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Memorandum

Date: 9/2/2016

To: Wade Salyards, MDT

Copy to: Russ Lay, Steve Grabill

From: Kathy Harris

RE: Swan River – Bridge St (Bigfork) UPN 9020000 STPB 9015 (126): Bridge Options Memo 1

Purpose of Memorandum

This bridge options memorandum is a planning level analysis to identify the most feasible options for the rehabilitation or replacement of the historic Swan River Bridge as part of a feasibility study. The memorandum is an initial effort to evaluate those options based upon previously-defined screening criteria and focuses solely upon structural engineering criteria. Separate efforts by the Steering Committee will develop the evaluations for other (non-structural) screening criteria. Future reports will combine these individual memorandum into the final feasibility report.

Background

The Swan River Bridge does not meet current design standards, is functionally obsolete and is structurally deficient. Without treatment of ongoing corrosion and deterioration, bridge closure is imminent. Timing of bridge closure is uncertain but the bridge may need to be closed for safety reasons in the near future. The owner (Flathead County), MDT and the project Steering Committee concur that, due to the unique nature and historic appearance of this bridge to the community of Bigfork, some current design standards do not need to be met. The project Steering Committee includes three members from the community, three members from Flathead County and three members from MDT.

Project Needs

The Steering Committee, Flathead County, MDT, and the community have collaborated to identify three major project needs for the Swan River Bridge. The Project Need and Screening Criteria Memorandum describes the process used to identify project needs, states the project needs, and details development of specific screening criteria for each need. The three project needs are:

- Provide a safe crossing of the Swan River
- Maintain the historic appearance
- Ensure the project is constructible and maintainable.

This memo focuses only on the structural engineering criteria to provide a safe crossing over the Swan River. Historic appearance and constructability/maintenance needs will be evaluated separately. Refer to the Project Needs and Screening Criteria Memo for details of development of the qualitative screening criteria.

Overview of Structural Screening Criteria

Screening criteria for a safe river crossing were further defined by the Steering Committee to provide a structurally adequate bridge that meets current design standards (codes) as much as possible and practical. This addresses both traffic and pedestrian safety features. Specific screening criteria were defined to be measurable for each option. These structural criteria focus on (qualitatively) comparing the load carrying capacity, the lifespan of the bridge, and maintaining vertical clearance above the river. These screening criteria are described below:

- Bridge options will be judged based on their structural adequacy and implementation of current design standards. The highest rating will be assigned to options that meet all requirements of current American Association of State Highway and Transportation Officials (AASHTO) bridge design standards such as seismic and wind resistance. A one-lane bridge is not typically provided in modern times; so this criterion also reflects if the one or two lane option is provided.
- Bridge options will be judged based on their load ratings. The highest rating will be given to options that can support at least an HS-20 truck loading, the standard design load for highway bridges.
- Bridge options will be judged based on their projected lifespans. The highest rating will be given to options that provide a 75-year lifespan, the current standard for highway bridges.
- Bridge options will be judged based on their ability to maintain the existing vertical clearance above the river. The vertical clearance changes based upon the elevation of the river which continually changes. There is no minimum clearance required for navigation and Flathead County requires a minimum of two feel of bridge clearance above the 100 year flood water elevation. The current bridge provides approximately seven feet of clearance above the 100-year flood surface elevation[1]. Floodway and floodplain impacts will be determined for the final option but are not expected to be a governing design factor due to the large existing vertical clearance. The highest rating will be given to options that either maintain the existing clearance or decrease it by less than one foot.

[1] Flood Insurance Rate Map (FIRM), Flathead County, Montana - Panel #2315, FEMA, 2007.

