Independent Review of Mitchell River Bridge, "Bridge Alternatives Evaluation and Life Cycle Cost Comparison dated April 28, 2011"

Prepared by: HDR Incorporated

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Overview

HDR Inc. (HDR) was contracted by Massachusetts Department of Transportation (MassDOT) as an independent consultant to review URS' "Bridge Alternatives Evaluation and Life Cycle Cost Comparison (Draft), dated April 28, 2011" examining five alternative options for the replacement of the Mitchell River Bridge in Chatham, MA.

HDR visited the site and performed a visual inspection of the Mitchell River Bridge on March 31, 2011 and investigated the existing condition of the bridge and familiarized the team with the surrounding community. We also reviewed documents (see attached list) and emails provided by MassDOT as well as project related websites that formed a baseline for the issues related to this project. As a result of this documentation review, HDR has a basic understanding of the issues raised by the community related to the selection of materials and structure type for this project.

HDR is a national engineering firm that is regularly engaged in the design and rehabilitation of modern and historic structures around the country. Areas of expertise include timber structures and movable bridges.

Review of URS' Bridge Alternatives Evaluation and Life Cycle Cost Comparison (Draft), dated April 28, 2011

HDR performed a review of URS' "Bridge Alternatives Evaluation and Life Cycle Cost Comparison dated April 28, 2011" and associated "Addendum to Bridge Alternatives Evaluation and Life Cycle Cost Comparison, dated May 12, 2011." The analysis investigates five alternative options (with two additional alternatives presented in the addendum) for replacement ranging from an all timber structure to a structure constructed of all modern materials. URS utilizes a series of project design categories to rank the various alternatives which includes roadway function & safety, context sensitivity, navigation & safety, initial construction cost, life cycle costs, maintenance & service life, and environmental impacts.

URS validated their recommendation by establishing the evaluation criteria, assigning values, and ranking alternatives. This approach to evaluating options is consistent with standard engineering practice and, in general, gives appropriate consideration to all relevant factors. URS also performed a Life Cycle Cost Comparison (LCCC) and the total usable life was established at 80 years (worst case) to 100 years (best case). Initial replacement costs were developed along with a schedule for anticipated maintenance, repairs, and major rehabilitations over the life of the structure. Future anticipated costs were discounted to current dollars and a total lifetime cost in current dollars was estimated. HDR reviewed this Life Cycle Cost Comparison and we found minor discrepancies between the text and calculated values, however, these discrepancies do not result in major changes to the LCCC and associated results. Based on our review, we do not disagree with the reports conclusion which identifies Alternative 5 as the preferred alternative. The analysis identifies that Alternative 5 is the best economic choice but does not incorporate the concerns and feedback received from the community.

HDR's Approach

URS' approach of assigning and weighing project design categories results in ranking alternatives relative to each other. There is inherent variability associated with each of the project design evaluation categories. There are subjective factors such as the context sensitivity of the design, differing opinions on engineering/economic inputs such as the appropriate discount rate in the LCCC, and variations in life expectancy of materials that could skew the results of the analysis. When the overall results cluster together, as we see in this case, selecting a preferred alternative becomes more subjective. If there is a larger spread between the rankings, the confidence level with the preferred alternative is greater. In this case, the analysis is further complicated by the use of different material types used in the comparison of alternatives. Concrete and steel are used extensively by MassDOT within the Commonwealth and, as a result, the associated service life is well established. This is due in part to the homogenous and uniform quality of the material. Conversely, the service life of timber is more variable. The use of timber piles within a marine environment and the less frequent use of timber lend itself to a service life resulting in more variability. Timber is a natural, orthotropic material that inherently has higher variability associated with its mechanical properties and durability. URS addressed this element in the comparison analysis by using best and worst case scenarios in the life cycle cost comparison and we concur with the use of this methodology in ranking alternatives. As noted above, the range of costs (initial and life cycle) is relatively narrow. Coupled with the uncertainty and variability of issues as described above, the selection of Alternative 5 is not the overwhelmingly strong alternative.

Our clustered outcome suggests another look at the essential functional, operational, and maintenance criteria coupled with the aesthetic concerns of the community.

Movable Bridge Span

The movable span must be operational, serviceable, reliable, and safe. The existing movable span has documented reliability issues which can be a source of frustration to users and a cost to the community. The table below indicates some of the existing deficiencies that HDR considers essential and that require action to mitigate problems in the future. We believe that the core drivers to the choice of this structure are safety, functionality, and serviceability over the life. At a minimum, these drivers should be satisfied for any replacement alternative considered.

