels

Manufactured by: Pentax, Japan make

Type: AFL 320

Setting accuracy: +/- 0.3 inch

Standard deviation: +/- 0.8 mm for 1Km double run leveling

Sensitivity: 8' / 2 mm

Following equipment was used for measuring Temperature.

1. Digital Temperature Indicator

Manufactured by: Precision Electronics, Bombay

Range: 0-600 ^{0}C

Resolution: 1^0 C

Display: 3 ½ Digit LCD with low bat indication

Power: single 9 V batteries

DEFLECTION MEASUREMENTS

Due to particular profile of the box girder, it was not possible to take deflection measurements inside the box girder. These measurements were, therefore made on the deck surface. The deflections measurements were taken by using an auto level and standard 3 Metre measuring staff with graduations of 5 mm. Auto level was positioned on the pier, at the center of the span and also the bench mark, these reference points, being on the rigid pier, are non-deflecting. On each cantilever three points were prepared on the tips, (Patna side and Hajipur side) with epoxy-sand mortar over the deck surface, one on up-stream side, second at the center and third on the down-

stream side of the selected span. Thus in all 6 points were selected for deflection measurements. For achieving maximum accuracy in measurements, during various stages of pre-stressing, the measurements of the all the points were taken with a single setting of the leveling instrument. Although all efforts were made to measure deflections at the accuracy of 1 mm, it was found difficult to measure accurately due to constant vibrations of the bridge deck due to vehicular traffic on the adjoining carriageway. Since these measurements were not so accurate these were used just for confirming behavior or trend of the span and not for actual calculations.

So deflection measurements were also taken with water level tube and scale attached at each location. For this purpose rigid M.S. angles, of about 1 meter height, were erected at nine locations. For three sections, i.e. Patna and Hajipur tips of the span and centre of the span, three locations each at downstream, upstream and centre of the road were selected. A water filled plastic tube of about 10-12 mm diameter was laid and fixed on the angles between centre and corresponding tip location. Scale was mounted on each angle erected so that water level in each tube can be measured with 1 mm accuracy. Advantage of this system is that even if water is reduced due to evaporation or water level varies due to expansion or contraction of the tube difference in levels at centre and tip will always give correct position of the tip with respect to the centre of the span (on the pier) which is supposed to be at constant level. Photo 07 and 08 shows arrangement for recording water levels on these spans. It was possible with this method to take measurements with the accuracy of 1 mm.

5.3 TEMPERATURE MEASUREMENTS

Apart from strain and deflection measurements, it was decided to have temperature measurements before and during pre-stressing so that strains and deflections due to variation of temperature can be estimated. For this purpose readings of surface temperature on the top slab and inside the box were taken along with ambient temperature that time. For recording concrete surface temperatures at different locations, temperature sensor called PT sensor was fixed at each location. Sensing surface of the sensor was kept touching to the concrete surface and was held in position by applying M-seal. Each PT sensor is having adaptor, which can be connected to the temperature indicator. Concrete surface temperatures were recorded at all locations of strain gauges, on top of deck slab and also at the bottom of box at both ends during temperature cycle and also during pre-stressing of cables.

Ganga Bridge at Patna

Strain gauge with Dummy gauge in position

Instrumentation for 24 Channels

2. TESTING OF THE KARAL RAIL OVER BRIDGE AT JNPT, NAVI MUMBAI FOR THREE SPANS REHABILITATED IN FIRST PHASE

Port at Nhava-Sheva, Navi Mumbai is managed by Jawaharlal Nehru Port Trust (JNPT). This port is one of the busiest ports and handles about 70% of container traffic of whole INDIA. Port is connected by roads to the National and State Highways in addition to Rail connectivity. A few bridges (Road over and rail over bridges) have been constructed for efficient traffic flow. Rail over bridge at Karal (Fig. 1) is one of such important bridge. 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. The portion is a slab-girder (T-Beam) bridge system and the pre-stressed slab system. The bridge was functionally designed for crossing railway line and was structurally designed for IRC 45R loading. As per the revised recommendations of IRC and prevailing practice, the bridge is now required sustain IRC Class 70 R loading.

