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NON-DESTRUCTIVE EXAMINATION OF CORRODED CONCRETE STRUCTURES USING RADIOGRAPHY

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Concrete deterioration and reinforcement corrosion occur due to many reasons. These two factors weaken the structural strength and result in the premature failure of the structures situated in aggressive environments. The condition of the concree as well as rebar embedded in it has to be assessed before taking up any remedial or repair strategy. Several electrochemical non- destructive techniques are available for this purpose. Some of them lead to indirect conclusions and some lead to partial quantification of corrosion. Radiographic technique is one of the promising non-destructive methods for determining the porosity of concrete, voids in the cement grout, rusting of mild steel, rusting of prestressing steel and snapping of prestressing wires. Laboratory and field experiments were carried out on model slabs, beams and concrete structures to study the various aspects of concrete corrosion. A 6 MeV high energy X-ray equipment was used for this purpose. Concrete thickness upto 30 cm was radiographed. Suitable safety measures were undertaken while carrying out the above work. The data obtained during this radiographic work and the X-ray photographs were analysed as per requisities of photogrammetric data analysis and results are presented in this paper. This pioneering work has yielded very interesting and useful results regarding the quality of concrete and grouting, condition of prestressing wires and other non-prestressed steel.

Keywords: Non-destructive, prestressed steel, radiography and radiation safety.

INTRODUCTION

Corrosion of steel in reinforced and prestressed concrete structures is threatening the building industry not only in India but throughout the World. Coastal structures are reported to be distressed due to corrosion even within five years. Some marine structures show severe damage within ten years and others have developed serious cracking. Catastrophic sudden failures have been reported [1-3]. Many of the strategic structures situated in coastal areas require immediate repair or rehabilitation. This is a global problem. Any decision on the repair or rehabilitation strategy has to be necessarily made only after assessing the present condition of the concrete and steel. Many electrochemical and non-electrochemical non-destructive techniques are used in different countries. Radiographic technique may be considered as one of the useful techniques for this purpose. Gamma radiography was tried for examining concrete structures in 1958 [4]. High energy X-rays produced by Linear Accelerator was found to be useful in collecting engineering data as well as from the safety point of view in Swathling Bridge, U.K., during 1978 [5]. Better picture quality and greater safety from radiation was established in 1985 using "Scorpion" system. A portable X-ray equipment called "Betatron" with a high energy [6 MeV] was successfully made use of for the first time in India to examine the prestressed concrete bridges. It was aimed at identifying defects if any, in the concrete, in the grouting, in the untensioned steel and in the prestressing steel. The data collected during this study has been analysed and reported in this paper.

EXPERIMENTAL

One span in each of the two prestressed concrete box girder type of bridges along the west coast of India were chosen for

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radiographic examination. One bridge was newly constructed and the other recommissioned. Span length was 50 metres. Thickness of web varied from 30 to 45 cm. The concrete mix used was M45. The girder had 12.5 mm diameter high tensile steel strands with untensioned mild steel reinforcements. The strands were kept in galvanized steel sheaths, grouted with cement grout, after stressing. PXB-6 Portable X-ray equipment "Betatron" of 6 MeV energy was used in this work. The maximum output radiation dose was 3 Rads/min at 1 metre in air. Radiation field coverage was 430 mm x 380 mm. The equipment can be operated by AC or generator. The focal spot was 0.2 mm x 1 mm. Radiographic sensitivity was down to 0.5%. The entire system consists of three units viz. (1) X-ray accelerator, (2) Power converter and (3) Remote control panel.

The output is an X-ray spectrum, extending from about 250 KV to a peak energy of 6 MeV and it produces images of excellent contrast and sensitivity. NDT 65 medium speed film supplied by Hindustan Photofilms, Ooty, was used for this work. Fluorometallic screens of thickness 1 mm supplied by M/s. J.M.E. Ltd., U.K., were used for preventing back-scattering and image intensification. The film was sandwitched between the fluorometallic screens and kept in a PVC Cassette in the dark room.

The three component units of the Betatron systems were taken inside the span through a manhole provided at the top of deck of the bridges for the purpose. The acccelerator unit was kept very close to the inner face of the box girder (Fig. 1). The focal spot was aligned with the centre of the segmental portion of the prestressing cable to be radiographed. The NDT65 film was fixed on the corresponding point in the outer face of the box girder. Lead brick wall of thickness of 5 cm and 50 cm height was erected surrounding the accelerator unit on all the three sides in order to reduce the scattered radiation to a minimum. Traffic was completely stopped on both the bridges during the actual radiographic examination.

After ascertaining that all the precautions with regard to radiation safety were completed, the X-ray accelerator was switched on and the required dose of radiation was incident on the film through the subject for a prefixed time by adjusting the knobs in the control panel. During actual radiographic examination, the operators were behind the control panel situated in the adjacent span, which was 25 metre away from the accelerator unit. The exposure period for each radiography was around 20 minutes. At the end of the exposure period, the accelerator was switched off. A few minutes later the film was processed immediately in the dark room. After drying the film, it was viewed by using X-ray viewer to find out any defects in the radiographed portion. To know the variation in the quality of cement grout, optical density was measured on the radiograph in the grout portion using optical density meter.

