FDOT Protocol for Condition Assessment of Steel Strands in Post-tensioned Segmental Concrete Bridges

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Final Report- Volume II- This document provides steps for condition assessment of steel strands in post-tensioned concrete bridges. The background information for the recommended steps are provided in the Volume I of the final report

DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation

CONVERSION TABLES

Approximate conversion to SI Units

Symbol	When you know	Multiply by	To find	Symbol
		Length		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		Area		
in^2	Square inches	645.2	square millimeters	mm^2
ft^2	Square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		Volume		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		Mass		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		Temperature		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		Illumination		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
lbf	pound force	4.45	newtons	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa

Approximate conversion to US Customary Units

Symbol	When you know	Multiply by	To find	Symbol
		Length		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		Area		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		Volume		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		Mass		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		Temperature		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		Illumination		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force and Pressure or Stress		
N	newtons	0.225	pound force	lbf
kPa	kilopascals	0.145	pound force per square inch	lbf/in^2

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16. Abstract

Post-tensioned bridges require a detailed inspection of their post-tensioning systems since damage in these systems is not evident and can result in costly repairs/replacements, loss of integrity and reduction in safety of the bridge. Different nondestructive Evaluation (NDE) techniques can be used for the inspection of post-tensioning systems however; there is no systematic way by which a particular NDE technology may be selected for a particular job.

This project presents elements and foundation for development of a systematic, job specific approach for the selection of NDE technology for inspection of the post-tensioning systems.

In order to achieve this goal, factors affecting the performance of NDE techniques used for the condition assessment of the post-tensioning systems are identified. NDE techniques are then grouped according to their underlying phenomenological bases to put forth the working principles, and pros and cons that can be used for the development of ranking system.

It has been found that major difference in grouting practice before and after 2000 affects the selection of NDE technique for the inspection of post-tensioning systems. Other factors affecting the performance of the NDE techniques are the duct system, geometrically difficult zones, and the types of defects. Separate sets of NDE technique are recommended for the internal/external ducts positioned along the traffic and geometrically difficult zones. A job specific “Ranking Index” is proposed for the selection of NDE that takes into account the not only the above mentioned factors but also the cost of conducting NDE.

Based on the project findings a roadmap to develop comprehensive methodology to effectively assess the condition of post-tensioned bridge systems is presented.

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EXECUTIVE SUMMARY

Post-tensioned structures require a detailed inspection of post-tensioning systems since damage in these systems is not evident and can result in costly repairs/replacements, loss of integrity and reduction in bridge safety. Different damages that require nondestructive Evaluation (NDE) are corrosion of main tension elements, ruptures of post-tensioning tendons, voids in grouted ducts, and damage of corrosion protective barriers. Current challenges of NDE of post-tensioning systems include absence of established framework, lack of proper and safe access, and optimization of level of effort and cost. A nationwide survey conducted as the part of this project indicates that 23 out of 27 states (that participated in survey) have a need for assessment of post-tensioning systems.

This project presents elements and foundation for development of a systematic approach for condition assessment of post-tensioned concrete bridges. The project provides a protocol for condition assessment of steel strands in post-tensioned segmental concrete bridges (Volume II of the report) that is based on investigation of state of the art improved inspection techniques for steel prestressing/post-tensioning strand (Volume I of the report).

NDE technologies that can be used for condition assessment of post-tensioning systems are grouped according to their underlying phenomenological bases. These phenomenological groups of NDE technologies are: Visual methods, Magnetic methods, Mechanical wave/vibration methods, Electromagnetic methods, electrochemical methods, Penetrating radiation methods and other methods. The grouping not only put forth the underlying principles of NDE technologies but also highlights the pros and cons in relation to their application to post-tensioning systems. The pros and cons are discussed and finalized at international workshop arranged by P.I.

Following the discussions at the international workshop, a matrix is established that identifies the merits of various NDT methods for assessing different conditions. It has been found that a major difference in grouting practice before and after 2000 affects the selection of NDE technique for the inspection of post-tensioning systems. Other factors affecting performance of NDE techniques are duct system (internal or external), geometrical challenges (anchorage zones, deviator, diaphragms, grout presence/absence), and types of defects.