Existing Problem	Type of Problem	Possible Causes	Suggestions to mitigate
Movable Span Misalignment	Operation and Reliability	Expansion and contraction of the timber due to moisture content It is well documented that timber structures and their associated connections undergo movement due to the nature of the moisture content of the timber Flexibility of the substructure (piles) under braking forces Possible shifting of entire structure after years of operation The modulus of elasticity for timber is considerably less than steel and concrete Deflection causes unnecessary strain on mechanical and electrical equipment	Movable span and piers should be replaced with a rigid structure
Exposed mechanical equipment	Safety and Serviceability 1) exposed cables 2) lack of redundancy with cable system 3) out dated technology – not in conformance with current AASHTO code	Historic nature and original design of the structure	Utilize a dry bascule pier with all machinery below the bridge deck HDR strongly advises against exposing functional equipment above the roadway of this structure which is a bridge utilized by pedestrians
Future Problem	**Type of Problem**	**Cause**	**Suggestions to mitigate**
Counterweight (all wood structure w/ 25' movable span)	Serviceability (submerging weighted end of lift span into salt water)	Movable span design and need for increased counterweight	Use a dry bascule pier to enclose the counterweight

In addition to the questions raised regarding the movable span misalignment and foundation rigidity, the existing bridge design does not meet current code requirements. The AASHTO LRFD design guidelines (PP 5.5.1) states, "where the span is normally left in the closed position, the machinery shall also be proportioned to hold the span in the fully open position against wind

load of 20psf on any vertical projection of the open bridge." This code requirement identifies the non-compliance of the current design and suggests a significant safety issue. This code provision would disallow the use of the current cable based design to raise the span since the design is not capable of resisting wind load in both directions. In order to properly control the span against the forces of the wind on the upright leaf, a revised design utilizing a geared mechanical system is necessary. This is not reasonably feasible with an all wood bascule span with this geometry.

In consideration of the misalignment issues being documented with the existing structure, potential for similar issues with an all timber structure, and with the wind related safety issues of the current cable based design, HDR recommends that the movable span be constructed of modern construction materials (concrete and steel) and that a dry bascule pier be utilized to protect the counterweight and associated mechanical equipment. This will result in a more dependable and safer structure for its replacement life span.

Timber versus Steel Piles

HDR also investigated the use of timber piles for the bridge substructure. Timber piles are used extensively in a marine environment; for piers, fenders, and wharfs. Timber is a feasible alternative for a structure that needs to be flexible to absorb the impact from ships/vessels or other marine vehicles as timber piles are flexible and absorb energy. We note that timber fender systems are being increasingly replaced with flexible composite piles. Timber piles have been documented to last 20 to 100 years. The longevity of timber piles is heavily reliant on the preservative. Timber piles which have lasted upwards to 100 years were installed at a time when creosote was widely used as a preservative in a marine environment and is now considered an environmental hazard. There is a fair amount of academic research currently available on preservatives but since these products are relatively new to the marketplace there is no long-term empirical data to support absolute service life. This lack of data raises concern relative to the anticipated longevity of timber piles.

HDR further investigated the use of tropical timbers and came to similar conclusions as URS. The timber industry promotes the use of Greenheart (species: ocotea rodiaei) timber pilings. Greenheart is a very dense and durable timber. Greenheart is environmentally friendly as it does not require the use of wood preservatives. In fact, the material is so dense that it is impractical to try to infuse any type of penetrating preservative. The available literature generally states that Greenheart is rated as highly resistant to attack by decay fungi and is also rated as highly resistant to attacks by marine borers, but industry research also suggests that this may vary from one locality to another, particularly in brackish water. There is little published data available to document the long-term performance of Greenheart as a piling in a marine environment. That being said, the timber distributor we contacted stated that Greenheart is rated for 25 to 30 year use. This reaffirms the assumptions for replacement of the timber foundation system made in URS' Life Cycle Cost Analysis.

It is also important to emphasize that MassDOT has experience with tropical timber pilings for the Powderpoint Bridge in Duxbury, MA. It has been 24 years since these piles were installed and they are showing significant signs of deterioration. Given the lack of industry wide data on tropical timbers mentioned above, MassDOT has its own data (though limited) on a single bridge which supports the assumption that the expected service life is in the range of 20 to 30 years. The observed pile condition at the Powderpoint Bridge further reinforces URS' Life Cycle Cost Analysis assumption with regard to timber pile life.

