Instrumentation for the second Thane Creek bridge

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Corrosion of mild steel reinforcement and prestressing wires in concrete structures located in aggressive marine environment is a world phenomenon. With a view to obtaining advance information about the level of possible corrosion damage in such structures, recent practice followed in some of the advanced countries of the world is to install suitable instruments in the body of the structure during construction, and monitor the readings at regular intervals. Similar practice is being adopted for the second Thane Creek bridge. The article presents a broad outline of the instrumentation scheme adopted for this bridge.

Worldwide experience has shown that despite the best protective measures, concrete structures located in marine and polluted environments suffer damages due to corrosion of steel reinforcement and/or their prestressing tendons. Over the years, the damages become severe enough to lower the load-carrying capacity of the structure, and in case of bridges it necessitates load and speed restrictions on the traffic plying on them. It is now customary to provide for future application of external prestressing force to restore the strength of the bridge to the possible extent. Once the process of corrosion sets in, it is not possible to reverse it or stop it completely. Even when additional prestress is applied in due course, a situation could arise where the bridge rating would drop low enough to warrant some corrective actions. It is, therefore, very useful to know, with some degree of accuracy, the state of corrosion of the main reinforcement or of the prestressing strands and the resultant loss of strength.

One of the relatively-accurate way to gauge the above parameters involves the use of electrical resistivity method and strain gauges. But their use in a long bridge comprising of a large number of prestressing cables and untensioned reinforcement in each span would be difficult and costly. It is therefore considered easier to use indirect methods for the purpose.

Any loss of strength of the superstructure due to corrosion damage would result in incremental deflections. If these deflections are monitored carefully over the years, it would be possible to estimate the corrosion damage fairly correctly and then take the necessary measures in time.

In case of the second Thane Creek bridge, the adopted instrumentation scheme envisages deflection monitoring of the entire bridge with electrical resistivity measurements and strain gauges fixed in a few units. One four-span unit of the bridge will be fully instrumented. This will help in establishing a correlation between deflections and corrosion of prestressing cables in these units. This can then be applied to units where only deflections are being monitored.

Instrumentation scheme

The following instruments/equipment are to be used to monitor strains, deflections and slopes in various sub-spans of the four-span units of the bridge :

1.	Embedded type vibrating wire strain gauges (V.W.G.)	-	for strain measurements
2.	Mechanical strain gauges	-	for strain measurements
3.	Water level and precision with invar staff	-	for deflection measurements
4.	Tilt meter	-	for slope measurement

Strain measurements

Strain measurements with V.W.G.

Vibrating wire stain gauges are proposed to be installed in a

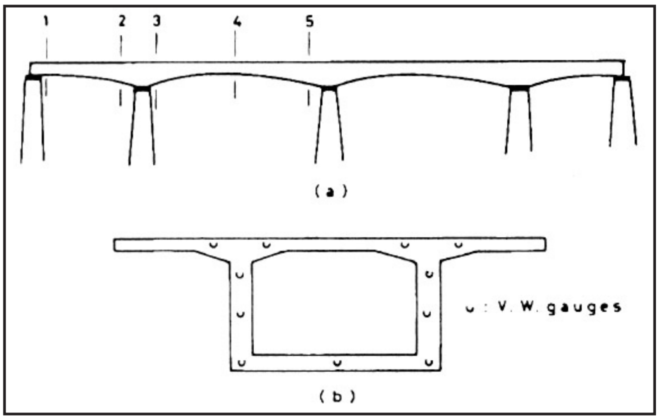

Figure 1. Strain measurements with vibrating wire strain gauge; (a) sections for locating V.W. strain gauges; (b) cross section showing location of V.W. strain gauges (11 nos.) at sections 1 to 5

four-span unit of the bridge as shown in Figure 1(a). Eleven V.W. gauges will be installed at each section to monitor longitudinal strains at different locations in the cross sections, Figure 1 (b).

Strain measurements with mechanical gauges

These are proposed to be installed at ten sections as shown in Figure 2(a). These sections include all those five sections where V.W. gauges are proposed to be installed.

