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October 31, 2017

Friends of Lake Park
Colleen Reilly, PMP, President
PO Box 71197
Milwaukee, WI 53211

RE: Structural Documentation Review of Lake Park Arch Bridge – Phase 1

Dear Ms. Reilly,

TranSystems was contracted by the Friends of Lake Park to provide an independent review of the structural documentation available for the assessment of Lake Park's Arch Bridge over Ravine Road and examine whether or not there is a viable cost-effective rehabilitation alternative that preserves the original design and extends the service life of the rehabilitated bridge beyond that that were previously estimated. These documents included the available 1905 plan sheets, 2015 In-Depth Inspection Report, which included material testing results, site photos and load capacity rating calculations as well as other documentation on the history of the bridge. On September 27, 2017, TranSystems conducted a site visit to confirm current conditions of the bridge with representatives from the Friends of Lake Park and Milwaukee County also in attendance.

Photo 1*: Lake Park Arch Bridge*

Based on the review of the available documentation, TranSystems recommends a further refined condition assessment of the structure that would clearly distinguish the areas of the bridge that require structural repairs and those areas that need aesthetic structural patching. A better understanding of these types of repairs, the material properties of the existing concrete, and the associated quantities of the repairs could significantly reduce the cost of the proposed rehabilitation alternative, making the rehabilitation of this bridge a cost-effective alternative over other bridge replacement alternatives.

TranSystems has worked extensively in the preservation and rehabilitation of historic bridges throughout the nation. Previous studies performed by TranSystems typically included other testing and analysis to evaluate rehabilitation alternatives of a historic concrete bridge. The results of the other testing and analysis can significantly influence the comparison of the cost-benefit analysis between the alternatives considered. TranSystems recommends considering the following topics in order to thoroughly evaluate historic concrete bridges, and develop feasible and prudent rehabilitation alternatives:

Material Testing

The 2015 In-Depth inspection report included results and discussion of a material testing program that tested the concrete for strength and asbestos. The compressive strength test results of the concrete ranged from 1,595 psi to 9,882 psi. Note the original design plans specifying a concrete compressive strength of 1600 psi. However, TranSystems routinely performs the additional concrete tests to determine if the concrete is adequate for structural repairs or aesthetic restorations:

1. CHLORIDE ION ANALYSIS - Chloride contents at shallow depths of approximately 1½" (relative to the face of the core) within a core sample are generally indicative of chloride penetration from external sources such as road salt, airborne pollutants, or pollutants present in soil. In comparison, the chloride contents at deeper locations in a core sample may be more indicative of the as-built chloride content of the concrete. Large concentrations of chlorides within the concrete near the steel reinforcement promote corrosion of the reinforcement and will determine the effectiveness of any cathodic protection systems or health monitoring systems installed during rehabilitation. Spalling of the concrete may result from ongoing steel reinforcement corrosion.

2. PETROGRAPHIC ANALYSIS - Petrographic analysis is used to identify if an alkali-silica reaction (ASR) is occurring between the minerals in the aggregates and the soluble alkaline components of the cement paste. ASR was poorly understood at the time this bridge was constructed. ASR weakens the cement bond to the large particles within concrete. The presence of ASR will limit the durability of repairs made to the existing concrete bridge, however better concrete mix formulas for the repair areas will ensure compatibility between the two types of concrete.

Photo 2: *Corner spalls with exposed reinforcing steel on the arch rib*

3. FREEZE-THAW ANALYSIS - Freeze-thaw analysis is used to gauge the durability of concrete under repeated cycles of freeze and thaw conditions. For concrete where the cement bond is already compromised, years of freeze-thaw will lead to failure of the cement bond often initially observed as "pop outs" where the stone aggregate separates from the surface of the concrete element.

The outcome of these additional tests can significantly influence the comparison of the cost-benefit analysis between the bridge alternatives and significantly increase the service life of the bridge and concrete repairs to greater than 30 years. A complete understanding of the chemical characteristics of concrete over 100 years old is important to any historic concrete bridge rehabilitation.

Photo 3: *Underside of deck with delaminations*

Live Load Rating

The 2015 load capacity rating analysis for this structure, in our opinion, was conducted with an overly conservative methodology that does not represent the actual capacity of the structure nor the original design intention of the bridge. This bridge was designed and built in the early 1900's before the Allowable Stress Design (ASD) methodology was developed and used widely. But the load rating method used (AASHTO Load and Resistance Factor Rating, or LRFR) was adopted in 2005 and is geared towards newer structures built within the last few decades. While LRFR can be applied to structures of any age, it is our experience that since LRFR is a probability-based, calibrated methodology compared to the more traditional, uncalibrated strength-based Load Factor Rating (LFR) method – the results from LRFR analysis are typically more conservative, often yielding lower allowable capacities when compared to those methodologies in common use closer to the design date of this bridge.

There is no requirement by State or Federal agencies that LRFR method be applied to an historic structure, and it is considered acceptable engineering practice to use a load rating method that is in line with the design method of the bridge. Additionally, the LRFR method is for bridges carrying vehicular loads and there is reason for not applying it to a structure designed for pedestrian use.