While neither timber nor concrete is exempt from future deterioration, the goal is to mitigate the risk of replacement of the substructure in the future for the reasons noted in URS' report, namely the increased cost of having to replace the entire structure if the foundation should fail.

The following are disadvantages to timber piles:

- Not as easily inspected nor are the majority of bridge inspectors well educated with timber inspection
- Piles are more flexible possibly contributing to movement or deformation of the lift alignment
- Susceptible to decay, borer attack in marine environment
- Lack of proven long-term preservatives and associated concerns relative to the environment
- Inability to determine the effects of internal decay, checks, splits on the remaining capacity of the pile

When the timber piles check and split, it is very difficult to determine the impact to the mechanical properties of the pile. Timber is an orthotropic material with unique and independent properties in different directions. Wrapping the timber piles with a strengthening material is a method used to reinforce a compromised pile and extend the service life of the piles but new concerns are introduced; most notably is the concern that you can no longer see and inspect the pile nor perform any traditional inspection techniques like sounding and probing the pile to look for the presence of interior rot.

While dependable empirical methods have not been established to quantify the extent and/or the rates of decay and deterioration, it is known that the rate of decay and deterioration of timber piles is directly associated with the site conditions. There are instances where timber is the most suitable choice for pile selection. For instance, timber piles used in building foundations that are completely submerged below the groundwater level have been documented to last well over 100 years. In the environment at the Mitchell River Bridge, the conditions are more aggressive for timber piles. This increases the risk associated with their use due to: exposing the timber piles and increasing the risk of decay and deterioration, use in a tidal zone where the water level fluctuates and the timber piles are susceptible to borer attack, and supporting a movable structure

which needs to be rigid. Therefore, we concur with the URS conclusion that piles will require replacement every 20 to 30 years necessitating major bridge reconstruction at that time.

The following are disadvantages to steel piles:

- Susceptible to corrosion
- Environmental concerns relative to the use of coatings

Steel is a common choice for piling in a marine environment across the country and is a suitable choice for pilings at this particular bridge site. Future problems can be mitigated by over sizing the steel pipe pile to allow for anticipated corrosion while also utilizing coatings to prevent corrosion. If the steel corrosion causes a reduction to the section it is easily detectable and measurable in the future. This reduction to the section is easily calculated and the remaining capacity of the steel pipe pile can be determined. Relative to coatings, there are modern epoxy coatings and three paint systems which are proven to work well in similar environments when properly maintained. With proper maintenance concrete filled steel piles will have a life expectancy as assumed by URS in the LCCC.

Conclusion

By working with the critical engineering components outlined above, HDR concludes that Alternative 3 is the best alternative when taking into consideration the communities concerns and feedback. Alternative 3 provides for a modern life span and functional structure while giving significant consideration to historic and context sensitivity of the bridge design at Mitchell River. While URS' methodology, data, and assumptions are reasonable, it can be argued that the results of the numbers are somewhat inconclusive. Alternative 3 retains key elements of the appearance of the original bridge and provides for a more dependable and predictable service life.

List of Documents Provided by MassDOT and reviewed by HDR

URS: Bridge Alternatives Evaluation and Life Cycle Cost Comparison (Draft) for Bridge Street over Mitchell River, Bridge No. C-07-001 (437), dated March 14, 2011

URS: Bridge Repair/Rehabilitation Feasibility Study, dated March 10, 2011

URS: Geotechnical Design Report for Bridge No. C-07-001 (437), dated November 2, 2010

URS: Sketch Plans of Proposed Bridge (Chatham, Bridge Street over Mitchell River), not dated

URS: Functional Design Report: Bridge C-07-001, Bridge Street over Mitchell River, dated February 2010

URS: Bridge Type Selection Worksheet for Bridge Street over Mitchell River, not dated

URS: Timber Railing Review Memo, dated February 21, 2011

URS: Treatment Alternatives for Bridge Street over Mitchell River, dated October 12, 2010

URS: 25% Highway Submittal, Chatham, Bridge No. C-07-001, dated February 2010

URS: Preliminary Right of Way Plans of Bridge Street (Bridge C-07-001) in Chatham, dated February 2010

URS: Addendum to Bridge Alternatives Evaluation and Life Cycle Cost Comparison, dated May 12, 2011 (life cycle cost backup calculations for alternatives 1A and 1B not included).

Categorical Exclusion (CE) Determination Checklist, not dated

Duxbury Inspection Report, dated August 27, 2010