The bridge wearing coat and expansion joints were severely damaged after the severe and heavy rains in July 2005. In addition, the vibrations in the bridge are becoming more and noticeable during the vehicle movement. In view of the above, JNPT decided to carry out the detailed inspection of this bridge and suggest the suitable measures to be taken-up for rehabilitation or maintenance of the bridge structure in order to enhance the service level. After complete analysis of the bridge it has been observed that the superstructure is inadequate for the revised IRC loading i.e. IRC class 70 R. Based on the critical site inspection and the comparison of the design load versus the strength of the girders of the Karal ROB(conducted by IIT Bombay), it was observed that (i) the girders provided in the bridge are not adequate to resist the design vehicle load as per revised IRC recommendation, (ii) the phenomenon of structural inadequacy of the girders is confirmed by occurrence of the structural cracks in the girders (i.e. vertical crack in the centre and diagonal cracks at the end) and (iii) the presence of visible sag in the superstructure also confirms that the superstructure may not be quite adequate to resist the increased vehicular traffic load on the Karal ROB in recent years. In view of the above, there was an immediate need for strengthening of girders and replacement of bearings/ expansion joints. A complete scheme for rehabilitation of the superstructure for slab-girder portion of the bridge recommended by Prof. Jangid, IIT Bombay is given in section 2.

Three spans have been selected for trial in first phase of the rehabilitation. Testing of bridge has been desired before and after rehabilitation to ascertain the effectiveness of rehabilitation. Based on the effectiveness of the proposed rehabilitation scheme implemented on three trial spans, the rehabilitation of remaining spans is to be

carried out. Each span consists of 8 girder beams with two carriageways (East carriageway and West carriageway). These beams are referred as G1 to G8 from east side to west side for purpose of this investigation.

The work of bridge testing before and after strengthening was entrusted to, Structural Engineering Department, Sardar Patel College of Engineering, Mumbai .The Department of Structural Engineering SPCE has adequate facility and expertise to arrange for such measurements and evaluation.

The scope of work includes various activities like planning of the instrumentation scheme, installation of sensors etc and processing of data to give the strains and deflections. The work of development of testing scheme, instrumentation and measurements of these spans was carried out.

SCOPE OF WORK

Scope of the testing work includes development of testing scheme in consultation with Prof. R. S. Jangid, and carrying out measurements before and after rehabilitation. 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.
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.
3. To assess the effect of retrofitting/strengthening on the ROB.
4. To submit the report on the experimental studies.

Instrumentation for Assessing Strength of Concrete

1. Digital Rebound hammer (Fig. 20)

Manufactured by: Proceq, Switzerland

Type: DIGI - Schmidt 2000, Model ND

Impact Energy: 2.207 Nm

Measuring Range: 10 to 70 N/mm^2

Display: Graphic LCD 128 x 128 pixels

2. Ultrasonic Pulse Velocity measuring instrument (Fig. 21)

Manufactured by: CNS Farnell , U.K.

Type: PUNDIT 6

Measuring Range: 0.1 and 1 μs

Accessories: Two ultrasonic probes with connecting cables

a) Instruments and Strain Gauges for Measuring Strains

1. Digital Strain Indicator (Fig. 22)

Manufactured by: 'VISHAY' Micro-Measurements, USA

Type : Model P-3 strain indicator and recorder

Range : ± 31,000 micro-strains at GF=2.00

Accuracy : ± 0.1% of reading ±3 counts

Input circuit : 60 to 2000 ohms, half, quarter or full bridge

(Internal dummy gauges provided for wheat-stone bridge completion.)

Gauge factor : Adjustable from 0.5 to 9.900

Power : 2 x 1.5V Battery Cells

2. Switching Unit (Fig. 23)

Manufactured by: HBM, Germany

Type: UMK-10

Capacity: 4 full bridges plus 10 channels half or quarter bridges

plus open position

External Circuits: Accepts quarter, half or full bridge

or any combination

Input Bridge Resistance: 50 to 2000 ohms

Switching Repeatability: Better than 1 μ /m

3. Omega type Displacement transducers (Fig. 24)

Manufactured by: TML, Japan

Type: PI-2-200

Capacity: ±2 mm

Gauge Length: 200 mm

4. Strain Gauges (Fig. 25)

Make: TML, Japan

Type: PL-60-

Gauge lengths used: 60 mm and 90 mm

b) Instrumentation for Deflection Measurement

Conductive Plastic Linear Potentiometers with its display unit (Fig. 26)