Steps for condition assessment of steel strands in post-tensioned concrete bridges are developed considering the above mentioned factors and are presented in volume II of this report. Separate set of NDE technologies are recommended for the internal/external ducts positioned along the traffic and

geometrically difficult zones. NDE technology from each set can be selected based on a job specific "Ranking Index" that is sum of "Efficiency Index" and "Cost Index". Tables are developed to facilitate the calculation of these indices. Although each NDE technology can have a different "Ranking Index" depending on the job, Magnetic Flux Leakage, Impact Echo, and Impulse Response are identified as promising NDE technologies.

Based on the project findings a roadmap to develop comprehensive methodology to effectively assess the condition of post-tensioned bridge systems is presented.

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1 Steps in Condition Assessment of Steel Strands in Post-tensioned Segmental Concrete Bridges – Existing bridges

1. Planning - Plan the investigation by reviewing the available documentations and extracting any related documentations or conclusions that could influence the condition assessment plan.

2. Identify the critical regions of the bridge by studying, type of exposure, traffic and structural considerations. These observations should lead to identifying the "hotspots" and critical areas of the bridge prone to defect or development of corrosion. Fault tree analysis could be used to assist this process.

3. Separate the areas to be investigated into two general categories, as follows:
    a. Straight portion of the longitudinal ducts, internal or external,
    b. Anchorage, deviators and diaphragms or any other special details, such as transverse post-tensioning elements

4. Use steps below to inspect the straight and sloped segments of the ducts parallel to traffic.
    a. Use procedures specified by ANSI/ASQ Z1.4-2008, entitled "SAMPLING PROCEDURES AND TABLES FOR INSPECTION BY ATTRIBUTES", to select length and segments of the ducts to be inspected.

    b. For existing bridges constructed using old grouting material (prior to 2002) and techniques, use corrosion detection as the parameter in statistical approach

    c. For existing bridges constructed using new grouting techniques and material (procedure specified after about 2002) use grout defect as statistical parameter. Alternatively use corrosion, if there is enough evidence of corrosion.

    d. If possible, use a fast method, such as sounding method for external ducts or air flow for internal ducts to assist selection of the segments to be inspected. Fast scanning methods are better applicable to external tendons and the sounding method is proven to be an effective NDT approach.

e. Using the information provided in tables 1 through 3, select the most suitable NDT method for condition assessment of the select portions of the internal or external ducts for corrosion or grout defect.

f. If suspect areas have been identified by an NDT method, select at least one destructive method, such as borescope or opening the external duct. If results are not confirmed, revise the selected NDE approach. This may require use of another NDT method or use of Hybrid approach.

g. Proceed with completing the condition assessment using the statistical approach.

h. Based on statistical approach confirm the predicted strand or grout conditions.

i. When grout defect was selected as statistical parameter, use destructive approach to determine if corrosion exists where there are grout defects. If corrosion is present then concentrate on areas with identified grout defects. If results are not conclusive or preferred, use corrosion as statistical parameter and proceed with condition assessment of the steel strands using same approach specified above for grouting practices used prior to 2002. i.e., use corrosion as statistical parameter to start with, rather than grout defect.

j. Confirm the state of strands with respect to corrosion by conducting destructive NDT methods and develop appropriate repair procedure

k. Develop a follow up condition assessment program

5. To inspect the condition of anchorages, following NDT methods are suggested to be used
    a. Borescope
    b. X-ray radiography, where appropriate. Consider the hazards associated with exposure to radiation
    c. Infrared Thermography with additional research

6. To inspect condition of tendons at the deviators or diaphragm locations, following NDT method are suggested to be used
    a. Borescope
    b. X-ray radiography, where appropriate. Consider hazards associated with exposure to radiation.