While six mechanical gauges are to be installed across the cross section at sections 1 to 5, where V.W. gauges also exist, nineteen gauges are to be installed at the remaining four sections marked 6 to 10, Figure 2(a).

The above installation of the gauges across the cross sections is as shown in Figures 2(b) and (c). The strain measurements at these gauges are to be taken during construction of cantilevers and also after completion of the construction of the four-span unit.

Deflection measurements

Deflection measurements with precision level

The deflection measurements are to be taken on the bench plates (B.M.) installed along the length of the four-span unit of the bridge. These plates are to be installed at pier locations and in alternate segments. Thus, there will be in all 18 (2 + 16) plates in each span of 107 m and 9 (1 + 8) plates in each span of 53.5 m. The scheme is also shown in Figure 3. The deflection measurements along the length of the unit are to be taken during construction as well as after the completion of the construction of the unit.

Deflection measurements with water level

The water level measuring equipment is to be installed at 10 (2+8) locations on each web of the longer span and at 5 (2+3) locations on each web of the smaller span of the four-span unit as shown in Figure 4. The deflection measurements with this equipment shall start after the completion of the four-span unit.

Slope measurements

These measurements will be taken by a tiltmeter located at five sections in the long span and on three sections in smaller spans of the four-span unit. At each section, two tiltmeter plates would be installed near the junction of webs with the soffit slab as shown in Figure 5.

This would enable the measurement of slopes of the box girder, both longitudinally and transversally.

Corrosion monitoring

One span of 107 m of the four-span unit is proposed to be monitored for corrosion. The corrosion monitoring will be carried out in the following steps.

1. Installation of 30 probes in the entire span.
2. Taking out electrical connections in 12 numbers of prestressing cables in one span of 107-m long.
3. Taking corrosion rate measurements three times at a regular time interval.
4. Taking electrical resistance measurements in 12 cables of one span at regular intervals.
5. Training the PWD staff in taking the above two measurements.
6. Analysis of data after one year and presentation of report to the sponsor.

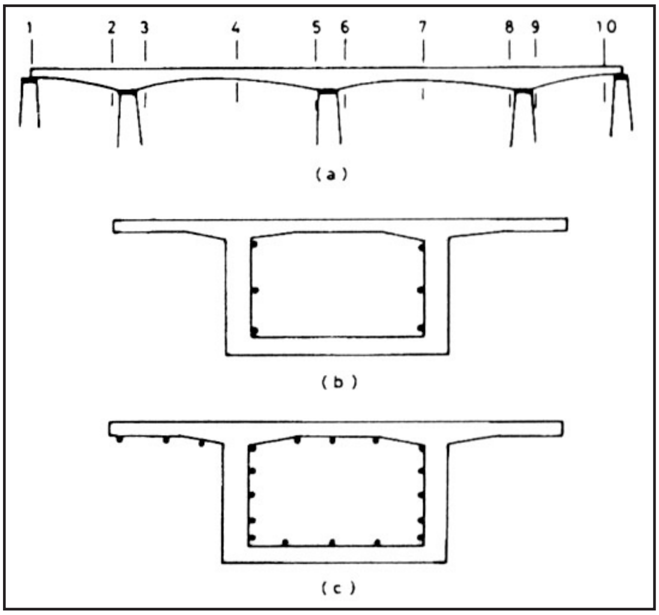

Figure 2. Strain measurements with mechanical gauges (a) sections for locating mechanical strain gauges; (b)cross section showing mechanical strain gauges (6 nos.) at sections 1 to 5; (c) cross section showing mechanical strain gauges (19 nos.) at sections 6 to 10

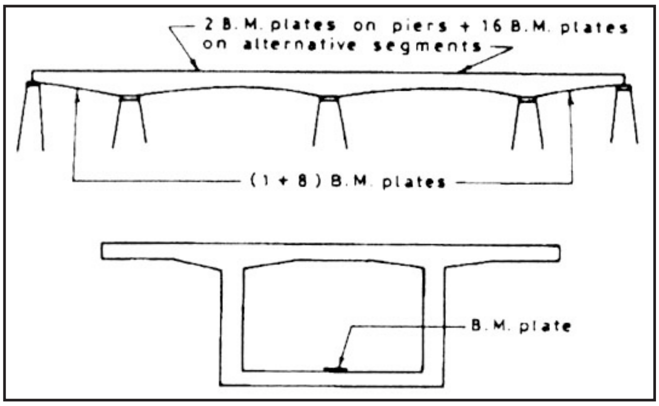

Figure 3. Deflection measurements with precision level (a)B.M. plates location for precision levelling; (b) cross section showing location of B.M. plate