The main structural arch rib elements of this bridge exceed the load capacity of their original design loads as well as the vehicular load as investigated and reported in the 2015 report. While there are several bridge elements that cannot carry their original design loads based on the current analysis, a more refined analysis utilizing ASD or LFR could significantly change the allowable capacity of those elements which in turn may reduce the amount of structural repairs/strengthening required, and thusly decrease the overall cost required for the rehabilitation alternative.

Condition Assessment
Based on our cursory site visit, there has not been any significant change in the condition of the bridge since the 2015 inspection. Many of the conditions noted in the field are a combination of failures of previous patch work and poor construction practices. The deck delaminations appear to be due to a lack of concrete cover over the reinforcing steel. This is evident in that the reinforcing bars are still bonded with the concrete for the majority of the circumference of the bars. While section loss of the steel may be present, the amount of loss is most likely not significant. Therefore, cleaning and rehabilitating several of these areas with the exposed reinforcing is a viable option as long as the material testing of the concrete concludes these types of repairs are compatible.

CONCLUSIONS

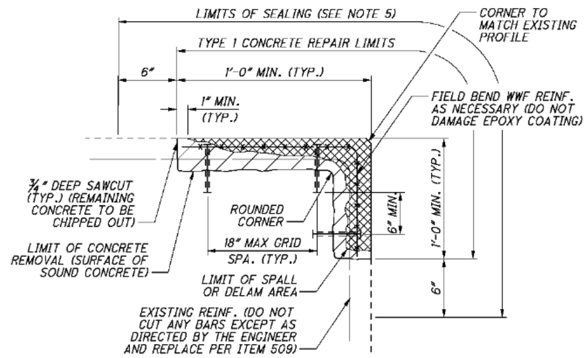
Based upon our review of the documentation provided by the Friends of Lake Park, TranSystems offers the following engineering opinions for the Lake Park Arch Bridge:

1. Based on the limited material testing data collected on the concrete samples of the original structure, the durability of the existing concrete and the effectiveness of extending the service life of the rehabilitated bridge alternative are inconclusive. Knowing the additional test results and data from the existing 1905 concrete will determine the depth of repairs to remove chloride contamination and ASR while ensuring that a cathodic protection system to limit corrosion in the reinforcing steel will meet the project objectives of extending the service live of the rehabilitated bridge beyond 30 years.

2. A proper analysis of the primary bridge elements should be performed to understand the true load capacity of the bridge. A comparison of engineering methodologies ranging from a basic Capacity/Demand Ratio (Factor of Safety) to ASD, LFR and the completed LRFR analysis will provide a more accurate representation of the capacity of the bridge and any future loading consideration of the exiting bridge.

3. Distinguishing the types of concrete repairs needed for various areas of deterioration would ensure a fair cost-benefit comparison between the proposed alternatives in the 2015 report. Quantifying the types of repair areas into the following five categories could significantly reduce the $1.8M cost estimate:

- Component Replacement In-kind
- Structural Strengthening Retrofit Details
- Structural Repairs (typically greater than 6” in depth)
- Structural Patching (typically 2”-3” depth repair with wire mesh)
- Surface Patching with Sealant



TYPE 1 REPAIR AT VERTICAL CORNER
(FOR INFORMATION NOT SHOWN SEE TYPE 1 CONCRETE REPAIR)
(NOT TO SCALE)

When the distinctive areas of repair types are known, a more refined cost estimate can be developed. While traditional concrete repairs and patching alone will address the spalling and exposed areas of the bridge, coupling them with other methods of rehabilitation will ensure a prolonged service life of a historic structure like this one. For example, using a cathodic protection and health monitoring systems can allow for an “inside view” of the onset of corrosion of the reinforcing, which is especially desirable after chloride contamination and ASR mitigation is completed. A system like this is a powerful tool when used after a finishing treatment, such as fiber reinforced polymer wraps or a penetrating sealants, is installed to rehabilitated areas. By being selective with what repair and rehabilitation options are applied, a viable cost-effective option is attainable that will allow for more than 30 years of service life.

TranSystems’ experience in major rehabilitation of concrete structures from circa 1900 in this region of the country would lead us to believe the Lake Park Arch Bridge can be rehabilitated in a cost-effective manner while extending the service life over 30 years – the design target for rehabilitation. However, to ensure the durability and longevity of the repair work, a complete understanding of the existing concrete is imperative to any feasibility study of preferred alternatives.

Due to the incomplete concrete testing program performed and the overly-conservative load rating analysis of the Lake Park Arch Bridge, TranSystems believes there are multiple combinations of standard industry practices that will provide for a longer service life beyond that previously estimated and could significantly reduce the estimated cost of $1.8M. TranSystems has approached the cost estimating phase on similar rehabilitation projects by providing the owner an “ala carte” selection of restoration alternatives that provide a fair cost-benefit analysis of a new structure versus repairs.

Therefore, TranSystems recommends that additional testing be performed to better identify which type of repair and/or treatment be applied and where. The results would allow for better cost-effective alternatives that can meet the goals of this rehabilitation of the Lake Park Arch Bridge.

Sincerely,
TranSystems Corporation

P.E.

Wesley Weir, PE
Senior Project Manager/Vice President