2 Recommended NDT Methods

This section of the report provides the list of NDT methods that are recommended to be used in condition assessment of the post-tensioned segmental concrete bridges. These methods are validated and have been applied in the field condition. The only exception are the Infrared Thermography and air flow NDT methods that demonstrate great potential for condition assessment of steel strands in post-tensioned concrete bridges. However, these two methods demand conducting additional limited research before they are used in practice with confidence.

1- **Visual Methods**
   a. Borescope
2- **Magnetic Methods**
   a. Magnetic Flux Leakage (MFL)
3- **Mechanical Wave/Vibration methods**
   a. Acoustic sounding (hammer tap)
   b. Acoustic Emission (AE)
   c. Impact Echo (IE) and Ultrasonic Imaging using shear wave (commercially available as MIRA and ICON)
   d. Impulse Response (IR)
4- **Electromagnetic Wave Methods**
   a. Infrared Thermography (IT)
   b. Ground Penetrating Radar (GPR)
5- **Electrochemical Methods**
   a. None recommended for post tension structures
6- **Penetrating Radiation Methods**
   a. X-Ray radiography
7- **Other Methods**
   a. Direct Prestress measurement
   b. Air flow

Detail description of each NDT methods, including their advantages, disadvantages, etc. are provided in Volume I of the Final Report.

3 Selection of NDT Method

The NDT methods that are ready for field implementation for condition assessment of steel strands in post-tensioned concrete bridges are specified in section 2 and are divided into seven categories. Following sections provides three tables that assist in selection of most appropriate NDT method for a given condition assessment plan. These tables are developed to assist in selecting the NDT method(s), most suitable, to assess the condition of steel strands in internal or external ducts and positioned along the traffic. The discussion on NDT methods recommended for condition assessment of anchorage areas, deviators, diaphragms or other challenging areas are provided in section 1 of this report. For these regions only handful of NDT methods are applicable.

The selection of NDT method(s) for condition assessment of internal or external grouted ducts and parallel to traffic is achieved by following steps outlines in Table 1. In particular the "Ranking Index" is the number that should be used for selecting the NDT method.

Table 1: NDT Selection table

Duct Type	Straight and Sloped Segments of Grouted Ducts parallel to Traffic					Comments
	Condition	NDT Method	Efficiency index	Cost Index	**Ranking Index**	
Internal – Plastic and metallic	Corrosion, Section loss And Wire breakage	Borescope				Other visual methods includes opening the ducts
		MFL				There are more than one version of using MFL method
		X-Ray radiography				Advanced 3D radiography is also available
		Infrared Thermography				The technology needs some additional research
	Grout Defect- Voids	Borescope				
		Impact Echo				Less accurate to detect voids in plastic ducts as compared to metal ducts
	Moisture Content	Air flow				This technology is used on a commercial basis. However, needs some additional research
	Monitoring for wire breakage	Acoustic Emission				It may result in developing large amount of data and forcing undertaking significant effort, where it is not needed
	Locating Duct	Ground Penetrating Radar				Could also be used for detecting voids in ducts
	Fast Scanning	N/A				As of 2012, air flow may be used for fast scanning. However, there is a need for additional research
External Plastic	Corrosion, Section loss And Wire breakage	Borescope				
		MFL				
		Infrared Thermography				
	Grout Defect- Voids	Borescope				Impact Echo may have applicability. However, the round surface of external duct provides challenges
	Moisture Content	Air flow				
	Fast scanning	Sound (hammer tap)				

Table 1 identifies the applicable NDT method(s) for a given defect type and given duct configuration. For each recommended NDT method, determination of three indices is needed. The column designated as “Ranking Index” in Table 1 is obtained by adding the “Efficiency Index” and “Cost Index.” The two Indices, referred to as “Efficiency Index” and “Cost Index” are job specific and are obtained using Tables 2 and 3, respectively.