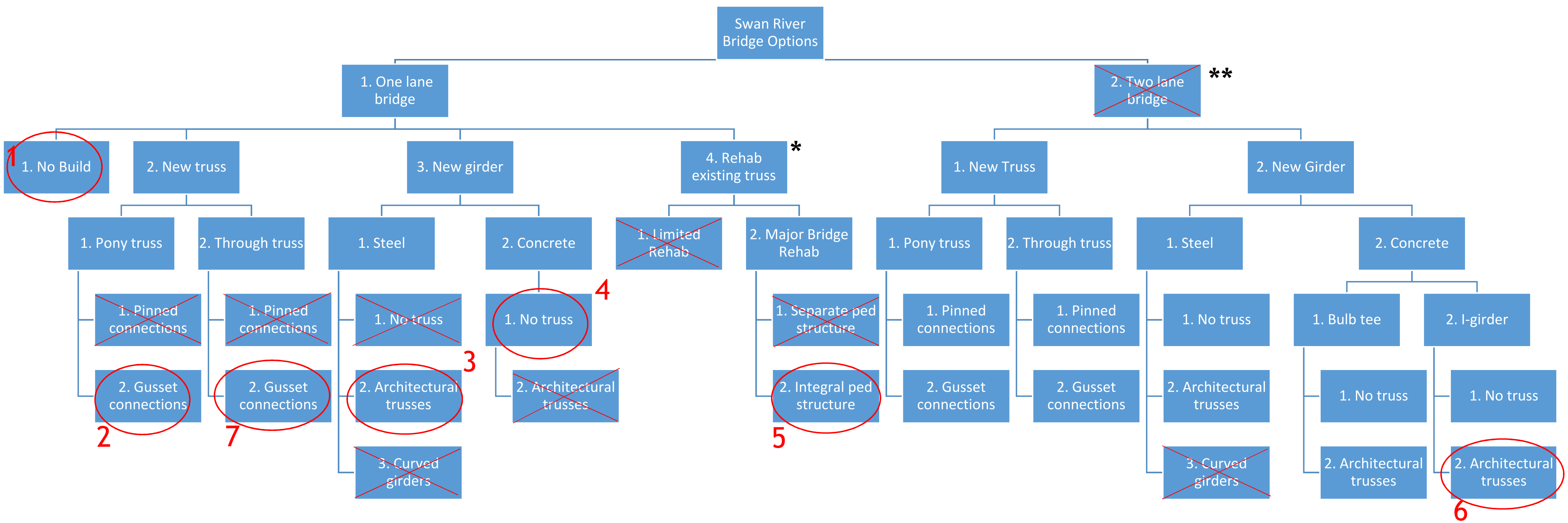
Bridge Options

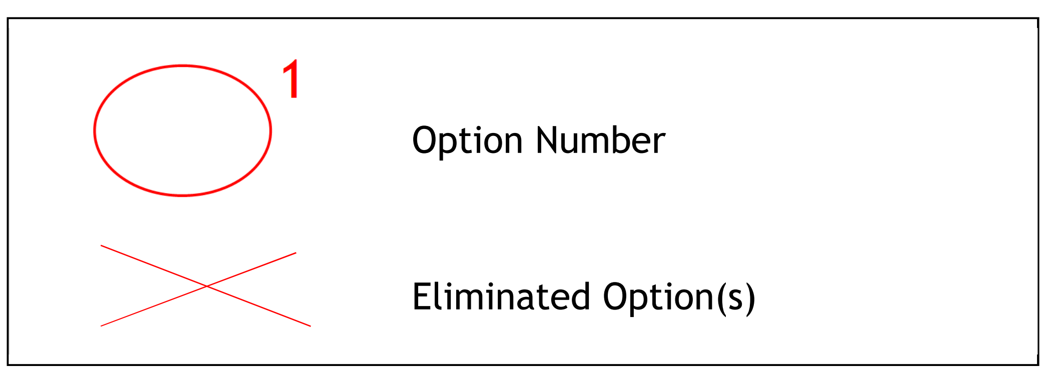
Approach for Selecting Bridge Options

A multitude of bridge options are available to meet the needs of the Swan River Bridge. For this feasibility study, options were developed using a decision tree approach. The decision tree approach provides the ability to investigate individual impacts of variations to each general alternative. Appendix A provides a description of this approach with **Figure 1** showing the results of a logic-based decision tree approach and the resulting seven bridge options evaluated herein.

Figure 1: Selection of Initial Bridge Options

FIGURE 1: SELECTION OF INITIAL BRIDGE OPTIONS (flowchart)





* See Appendix B for a description of truss bridge rehabilitation & analysis, design loading determination, and bridge configurations.

** See Section 4.3 for a description of the two lane bridge consideration and disqualification. The two lane bridge option circled in this chart is provided to show the extent of options considered.

Bridge Options Eliminated

One bridge option was disqualified from initial consideration as it was deemed unfeasible:

- Superimposed Arch – This concept inserts a new arched support structure to carry bridge loads and retains the existing, historic trusses as architectural (not structural) features. This would retain the NRHP listing but introduce a major visual change to the bridge. Due to public comments (sustaining the existing appearance), this concept is not forwarded.

Figure 1 shows the decision logic for selecting bridge options. The decision tree shows that once a characteristic is known to be unfeasible, all subsequent options containing that characteristic (path below) can also be disqualified.