Manufactured by: 'Sakae' Japan make

Model: 13 FLP

Range: 0 – 25 mm

Resolution: Infinite depending upon display used

Display: 4 ½ Digit LCD

c) Instrumentation for Vibration Measurement

1. Piezoelectric Accelerometers (Fig. 27)

i) Manufactured by : B & K, Denmark

Model : Type 4392, Piezoelectric with suitable charge amplifiers

ii)) Manufactured by : PCB Piezotronics

Model : ICP type, Model 353B33, Piezoelectric with cables

2. Portable Real Time Multi-channel Vibration Analyzer cum Recorder (Fig. 28)

Manufactured by : 'OROS', France

Model : OR36-FREQ-8Special with software ORNV –FFT

Channels: 8 with AC or ICP input

Software: NV Gate software platform supporting optional plug in analyzers,

real time and post processing operation

TEST PROCEDURE

The procedure followed for taking measurements on each span before and after strengthening is explained in the following paragraphs.

Standard vehicle (Fig. 35) having distance of 3.1 meter between front and middle axel and 1.4 meter between two rear axels and weighing 32 Ton each (average weight) were used for loading each span before and after strengthening. Six different static load cases and two dynamic load cases were considered measurements. Two standard vehicles have been placed side by side for static measurement. Following are the six static load cases.

1. Load case 1 – For generating maximum shear stress on main girders near support B (towards JNPT) of the span for east side carriageway. (Fig. 36)
2. Load case 2 – For generating Maximum deflections and maximum bending moment on main girders of the span for east side carriageway. (Fig. 37)
3. Load case 3 – For generating maximum shear stress on main girders near A (towards Uran) of the span for east side carriageway. (Fig. 38)
4. Load case 4 – For generating maximum shear stress on main girders near support A (towards Uran) of the span for west side carriageway. (Fig.39)
5. Load case 5 –For generating Maximum deflections and maximum bending moment on main girders of the span for west side carriageway. (Fig. 40)
6. Load case 6 –.For generating maximum shear stress on main girders near support B (towards JNPT) of the span for west side carriageway. (Fig. 41)

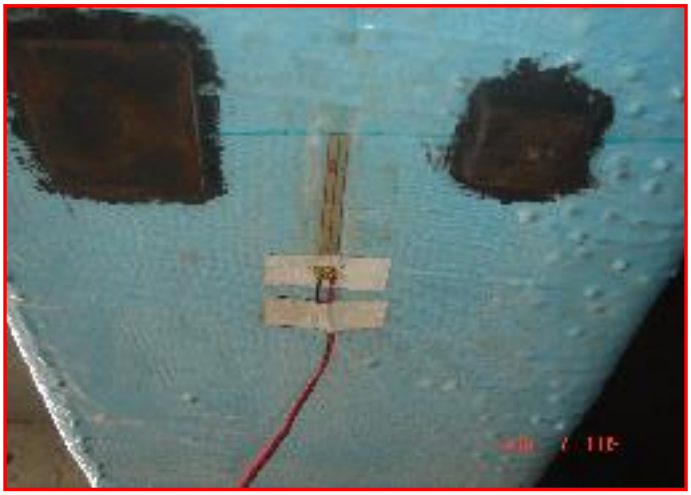
Two dynamic load cases decided were as follows:

a) Load case A – Both vehicles running one after other at the speed of 25 kmph with distance of 3 meters between two vehicles. Vehicles moving on east side carriageway from JNPT to Uran.
b) Load case B – Both vehicles running one after other at the speed of 25 kmph with distance of 3 meters between two vehicles. Vehicles moving on west side carriageway from Uran to JNPT.

Axel positions were marked on the road for both carriageways for static load cases, so that vehicles can be located exactly for a particular load case. After all these initial preparations, strain, deflection and omega type transducer readings were taken during no traffic condition. This is taken as no load or zero reference for calculating strains, deflections etc. For static loading on the span, two loaded vehicles were positioned on the span as marked for load case 1 and readings for strains and deflections were taken. Vehicles were then moved successively to the positions marked, from load case 2 to load case 6 and readings of strains and deflections were taken for each case.

After this two dynamic load cases were recorded. Initially no load signal was recorded for all accelerometers for ambient vibrations, if any, for few seconds. Next vibration signals were recorded on multi-channel vibration recorder and analyzer, for load case A, for which vehicles were made to run from JNPT side to Uran side at pre-defined speed and pre-defined manner. Similarly vibration signals were recorded for load case B.