Table 2 provides a procedure to calculate the Efficiency Factor, used in table 1, for each of the recommended NDT methods. The Efficiency Factor is job specific. As a result, some of the information in Table 2 is left to be populated by user. The job-specific considerations in obtaining the Efficiency Factor in Table 2 are related to specifying the “Weight Factors” for each parameter influencing the Efficiency Factor. The parameters that influence the Efficiency Factor for each NDT method are:

a) **Operator Expertise—**This factor ranges from 1 to 10. Table 2 provides the relative operator expertise index where applicable. One (1) represents requiring high expertise to operate the equipment and interpret the NDE data, while ten (10) represents requiring very low expertise.

b) **Time Requirement—**This factor ranges from 1 to 10 and reflect the relative amount of time needed to operate and carry out the NDE test in the field. One (1) represents a NDT method that is very time consuming for field application, and ten (10) indicates a NDT method requiring minimal amount of time for field application.

c) **Access Requirements—**Some NDT methods require good access for conducting tests, while access is not a major issue for others. The Access requirement factor ranges from 1 to 10, with 1 representing NDT method requiring very good access and 10 representing NDT method insensitive to access issue.

d) **Defect Sensitivity—**Different NDT methods have different thresholds for detecting defects in field conditions. This factor ranges from 1 to 10, with 1 representing a NDT method capable of detecting only very large defects, while 10 represents a NDT method capable of detecting a very small defect.

The Operator Expertise, Time Requirement, Access Requirement, and Defect Sensitivity factors are specified for various NDT methods in table 2. These values reflect the project findings. The weight factors for all NDT methods and conditions are intentionally left blank in table 2. The weight factors are job specific and require careful consideration by the maintenance engineer.

Table 2: Efficiency Index Calculation for Selecting NDT Method

Category	NDT Method/Condition	Operator Expertise		Weight Factor		Time Req.		Weight Factor		Access Req.		Weight Factor		Defect Sensitivity		Weight Factor		Efficiency Index	
		Corrosion/wire breakage	Grout Defect/Voids	Corrosion/wire breakage	Grout Defect/Voids	Corrosion/wire breakage	Grout Defect/Voids	Corrosion/wire breakage	Grout Defect/Voids	Corrosion/wire breakage	Grout Defect/Voids	Corrosion/wire breakage	Grout Defect/Voids	Corrosion/wire breakage	Grout Defect/Voids	Corrosion/wire breakage	Grout Defect/Voids	Corrosion/wire breakage	Grout Defect/Voids
Visual Methods	Borescope/ Corrosion, Grout defect	10	10			1	1			10	10			5	5				
Magnetic Methods	MFL/Corrosion, Section loss, Wire Breakage- Internal Ducts	2	NA			6	NA			7	NA			7	NA				
	MFL/Corrosion, Section loss, Wire Breakage- External Ducts	5	NA			7	NA			8	NA			10	NA				
Mechanical Wave/Vibration Methods	Acoustic Sounding (Hammer tap)/ Fast scan for grout defect for external tendons	NA	7			NA	9			NA	10			NA	4				
	Acoustic Emission/Monitoring for wire breakage	9	NA			8	NA			10	NA			8	NA				
	Impact Echo/ Grout Defect-internal duct-metal duct	NA	3			NA	3			NA	7			NA	6				
	Impulse Response/ structure signature	NA	NA			NA	NA			NA	NA			NA	NA				
Electromagnetic Wave Methods	Infrared Thermography/corrosion, grout defect	3	3			6	6			5	5			7	7				
	Ground Penetrating Radar/locating tendons	NA	NA			NA	NA			NA	NA			NA	NA				
Penetrating Radiation	X-Ray radiography/corrosion, grout defect, tendon locations	8	8			5	5			4	4			7	7				
Other Methods	Direct stress Measurement/available prestress	NA	NA			NA	NA			NA	NA			NA	NA				
	Air Flow/moisture content in the duct	NA	6			NA	6			NA	7			NA	5				

Operator Expertise	1= High expertise needed	10=Low expertise needed
Time Requirement	1= Time consuming for field application	10= Fast method to apply in the Field
Access Requirement	1= Requires good access for inspection	10= Access is not an issue
Defect Sensitivity	1=Low sensitivity. Can detect large defects	10=High sensitivity. Can detect very small defects
Total Efficiency Index	(Operate Expertise * W.F. + Time Req. * W.F.+ Access Req. * W.F. + Defect Sensitivity * W.F.)	