- Limited truss rehabilitation - Limited rehabilitation would only replace extremely deteriorated elements (e.g. bearing pins, stringers) to prevent impending structural failure. Other structural members would remain undersized. Limited rehabilitation that does not substantially increase the load rating and does not address the subsequent decreasing of the load rating (which will effectively close the bridge to public travel) is not a feasible or cost effective option.
- New truss with pinned connections – Truss bridges are no longer manufactured with pinned connections which are now replaced with more efficient bolted or welded gussets. Manufacturing a new truss with antiquated pinned connections would require extremely specialized construction and manufacturing and would be cost prohibitive.
- New curved steel girders - The existing roadway alignment meets design standards for a 25 mph roadway within the existing right of way. A new road and bridge alignment using curved girders was deemed unnecessary due to substantial costs and right-of-way changes which would redefine the lands adjoining the bridge and eliminate the small-town feeling desired in Bigfork.

Bridge Options Considered

The bridge options considered ranged in complexity and projected cost. The minimal treatment, Option 1, represents the “do nothing” approach where no repairs to the existing bridge are provided and only routine maintenance is continued. The most extensive option, Option 6, would provide a new, two-lane, concrete I-girder bridge with the existing trusses attached to the sides as architectural (not structural) features, which would meet all roadway and bridge design standards.

The seven bridge options forwarded from the decision tree approach and their screening criteria are presented in the following sections.

For any options that widen or replace the existing structure, the existing concrete abutments will either require widening or (more likely) replacement of the century-old concrete. Although it is desirable to retain the existing concrete abutments as is, there may be issues which are beyond the scope of this memo that could be addressed with geotechnical testing and/or future analysis.

Option 1 – No Build (Do Nothing)

The routine maintenance typically performed by Flathead County will continue, but no other rehabilitation or replacement measures will be taken.

Option 2 – New 1-Lane Steel Pony Truss

A new prefabricated steel pony truss superstructure with integral walkway will replace the existing truss bridge. Due to modern construction practices, and increased costs, new truss connections will be bolted or welded gusset plates rather than antiquated pinned connections. The bridge design could incorporate architectural overhead truss features to imitate the existing through truss style, (depending on project budget) this option would still be a pony truss. The bridge deck material is not finalized at this level of review. This option would likely require replacement (or possible widening) of the existing abutments.

Option 3 – New 1-Lane Steel Girder Bridge with Architectural Trusses

A new prefabricated steel girder superstructure with integral walkway will replace the existing truss bridge. The existing trusses will be attached to each edge of the new girder bridge as architectural features that imitate the existing truss appearance. Steel girders were chosen over concrete girders because steel girders are more aesthetically cohesive with the steel truss. The bridge deck material is not finalized at this level of review. This option would likely require replacement (or possible widening) of the existing abutments.

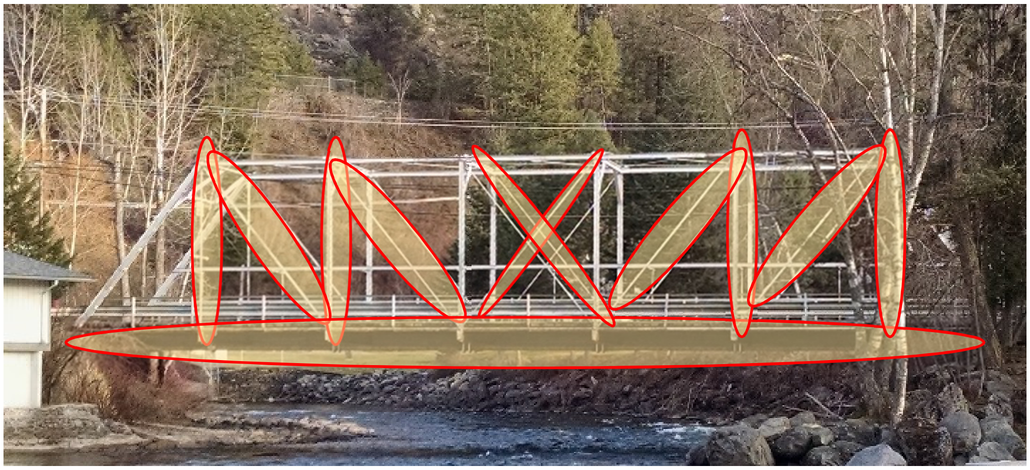
Option 4 – New 1-Lane Concrete Girder Bridge

A new prestressed concrete girder superstructure with a concrete deck and integral walkway will replace the existing truss. This could be accomplished with either concrete I-girders, or Bulb-T girders. This option would likely require replacement (or possible widening) of the existing abutments. A concrete girder bridge is presented as an option even though it does not maintain the historic truss appearance because this type of bridge is typical for new construction and is historically the most cost effective construction type.