RESULTS AND DISCUSSION

The site plan of the bridges and the spans radiographed are given in Fig. 1. Fig. 2 represents the cross section of the girder of bridge 1, location of the "Betatron", the film and that of prestressing cable. The optical densities measured on the X-ray films at different locations are presented in Table I. Figs. 3 and 4 are positive prints of the radiographs of the same. It is seen from Fig. 3 that six numbers of vertical non-prestressing steel are identifiable. Two numbers of horizontal reinforcements at the bottom are identifiable. In addition the support hook for the cable sheath is also clearly seen. The corrugated cable sheath is fully distinguishable. It is observed that the prestressing strands are centrally positioned at this region. The cement grout surrounding the strands appears less dense, though it uniformly covers. The cement grout between the strands is also distinguishable.

Seven numbers of non-restressing steel are identifiable in Fig. 4. The untensioned support hook for the cable sheath is also distinguishable. One horizontal reinfaorcement at the bottom is also seen. The corrugated cable sheath is visible

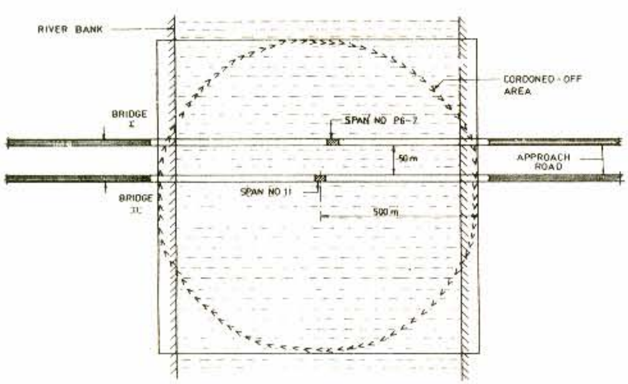

FIg. 1: Site plan of two bridges radiographed

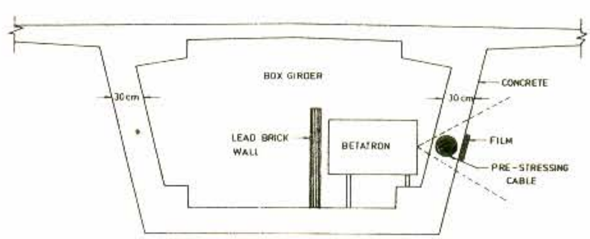

Fig.2 : Cross section of a grider in bridge 1

TABLE I: Typical optical densities measured on radiographs

Sl. No.	Portion	1	2	3	4	5
1.	Top	1.52	1.52	1.52	1.46	1.28
	Bottom	1.81	2.01	2.12	1.02	1.63
2.	Top	1.34	1.74	2.01	2.13	1.88
	Bottom	1.28	1.71	1.89	1.88	1.49
3.	Top	2.19	1.89	1.72	1.51	1.29
	Bottom	1.61	1.59	1.46	1.42	1.77
4.	Top	1.24	1.69	1.84	2.07	1.96
	Bottom	1.25	1.57	1.73	1.93	1.87
5.	Top	1.73	2.00	1.98	1.90	2.09
	Bottom	2.53	2.94	2.94	3.11	2.96
6.	Top	2.95	3.00	3.14	2.55	2.32
	Bottom	2.51	2.80	2.62	2.21	2.45

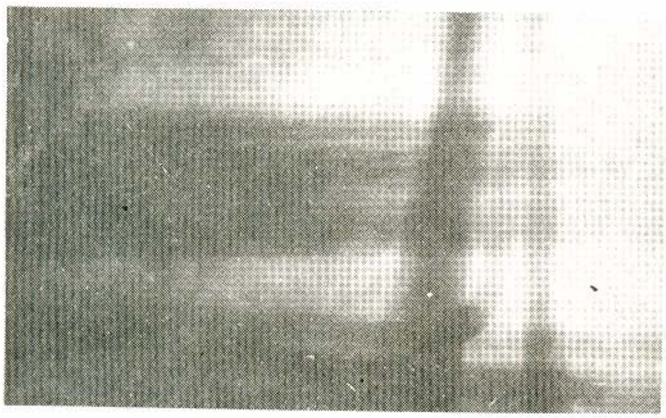

Fig. 3: Positive print of radiograph taken in bridge 1

and is also observed that the prestressing strands are centrally positioned at this location. The cement grount surrounding the strands is also clearly seen. However, the cement grout appears to be less dense at the top portion.

CONCLUSIONS

1. From this investigation it could be established that it is quite safe from the hazard point of view, to carry out radiography, using this equipment in the field.

Fig. 4: Positive print of radiograph taken in bridge 2

2. Variation in the quality of the grout can be identified from the optical density measurements.
3. Voids in the concrete can be located.
4. Location of prestressing cables is possible.

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