The bottom portion of Table 2 provides the procedure to calculate the Efficiency Index for various NDT methods. These Efficiency Indices for each NDT method is then input in Table 1 for determining the Final Raking Index associated with each NDT method and selecting the most optimum NDT method.

The last input needed in Table 1, to select the optimum NDT method, through Ranking Index, is the determination of “Cost Index”, as required by Table 1. The “Cost Index” is job specific and input from consultants, subcontractors or entities responsible for conducting NDT is needed. Table 3 provides a template to establish the “Cost Index”.

Table 3: Cost Index Calculation for Selecting NDT Method

Category	NDT Method/Condition	Cost Index	
		Corrosion/wire breakage	Grout Defect/Voids
Visual Methods	Borescope/ Corrosion, Grout defect		
Magnetic Methods	MFL/Corrosion, Section loss, Wire Breakage- Internal Ducts		
	MFL/Corrosion, Section loss, Wire Breakage- External Ducts		
Mechanical Wave/Vibration Methods	Acoustic Sounding (Hammer tap)/ Fast scan for grout defect for external tendons		
	Acoustic Emission/Monitoring for wire breakage		
	Impact Echo/ Grout Defect-internal duct-metal duct		
	Impulse Response/ structure signature		
Electromagnetic Wave Methods	Infrared Thermography/corrosion, grout defect		
	Ground Penetrating Radar/locating tendons		
Penetrating Radiation Methods	X-Ray radiography/corrosion, grout defect, tendon locations		
Other Methods	Direct stress Measurement/available prestress		
	Air Flow/moisture content in the duct		

4 Steps in Condition Assessment of Steel Strands in Post-tensioned Segmental Concrete Bridges – New bridges

The major challenge with condition assessment of steel strand in post-tensioned concrete bridges is the lack of having adequate information that could have been collected during construction. This is especially true with respect to segmental concrete bridges constructed prior to 2002. Until such time that grouting is used as a means to protect the steel strands in internal and external ducts, it would be beneficial to assess the condition of grouting during the construction and identify any areas of the duct with inadequate grouting, such as existence of Voids or grout that does not set after about 7 days following the completion of grouting operation. For internal ducts, Impact Echo and air flow NDT methods could be used to scan condition of grouting immediately after the grouting operation and about seven days after the grouting. This can identify the areas with voids. Such information could then be used to identify the areas prone to developing corrosion in the future. For external ducts sound and air flow NDT methods could be used to obtain similar data.

5 Establishing Bridge Signature

Corrosion of steel strands in internal and external ducts in post-tensioned bridges does not generally result in major changes in global response of these structures, until it is way too late. To safe guard and reduce risk for critical bridges, consideration should be given to developing the signature of the bridge in term of mobility using Impulse Response and direct prestress NDT methods. Select segments of the bridges could be tested and global response of structure could be obtained. These NDT methods are quick and can be carried out periodically to ensure that there are no major changes to global response of segmental bridges. This philosophy is applicable to both existing and new bridges.

6 Summary, Conclusions and Recommendations for Future Development

This project presents elements and foundation for development of a systematic approach for condition assessment of post-tensioned concrete bridges. Information presented is currently specific to segmental post-tensioned concrete bridges. However, many recommendations are also applicable to other post-tensioned concrete bridges, such as I girder bridges.

On Development of Overall Condition Assessment Plan

Selecting the most appropriate NDT method is just one element of condition assessment process. Section 1 of this report provides an outline of steps needed to be carried out in order to assess the condition of steel strands in post-tensioned concrete bridges. However, this is not enough and there is a need to better identify the details of the condition assessment plan.