ROB (Rail Over Bridge) at Karal Junction, JNPT



Installation of strain gage for flexural strain measurement (ERSG - 90 mm gage length

(Strain gage for shear strain measurement before strengthening

Figure 33. Installation of Linear potentiometer (deflection sensor)

Accelerometer mounted at beam bottom

Installation of piezoelectric accelerometer (Vibration sensor)

3. PROOF CHECKING OF DESIGN & DRAWING OF THE BRIDGE STRUCTURES IN ARUNACHAL PRADESH

The department had undertaken and completed the proof checking of design & drawing of the following bridges at Arunachal Pradesh.

1. Superstructure of Namchik Bridge (Span 40m)

2. Superstructure of Namgoi Bridge (Span 35m)

3. Substructure of one abutment of Namgoi Bridge

This work was assigned by Government of Arunachal Pradesh, PWD, Jairampur Highway Division.

4. FIELD INSTRUMENTATION OF SUPPORTING STRUCTURE FOR MUMBAI MONO-RAIL PROJECT

The purpose of field instrumentation and measurement during the testing phase of the monorail is to evaluate the properties of a constructed guide-way beams and supporting structure, and relate these to the required performance parameters. Additionally, assumptions made during the design regarding the dynamic augmentation factor and the hunting loads also need be verified using field measurements. One five-span continuous straight span frame (Frame No. 128) and one three-span continuous curved span frame (Frame 131c) have been identified for the field testing. Due to operational constraints, all external measurements of displacements and strains in the monorail guide-way beams have to be done from the bottom of the guide-way beam. Due to this constraint, centre of span is the most suited location to measure vertical and lateral displacements, and the longitudinal surface strains. For this purpose 4-strain gauges of 120 mm gauge length were placed at the centre section of the span for longitudinal strain measurements. Two strain gauges were placed on the bottom surface of the guide-way beam 150mm from the edges (SG 1 & 2) and the remaining two were placed on the side-face of the guide-way beam 150mm above the bottom surface (SG 3& 4). Additionally, four more strain gauges were put at L/3 span section – similar to the centre section (SG 5 & 6, SG 7 & 8). One multi-channel+ Data acquisition system with sampling rate of more than 50 samples per second was used for each span. Depending on the availability of the number of sets of instruments, both spans of a frame can be taken together or one by one.

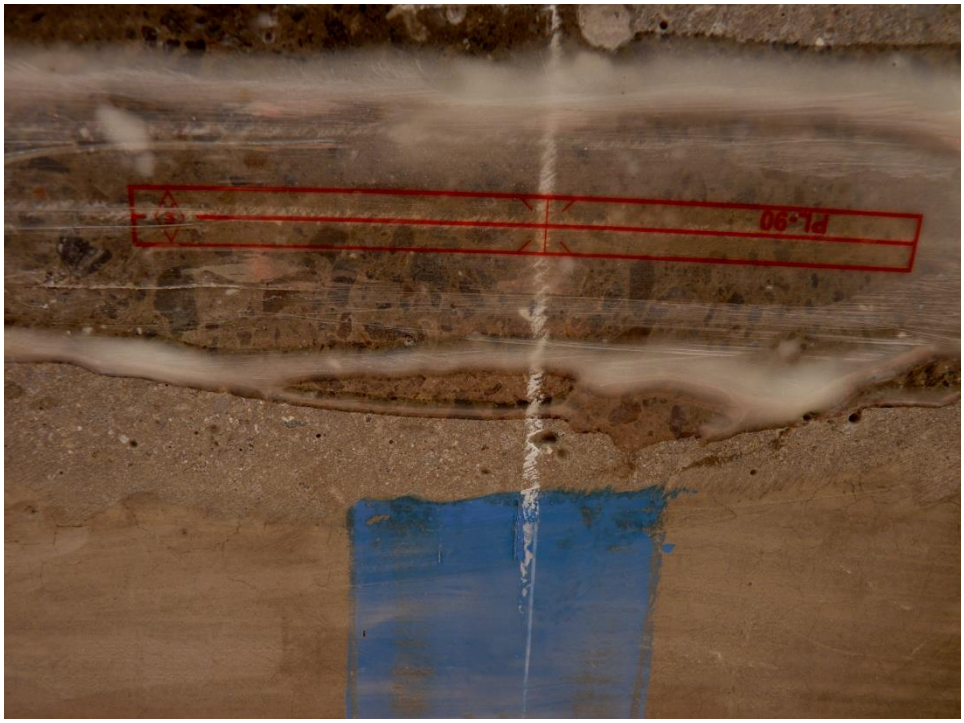
For each span, total of **five load cases were studied**:

(1) Static – monorail without pay load, (2) Static – monorail with symmetrically placed pay load, (3) Dynamic at design speed of frame – monorail with symmetrically placed pay load, (4) Dynamic at design speed of frame – monorail with un-symmetrically placed left-centric pay load, and (5) Dynamic at design speed of frame – monorail with un-symmetrically placed right-centric pay load. **All measurements were repeated six times** – monorail approaches the instrumented span from both sides three times.

Frame 128 of Monorail Guide-way

Frame 103A of Monorail Guide-way

Field testing of Mono rail Project



Strain gauge fixed at the bottom of Guide-way beam

Strain gauges and dummy blocks in position

Instrumentation for Dynamic strain measurements

PT sensor reading is being taken below sofit slab

Receiver mounted at beam bottom for deflection measurements

Transmitter mounted on ground for deflection measurements

5. NON-DESTRUCTIVE TESTING OF OLD BRIDGE ON RIVER SONE NEAR CHOPAN

INTRODUCTION

This bridge across river Sone in Sonebhadra district of Uttar Pradesh is situated on State Highway No. SH-5A(Varanasi-Shaktinagar Road). This is an old bridge constructed in 1956 by M/s Gammon India Ltd, as a trunk line of communication with the Rihand dam, mainly to facilitate flow of construction equipment, cement and other building material for its construction. Presently this bridge is not in use and a new bridge constructed by the side of this bridge is used for regular road traffic. (Photo:01). When Uttar Pradesh State Highway Authority (UPSHA) awarded, work of 'Four Laning of Varanasi - Shaktinagar Road' to M/s Chetak Enterprise Limited (CEL), it was decided to repair and rehabilitate this bridge, so that it can be utilized for one way traffic from Varanasi to Shaktinagar.

This bridge is 1006.5 m long having 22 spans of 45.75 m centre to centre on piers. The bridge carries a 7.32 m wide carriageway. The superstructure comprises composite pre-stressed and reinforced concrete construction. Each span has four beams cast monolithic with the slab and cross braced by deep reinforced concrete diaphragms. The beams span 44.1 m centre to centre of bearings, and are 2.44 m deep and 125 m wide. The cross beams are

spaced 4.9 m on centres and are 125 mm wide and 2.15 m deep. The main beams are spaced at 1.98 m centres and support a slab 150 mm deep, a portion of slab being cantilevered out 0.847 m on either side of outer beams, Details of the longitudinal and cross beams are shown in Fig. 01. The Freyssinet system of pre-stressing has been adopted for decking of the bridge. The bridge is designed to carry two lanes of I. R. C. Class 'A' loading.

Before rehabilitating this bridge, it was necessary to assess existing condition of the bridge. For this purpose M/s CEL allocated work of condition survey and NDT of this bridge to M/s Freyssinet Prestressed Concrete Company Ltd. (FPCC). M/s FPCC, in turn, approached Department of Structural Engineering, Sardar Patel College of Engineering (SPCE), Mumbai, for condition survey and NDT of all 22 spans of this old bridge on Sone river near Chopan. This Department of SPCE has adequate facility and expertise to arrange for such measurements and evaluation. The proposal was put up to the Principal of the college by Head of structural Engineering Department and was approved vide letter No. 101/2013-14/4748 dated 21.06.2013. The scope of work involved Non Destructing Tests, like rebound hammer test, Ultrasonic Pulse Velocity and Half- cell Potentiometer tests, and also core cutting and mechanical and chemical analysis of these cores. Since we didn't have sufficient manpower, condition survey of all spans, physical inspection of bearings etc. was looked after by FPCC engineers. In short the various activities like planning of the instrumentation scheme, NDT and processing of data was the responsibility of SPCE and marking of NDT locations and providing access to these locations was responsibility of FPCC. For accessing locations on beams from below, a gantry was proposed by FPCC which will move on rails and cover whole bridge. Fabrication of this gantry took almost a year and FPCC approached SPCE again on January 2014 for this work. After various meetings and discussions, final offer was given to FPCC vide letter No.101/2013-14/3668 dated January 23, 2014 and actual work could start only in March 2014.

