Final Report

Inspection of Post Tension Cables in concrete using High Energy X-rays, Ramp D at the Ft Lauderdale Airport

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Scope

To determine High Energy X-rays capability to inspect and detect flaws in post-tension concrete roadways.

Introduction

The system chosen was a Varian Mini-Linatron operated by HESCO Corp. of La Honda, Ca. The equipment utilizes standard s-band technology common to most industrial linacs, and produces the same high radiographic quality through thick sections as can be expected from these fixed units. The overall system has been condensed and repackaged for field use. It consists of a power supply cabled to a small remote control, an R.F. generator and the small linear accelerator itself.

Location and Description

The Ramp D overpass at the Ft. Lauderdale Airport is a Box style overpass made of high tensile strength concrete construction. The roadway is segmented or sectioned and joined together with tongue and groove joints, epoxy, and post tensioning cable. The ramp is a banked and pitched roadway with an approximately 20° downward pitch running south to north. The bottom side of the roadway was accessible thru a man hole at the underside of the box structure.

Site Preparation

Sixteen locations were chosen (8 per side) along a 300 foot long stretch of the roadway. The locations were marked top and bottom in order to align the x-ray source with the film and locations were identified by the segment designations. Locations identified as R for Right were re-identified as S and L for Left was re-identified as SS.

Equipment Set-up

The HESCO 6MV portable linear accelerator (LINAC) was air freighted and trucked to the site. FDOT supplied the "Snoop" man lift, night lighting, and portable generator. The contractor supplied a Gradeall type forklift. The Gradeall type forklift was chosen because it has an articulating head which makes possible the angled shots required for this job.

The x-ray and rf-heads were strapped to the forks and covered for whether protection. The modulator (power unit) and chiller remained in the truck. The control box was moved to a safe area just below the roadway.

Film Identification

The film locations were identified with lead lettering and one steel 2.7 film side penetrameter. Source side wire penetrameters were also placed on the roadway. The locations of the lead lettering were painted on the underside of the roadway for future reference.

X-ray Procedure

Prior to testing, a radiation survey was performed to determine radiation safety compliance, (see Radiation Safety). The testing was conducted by two technicians, one technician positioned and operated the x-ray machine, while the second technician remained inside the box roadway to position the film for each location. The film was placed into position using a telescoping pole and tray which held the film against the underside of the roadway.

Radiation Safety Survey and Procedure

A radiation safety survey was conducted to determine radiation levels in the test area. The x-ray source is collimated to a 30° forward primary beam and is positioned down towards the roadway. A walking survey determined that the radiation levels directly below the x-ray beam was 5 mr/hr, the highest recorded level was at 20 mr/hr, approximately 200 ft away at the adjacent freeway off-ramp leading to the Ft. Lauderdale air terminal.

The Florida Highway Patrol provided road control during testing. Prior to each shot, (x-rays on), the x-ray tech would signal that the roadway be secured. Personnel on site would move to safe locations and the shot would begin. Shot times varied from a couple of minutes to 18 minutes for the thickest angled shot. Closing the roadway was a precautionary measure when taking into consider the recorded levels. A typical inspection would allow traffic to flow through the test area making the following assumptions: Cars traveling at 45 miles per hour or 66 ft/sec would receive a dosage of less then .02 mR total. Cars traveling at 35 miles per hour or 51 ft/sec would receive a dosage of .03 mR total. Even a bicyclist traveling at 10 miles per hour or 14 ft/sec would receive a dosage of .12 mr which is certainly less then the 2 mr/hr requirement.

The x-ray technician inside the box measured readings of less then .15 mr/hr up to 20 ft away from the primary beam.

Film Viewing Results

High energy X-rays has the ability to penetrate and view defects in concrete as small as 1/16" or less. The table below lists all visible defects in the grout, strands, and concrete. The defects listed as ground strands may also be interpreted as voids on top of the strands

The areas that contain the fabricated defects offer an extra layer of interpretation. The exploration and back filling of an area with grout creates its own set of defects and creates density changes due to the difference in material and installation techniques. As an example, the concrete saw cutting lines are visible as sharp lines cutting across the cable. Locations that where not excavated and backfilled, for example segment 79-11B, contain less defects and a uniform film density between cabling, grout, and concrete.

Table 1

Segment	Hole I.D.	Defects	comments	Exposure time (minutes)
89	S1	Broken and cut strands, voids in grout		5
88	SS1	Voids in grout, ground strands		6 1/2
88	13C	voids in conduit at left, voids in concrete		2 1/2
88	13D	Voids in grout, ground strands, strands have been separated, broken conduit casing		18
87	11A	1" x 1/2" void in center of film w/smaller 1/4" voids surrounding, possible broken cable B-B, coil of wire		3.3
86	SS3	Cable has been ground/cut in two, partial pcs of rebar, pulled back conduit sheeting is visible	Shot is off center	4.6
86	SS9	Cable conduit on right contains large void and is ground and cut, cable in center of view is ground and cut, missing sections of cable, strands of center cables or broken at bottom of view. Partial pcs of rebar, large "staple" in lower left also electrical wire, voids in grout	Shot is off center	2 1/2
85	5A	Film moved, not readable	Film or source moved during shot	4 1/2
79	SS9	Saw cut from A to A, cable conduit and some cable cut, missing section of rebar, saw cut from B to B, voids in concrete		2.2
79	5B	Small voids in grout	Shot is off center	4 1/2
79	13A	Large void in concrete by wire IQI, breaks in conduit wall, broken cable strand below "B" on right, voids in grout		3
77	11B	Voids in concrete, cable in center has large strands	Shot is slightly off center	8.3
76	S1	Not tested		
76	SS3	Not tested		
69	11B	Not tested		
56	S5	Not tested		

X-ray Films

The x-ray film used was Kodak AA, size 14" x 17". Shot times varied due to concrete thickness variations.

The x-rays have been sent to Habeeb Saleh for digitization. Habeeb is with the Federal Highway Administration , NDE Validation Center, 6300 Georgetown Pike, Mclean, Virginia, 22101, Phone # 202-493-3123, E-Mail Habeeb.Saleh@igate.fwha.dot.gov. Digitized x-rays should be available early late next week.

Conclusion

High Energy X-rays are a very affective method for inspection of post-tensioned concrete roadways. An x-ray image which is a picture, can be reviewed and discussed, and held for future reference of the specific area or to develop a historical record and case studies to help improve the fabrication process or design of the structure.

Project Notes, Lessons Learned, Improvements

1) This project was a coordinated effort between HESCO, DMJM-Harris, Florida Department of Transportation, Federal Highway Administration, and PCL .
2) An acceptance/rejection criteria must be established for x-ray interpretation of grouted areas and post tensioned cable.
3) Positioning the x-ray machine above approximately equals the time to position and locate the film.
4) Road or lane closer of the roadway being inspected is essential for inspection. Closer of adjacent roadways may not be necessary as with this project. Future inspections may be performed with extra lead shielding to limit scatter radiation.
5) The cost for inspection of a single overpass is comparatively high since a high percentage of the cost is the transportation of the machine and personnel. Longer-term projects at multiple locations will prove to be more cost effective.
6) Road closer coordination took between 25% to 50% of the time for each x-ray location.
7) Film review should be closely coordinated with cognizant department of FDOT.
8) Digitized x-rays can be put into a computerized format and sent to various locations via E-mail.
9) Future advancements in machine portability will allow the x-ray machine to be placed inside the structure, further increasing radiation safety and decreasing the need for time consuming and costly traffic management.
10) See Caltrans report attached.