On NDT Methods

Combined, Volume I and Volume II of final report, provides State of the Art on NDT methods. NDT methods that are ready for field applications are identified, which are as follows:

1- **Visual Methods**
   a. Borescope
2- **Magnetic Methods**
   a. Magnetic Flux Leakage (MFL)
3- **Mechanical Wave/Vibration methods**
   a. Acoustic sounding (hammer tap)
   b. Acoustic Emission (AE)
   c. Impact Echo (IE) and Ultrasonic Imaging using shear wave (commercially available as MIRA and ICON)
   d. Impulse Response (IR)
4- **Electromagnetic Wave Methods**
   a. Infrared Thermography (IT)
   b. Ground Penetrating Radar (GPR)
5- **Electrochemical Methods**
   a. None recommended for post tension structures

6- **Penetrating Radiation Methods**
   a. X-Ray radiography
7- **Other Methods**
   a. Direct Prestress measurement
   b. Air flow

Magnetic Flux Leakage NDT method remains as one of the best NDT methods for inspecting external tendons. MFL is also applicable to internal tendons. However, in the case of internal tendons, use of MFL needs to be in conjunction with strategy identified in Volume I.

Impact Echo (IE) and Ultrasonic Imaging using shear wave (commercially available as MIRA and ICON) have shown good promise for locating grout defect and could well be suited for internal tendons, especially for metallic ducts. The field applications of these methods have been limited.

Impulse Response (IR) test is an ideal NDT method to obtain signature of any post-tensioned concrete bridges at the time of construction or, at any point in time, to investigate possible major changes to bridge behavior between the inspection cycles. It is recommended that IR be used for obtaining bridge signature. The technology is simple and is not very time consuming.

Infrared Thermography is an extremely promising NDT method for inspecting external, internal tendons and hard-to-inspect regions, such as anchorages. The best attribute of the method is that results are in picture form and easy to interpret. However, there is a need to conduct some limited research before the method is applied with confidence to field condition.

Electrochemical NDT methods are in general not recommended for field application. There may be special cases where these methods present merits.

X-Ray radiography's best attribute is the easy interpretation of the results. The short coming is the exposure to radiation. Recently 3-D radiography has been used with success and this method could have a good application for inspecting hard to reach regions, such as anchorages, deviators, and diaphragms.

Direct stress measurement method is a very promising technique. This method, with some development, could be an effective approach for measuring the available prestress forces in bridge elements. It is also a good NDT method for use in conjunction with prestressed or post-tensioned concrete I girders.

Air flow is another promising technology that is easy to apply in the field condition and can be extended to detect grout defect and other abnormalities associated with grouts in both internal and external tendons. It is also a good NDT method for developing preliminary information for hard to reach regions such as anchorages, deviators and diaphragm.

On Selection of NDT Method

Tables 1, 2 and 3 in Volume II of this report provide a systematic approach to select the optimum NDT method. However, many elements of these tables need to be reviewed and there is a need to develop consensus. It is recommended that arrangement be made so that maintenance and other bridge engineers become involved in further development of these tables.

On Hybrid Approach

There is a need to develop better guidelines for using more than one NDT method during the condition assessment.

On Developing Examples

The best approach to demonstrate the use of recommendations made by the project is by developing at least one comprehensive example. A segmental bridge in District 4 is scheduled for demolition. This provides a great opportunity to use the bridge scheduled for demolition as a test bed for the purpose of verifying the project recommendations and at the same time developing a comprehensive case study.

On Development of a stand-alone Guide and devoted to Condition assessment of post-tensioned bridges

As described in section 9 of Volume I final report, there is a need to develop a stand-alone document and devoted to condition assessment of post-tensioned concrete bridges. This document can provide the entire process in a very transparent form and act as a single reference point.

On development of Computer Tools

The level of efforts necessary for developing condition assessment plan for post-tensioned bridges and comprehending the information provided in Volume I and II of the final reports, could be overwhelming. It is recommended that window based computer programs with “artificial intelligence” be developed to assist in navigating through the information. The final outcome of this computer program could be development of a complete condition assessment and maintenance plan for post-tensioned concrete bridges.