The work of instrumentation and NDT measurements of 22 spans was carried out by team of structural Engineering Department lead by Dr. M. M. Murudi, Professor and Head, Structural Engineering Department (Work Order No. YHS:2014:SC259:114 dated January 31, 2014). Details of instrumentation scheme, instruments used for the measurements, the methodology of measurements and also the observations and results are described in following pages of this report.

NON DESTRUCTIVE TESTING OF CONCRETE:

Non-destructive testing (NDT) methods for testing of structures are techniques used to obtain information about the properties or internal condition of materials and components in such way that allows materials to be examined without changing or destroying their usefulness. It is a quality assurance management tool which can give impressive results when used correctly. It requires an understanding of the various methods available, their capabilities and limitations, knowledge of the relevant standards and specifications for performing the tests. NDT techniques can be used to monitor the integrity of the item or structure throughout its design life.

In most of the cases, an estimate strength of concrete in the structure is needed although parameters like overall quality, uniformity etc., also become important. There are various methods that can be adopted for *in-situ* assessment of strength properties of concrete but following NDT techniques were chosen by concerned authorities to assess the condition of the bridge during this project.

I) Non Destructive Tests :
   i) Rebound Hammer for assessing strength of concrete and surface hardness.
   ii) Ultrasonic Pulse Velocity Test for assessing homogeneity and quality of concrete.

II) Partially Destructive Tests for Concrete :
   i) Core cutting and compressive testing of cores
   ii) Half cell Potentiometer test for knowing probability of corrosion of reinforcement bars.
   iii) Chemical Analysis of concrete samples to know chloride and sulphate content

INSTRUMENTS USED

Following instruments were used for NDT work.

1. Digital Rebound hammer

Manufactured by: Proceq, Switzerland

Type: DIGI - Schmidt 2000, Model ND

Impact Energy: 2.207 Nm

Measuring Range: 10 to 70 N/mm^2

Display: Graphic LCD 128 x 128 pixels

2. Digital Rebound hammer

Manufactured by: Proceq, Switzerland

Type: Silver - Schmidt, Model PC, N-Type

Impact Energy: 2.207 Nm

Measuring Range: 10 to 100 N/mm^2

Memory data: 99 Number of Impacts per series

Display: Graphic LCD, 17x71 pixels

3. Ultrasonic Pulse Velocity measuring instrument

Manufactured by: RoopTelesonicUltrasonix Ltd.

Type: 4600

Measuring Range: 0.1 to 9999.9 µs

(10 mm to 5 Meters in Concrete)

Accuracy: ± 100 nano seconds

Frequency Response: 20 kHz to 500 kHz

Display: LED 5 Digit

Accessories: Two ultrasonic probes (60 kHz)

with connecting cables

4. Half Cell Potentiometer

Manufactured by: Technical and Scientific Sales, Mumbai

Type: TASS-1

Electrode type: Copper with copper sulphate

Display: High Impedance digital multimeter,

5. Core Cutting machine set

Make: Bosch

Capacity: 38 mm to 150 mm Core drilling

Battery operated drilling machine:

Core bits: 72-77 mm diameter (Tryloit make)

Rebar detector meter: Bosch make

NDT project on Chopan Bridge in U. P.

Core cutting on Girder

Half cell Potentiometer test

Ultra Pulse Velocity test by indirect method

Rebound hammer Test

6. Deflection Measurement Of BaitarniBridge,Orissa

1. INTRODUCTION

   The existing bridge on SH-9 across river Baitarani, located between Chandbali to Rajkanika, in Dist of Bhadrak, Odisha. The total length of bridge is 287 m. The carriage way is 7.5m with 0.5m kerb railings. The nearest habitat town is Chandbali in Dist of Bhadrak, Odisha. The bridge has 5 span configurations with 3 Spans of PSC balanced cantilever portion with end slabs of RCC and 2 spans of PSC box girder superstructure. Balanced cantilever portion is resting on plate piers; simply supported spans are resting on regular piers. Return wing walls are of RCC. The bridge is about 9 years old.