Limitations of corrosion monitoring

1. The rate of corrosion obtained by this technique is representative of the corrosion rate of the metal element kept in the concrete environment near the rebar.

2. The measurements of electrical resistance of the cables involve interference of a bunch of wires in the cable sheath and this may introduce some element of uncertainty.

3. The calculations will be based on certain theoretical combinations.

4. The corrosion rate calculations will be based on the assumptions that the wires undergo uniform corrosion. If localised corrosion occurs, it may introduce some errors.

5. Inspite of the above limitations, periodic corrosion monitoring would indicate the relative condition of the tendons.

The number and location of measurement points described above are subject to alteration, depending upon site problems and preparation of a detailed scheme. Considering the high cost of instrumentation, its scope is restricted to a few sections/locations as detailed above. It is to be noted that in spite of the utmost care taken in installation, malfunctioning or mortality of some of the sensors cannot be ruled out.

Optional instrumentation

Monitoring of an additional unit of four spans

Monitoring of any other similar unit is kept optional. To reduce the cost, additional four-span unit is to be instrumented on a comparatively limited scale. Strain measurements with V.W.G. precision levelling and slope measurements are to be done in such a unit. At each section, only eight gauges are to be provided as shown in Figure 6.

The precision levelling and slope measurements are however to be done as already described above.

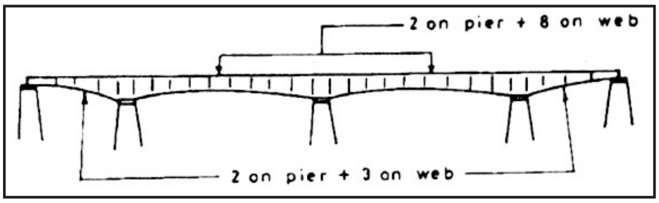

Figure 4. Water level locations on each web for deflection measurements

Temperature measurements

The temperature gradient along the depth of the superstructure assumed for the purpose of design by the Public Works Department (PWD) of the State of Maharashtra is not based on actual observations in the Maharashtra. It is based on the codes of some countries having similar climatic conditions. It was therefore decided to avail of the instrumentation opportunity at the second Thane Creek bridge to observe such variation of temperature along the depth of concrete box girder by embedding temperature gauges and observing the temperature at various points over a long period. With this end in view, it was decided to embed vibrating wire temperature gauges in the cross section as shown in Figure 7. It is hoped that the design for temperature can be rationalised in future on the basis of these observations.

In addition to the above, it is proposed to carry out radiographic examination of the cables of one of the superstructure units of the southern carriageway to see how well the cables are being grouted in actual practice.

It is proposed that the readings on these instruments will be carried out jointly by the State PWD and the Maharashtra Engineering Research Institute (MERI), Nasik for one or two years. During this period, the staff of MERI and the State PWD will be adequately trained and will carry out future monitoring on a continuous basis. For this purpose, a "Monitoring Unit" consisting of staff from the Executive Engineer's office, Designs Circle's office and the MERI has been set up. Suitable computers have also been installed at site to keep a track of all the measurements and monitoring the behaviour of the structure.

