Methodology for Risk Assessment of Post-Tensioning Tendons

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Through international exchanges, the Federal Highway Administration (FHWA) has identified the following four common, globally shared goals:

- Advance infrastructure intelligence
- Improve infrastructure resilience
- Improve infrastructure service life
- Develop a well-trained workforce

A technology exchange held by the FHWA in November 2022 highlighted eight post-tensioning (PT) advancements that improve PT tendon resilience, intelligence, and corrosion resistance. In addition, an outcomes report was developed from this exchange.[1] This PT technology exchange was the result of a collaboration between the FHWA and the American Segmental Bridge Institute (ASBI) and was made possible by sponsorships from ASBI members.

This article highlights one of the eight advancements presented at the exchange on the theme of improving infrastructure service. This advancement is a methodology for conducting a risk assessment of PT tendons to aid designers in selecting corrosion-protection strategies for PT systems in bridges.[2]

The methodology applies the risk-based decision-making process to the goal of improving the durability of post-tensioned bridges. According to Dr. Glenn Washer, the principal investigator of National Cooperative Highway Research Program (NCHRP) Project 12-82,[3] to systematically evaluate risk on any project, engineers must answer three fundamental questions as part of the risk-based inspection process:

- What can go wrong?
- What are the chances of the event happening across a given time frame?
- What are the consequences?

Formulaically, this is expressed as follows:

$$R = POF \times C$$

where

R = risk

POF = probability of failure

C = consequence of the failure

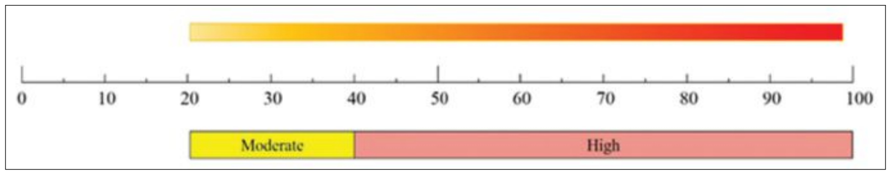

Figure 1. Example of risk levels based on 100-point scale.[1] All Figures and Tables: Federal Highway Administration.

Probability of failure can be defined in terms of likelihood, frequency, or occurrence (that is, how likely a certain event is to occur). To determine the probability of failure, engineers use failure testing, deterioration models, expert knowledge, or point estimates.

Consequences of failure are typically described in terms of economic impacts, environmental impacts, or safety impacts, and these evaluations may rely on expert judgment. Risk may be visually represented using either a risk scale (1 to 100, with higher values indicating higher risk, such as in **Fig. 1**) or a risk matrix. For the risk scale, the risk factor can be expressed by the following equation:

$$Risk\ Factor = OF \times CF \times 100$$

where

OF = occurrence factor, a measure of the likelihood of the event

CF = consequence factor, a measure of consequence

The strategy is to apply the processes developed for NCHRP Project 12-82 to the risk assessment of PT tendons. This process outlined by NCHRP requires first forming a risk assessment panel (RAP) of experts in the subject of the risk analysis. Next, relevant attributes and risk criteria are developed from an expert elicitation of the RAP.

This general process can be applied to PT tendons to provide guidance on risk reduction and mitigation strategies for bridge designers. Based on input provided by the RAP assembled

Figure 2. Attributes and associated ranks identified by the risk assessment panel.[1]

Attribute	No.	Attributes	Rank
PT Tendon and Profile	A1	Tendon Length	High
	A2	Tendon Vertical Profile	Very High
	A3	Tendon Curvature	Moderate
	A4	Profile Conflict Avoidance	Moderate
PT Tendon Joint and Closure	A5	Cold Joints, Precast Segments	High
	A6	Cold Joint, Cast-in-Place (CIP) Segments	Moderate
	A7	Closure Pours	High
PT System Materials and Components	A8	Anchorage Protection, Interior	Moderate
	A9	Anchorage Protection, Exposed	High
	A10	Venting Protection	High
	A11	Grout Material Performance	High
	A12	Materials Specification	Moderate
	A13	Venting	High
	A14	Use of Diablos	High
PT Installation Quality	A15	Construction Quality	High
	A16	Quality Assurance	Moderate
	A17	Grouting Procedures	High
Environmental	A18	Macro Environment	High
	A19	Micro or Local Environment	High

Figure 3. Consequence attributes identified by the risk assessment panel.[1]

No.	Attribute	Rank
C1	Tendon Importance, System Level	High
C2	Ease of Tendon Replacement	High
C3	Bridge Importance	Optional

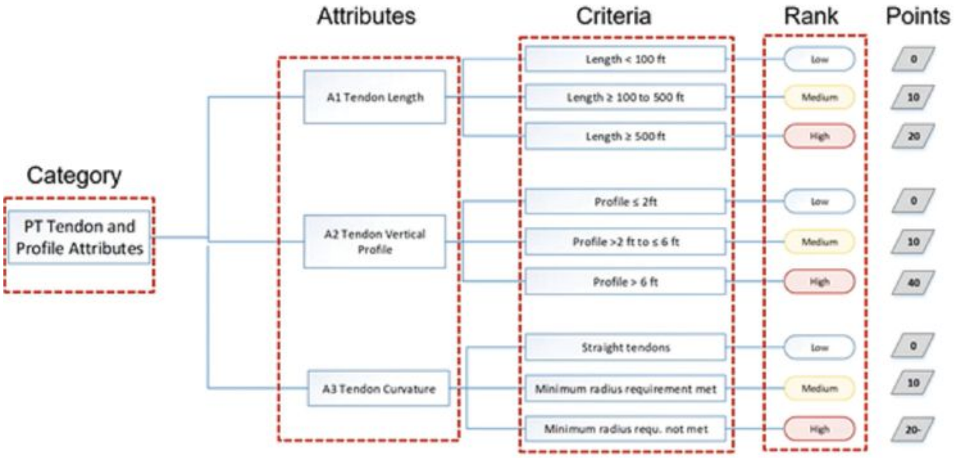

Figure 4. Flowchart for the risk assessment, including the overall category, individual attributes, the specific risk criteria, a given risk rank, and the possible risk points for each.[1]

for the project, this methodology includes a risk model in which 19 attributes are ranked and scored to provide an estimate of the likelihood of corrosion damage, and three attributes are ranked and scored to estimate the consequence of corrosion damage (**Fig. 2** and **3**).

To calculate the likelihood of an event, individual attribute scores are summed to provide the relative estimate of the likelihood of corrosion damage:

$$OF = \sum S_i / \sum S_0$$

where

S_i = score recorded for each attribute

S_0 = maximum score for each attribute

The same process was used to provide a relative estimate of the consequence:

$$CF = \sum C_i / \sum C_0$$

where

C_i = score recorded for each attribute

C_0 = maximum score for each attribute.

Figure 4 shows an example of the scoring for this system.

A sensitivity study to assess the scoring process resulted in setting risk thresholds with three levels of consequence: low, moderate, and high. Using these processes, appropriate risk-reduction and risk-mitigation procedures can then be developed by bridge designers.

For more information, a presentation on this methodology delivered by Dr. Glenn Washer and a PT risk-assessment tool are available under the heading FHWA Post-Tensioning Assessment Tool on the Resources page of the ASBI website (https://asbi-assoc.org/resources).

References

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