Sr. No.	Type of Structure	Length (m)
1	Balanced Cantilever-01	104.4
2	Balanced Cantilever-02	103.15
3	Simply Supported-01	32.61
4	Simply Supported-02	33.15
5	Floating span-01	7.04
6	Floating span-02	6.95
		287.3

2. PROCEDURE FOR DEFLECTION MEASUREMENT

   The deflection measurements were carried out using Potentiometer Transducer. The readings were taken in millivolts and were converted to mm. On site calibration was done in presence of Mr. Charan Singh (PWD Assistant Engineer Chandbali-R&B Division) and Mr. B.A .Dora (FPCC-Site Engineer)for this conversion. The readings were taken for live traffic flow. The traffic flow on bridge was minimal consisting mostly of light vehicles and very few heavy vehicles (> 30T).

   The readings were taken at 4 locations. (2 Locations per span- at cantilever ends). Observations were made for heavy vehicles (50 T, 40T, 30T) and light vehicles.

3. INSTRUMENTS USED FOR DEFLECTION MEASUREMENT-

i. Digital Storage Oscilloscope-Model-TPS2012B
Channels-2
Bandwidth-100MHz

ii. Draw-Wire Displacement Sensor Series-WDS
Output-Potentiometer
Model-WPS-250-MK30-P10
Measuring Range- 250mm

Fixing of Sensor

Calibration of Draw-Wire Displacement Sensor

4. INSTRUMENTATION SCHEME

i) Displacement Sensor locations- As shown in Figure 1 below, observations were made at cantilever ends of both the spans.

ii) Fixing of Displacement Sensor-The sensor was anchored on bed of the river .Since the sensors were to be fixed on a concrete surface ,initial preparation for fixing of sensors had to be made. A portion was marked on the location were sensors were to be fixed. This portion of the surface was first rubbed with a brush so as to remove loose particles of concrete, dust if any. Then this surface was ground with a grinder having diamond – grinding wheel to remove unevenness of concrete surface. The sensor was fixed on steel bracket as shown in figure below. The sensor was anchored in bed of the river using nylon rope.

iii) Calibration of system- For correctness of results it is necessary to calibrate system. For this job on site calibration was done in presence of Mr. Charan Singh (PWD Assistant Engineer Chandbali-R&B Division) and Mr. B.A .Dora (FPCC-Site Engineer). Table 1 shows corresponding change in output voltage after extending wiper by 20mm.

7. Structural Audit Of Bridge At Reay Road Mumbai

1. Introduction

The existing Bridge is constructed in year 1994 & Maintained by Mumbai Post Trust. The bridge is constructed for two way vehicular movement above the bridge. Below the bridge 3 bay openings are provided, two bays are for vehicular movement & one for train movement. At present only two bays are in working for the purpose of vehicle movement below bridge and the third bay for train movement is not functional.

After Construction, during a life span of 26 years extra concrete has been laid over the top surface to maintain proper movement of traffic over the bridge. Pathway of bridge is encroached & temporary hutments are constructed over it. Due to development of surrounding area the vehicular traffic intensity on bridge increase up to a large extent. Due to improper drainage system, water seeps into bottom of girders and at various location resulted in corrosion of girders at various locations. Climatic effects had affected appearance of structure. Considering above facts in order to assess the present condition of bridge, the authority of Mumbai Port trust decided to do carry out structural audit of the bridge structure so as to take corrective measures to strengthen the bridge. For this purpose Mumbai Port Trust, approached Department of Civil Engineering, Sardar Patel College of Engineering (SPCE), Mumbai. The structural audit was carried out by team of civil Engineering Department under the guidance of Prof. M.M. Murudi, Head, Civil Engineering Department.

A. Marking of Various Structural Element of Bridge

For the purpose of identification, the bays and frames are marked as shown in the figure.

View Towards Orange Gate – Detail Marking of various elements

Bay – 1-2-3 - Grid Numbering

B. Structure Geometry

Main Girder -

Main Girder is of plate welded to form C – Shape box open at top, arranged in sequence of alternate grid up and down. Top, Bottom and web are connected with rivet. Main girder span is 30 feet & width 81 feet, down portion of box is filled with Concrete.

Photographs of Main girder arrangements

Steel braced Frames -1 & 2

The top member of intermediate braced frame supporting main girders consists of double I beam section. The double I beam is supported on 6 columns at a spacing of 13’4”. These frames are diagonally braced on upper half height of frame as shown in the fallowing photographs. Also the frames are numbered and frame -1 and frame-2 as shown below:

Frame -1

Frame -2

Main Girder Supported On Steel Braced Frame

Details of Intermediate Frame supporting main Girder