Load test

After completion of the bridge (which is being accomplished in two parts, that is, north carriageway by November 1994 and

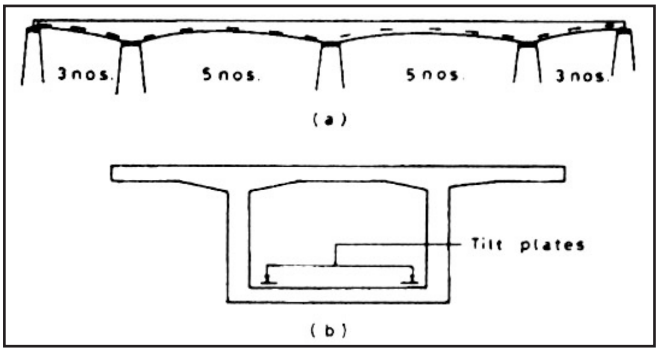

Figure 5. Slope measurements (a) longitudinal locations of tilt plates (b) transverse locations of tilt plates

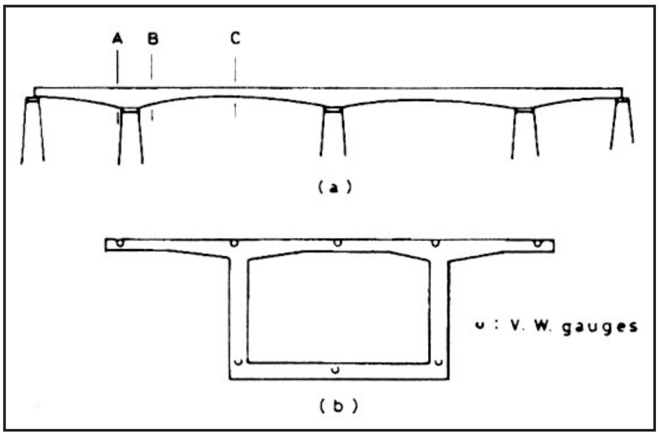

Figure 6. Monitoring of an additional unit of four spans (a) sections for V.W. strain gauges (b) cross section showing location of gauges (8 nos.)

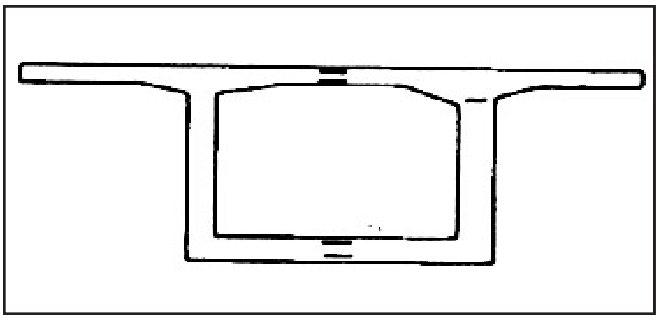

Figure 7. Cross section showing location of V.W. temperature measurement gauges (5 nos.)

south carriageway at a later date) but before opening of the carriageways to traffic, load test on both the carriageways will be performed. The objective of the first load test is to get a datum for performance of the bridge behaviour during its life span and, secondly, to observe any shift in the response behaviour of the bridge, so that a closer inspection could be undertaken, if necessary. This was corisidered important since all the spans have not been instrumented and it would not be reasonable to assume that all the spans will behave in the same manner as the instrumented spans.

Further, if it is difficult to test all the spans, then only a few spans will be selected for load testing. These load tests will be carried out periodically to monitor deflections at selected points. The loadings will be in the form of series of loaded trucks placed at the centre of the span and deflections and surface strains will be measured during loading and unloading cycles. Similar measurements will be taken periodically for similar loads, say after every 2 to 3 years. The deflections will be measured with the help of precision instruments like electronic levels. The loadings for testing will be in four stages as follows :

Stage I	-	3 trucks of 16 tonnes each
Stage II	-	2 trucks of 16 tonnes each at each stage
Stage Ill	-	2 trucks of 16 tonnes each at each stage
Stage IV	-	2 trucks of 16 tonnes each at each stage

To start the tests, three trucks (Stage - I) shall be placed at the mid span in the three lanes. After the strain and deflection readings have been taken, two trucks (Stage - II) shall be placed and the readings taken. This process shall be repeated for Stages - III and IV. During unloading, the above process would be reversed, starting with the removal of the trucks in Stage - IV first.

Consultant

The Structural Engineering Research Centre (S.E.R.C.) at Gaziabad and Central Electrochemical Research Institute at Karaikudi are the consultants to FWD, Maharashtra, for this work and instrumentation and monitoring will be done under their guidance.

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