Option 5 –Truss Rehabilitation with Integral Pedestrian Walkway

(See Appendix B for discussion of determining rehabilitation options).

The existing steel truss and the walkway will undergo major rehabilitation efforts, and the structure will be rehabilitated to support an HS 20 load. Rehabilitation efforts would also include remediation of the lead based paint on the structure. Damaged and corroded bridge components that require replacement include truss pins, bearing assemblies, bottom chord members, stringers, floor beam hangers, floor beams, bottom lateral bracing, and truss members with substantial vehicular damage. The increase in costs to increase the bridge loads from H-15 to HS-20 is minimal and therefore, it is justifiable to provide the standard (HS-20) highway loading. Approximately 75% of truss members will be repaired or replaced and 100% of stringers and floor beams will be replaced. The photo below gives a graphical representation of the quantity of members to be replaced.



The existing walkway on the upstream side of the bridge will be widened for ADA compliance and modified to safely carry the pedestrian load and adequately transfer the load to the truss superstructure. The walkway floor beams will be replaced. The existing concrete abutments will be re-used and provide support for both vehicular and pedestrian traffic on the bridge. The wooden bridge deck may be replaced with alternate materials.

Option 6 - New 2-Lane Concrete I-Girder Bridge with Architectural Trusses

This option proposes a new two lane concrete I-girder superstructure with integral walkway which meets current road and bridge design standards (including two travel lanes) to replace the existing truss bridge. The existing trusses will be attached to each edge of the bridge as architectural features to imitate the look of the existing truss bridge. The acquisition of new right of way is expected for this option. New cast in place concrete deck and abutments are expected in this option. Although a two-lane bridge option is opposed by the Steering Committee and public, this option would compare the cost and criterion for a new bridge that is fully compliant with modern design codes, to the other options being considered. The two-lane bridge would require roadway realignments and additional right of way. The two-lane option presents a baseline to decision makers and the public.

Option 7 – New 1-Lane Steel Through Truss

A new prefabricated steel through truss superstructure with integral walkway will replace the existing truss bridge. The new truss could be designed to somewhat resemble the existing truss, with overhead truss bracing and similar truss height. However, the new bridge would utilize modern construction practice of bolted or welded gusset plate connections rather than antiquated pinned connections. The bridge deck material is not finalized at this level of review. This option would likely require replacement of the existing abutments.

Summary of Bridge Rehabilitation Issues

The truss rehabilitation analysis is detailed in Appendix B and details the challenge to determining which (truss) members need to be improved to provide a safe bridge crossing for both vehicular and pedestrian travel. The items below represent key items in the rehabilitation option forwarded (Option 5):

- Rehabilitation will require replacing approximately 75% of the steel truss members. Need to confirm how this may affect the NRHP listing (based upon Criteria C for integrity).
- The costs for rehabilitation material is minimal compared to the construction costs for shoring and labor. Therefore, the costs to rehabilitate for a full HS-20 loading is only slightly greater than the cost to rehabilitate for the reduced H-15 loading. The H-15 loading was not forwarded as minimal cost savings are expected.
- All existing steel stringers and steel floor beams are inadequate and will need to be replaced. The stringers can be designed to support the walkway.
- The existing wood deck is inadequate but can be modified by repositioning the stringers.
- Removing the attached walkway does not have a significant effect on the truss rehabilitation.
- Lightweight fiber-reinforced-polymer (FRP) deck does not have a significant effect on the truss rehabilitation but offers a substantially lower lifecycle cost than a wood deck.

Screening of Bridge Options

Figure 2 shows the seven bridge options and the structural screening criteria ratings.

Figure 2: Screening Criteria: Structural

#	Description	Screening Criteria				Relative Cost
		Provide Structurally Adequate Bridge	Increase Load Rating	Provide 75 Year Bridge Life	Maintain Vertical Clearance	Bridge Only*
1	No Build	Detrimental or Lowest Rating	Detrimental or Lowest Rating	Detrimental or Lowest Rating	Beneficial or Optimum Rating	0
2	New, 1-Lane, Pony Truss	Moderate Benefit	Beneficial or Optimum Rating	Beneficial or Optimum Rating	Moderate Benefit	$
3	New, 1-Lane, Steel Girder w/ Arch Truss	Moderate Benefit	Beneficial or Optimum Rating	Beneficial or Optimum Rating	Moderately Detrimental	$$
4	New, 1-Lane, Concrete Girder	Moderate Benefit	Beneficial or Optimum Rating	Beneficial or Optimum Rating	Detrimental or Lowest Rating	$
5	Rehab, w/ Integral Walkway	Moderate Benefit	Beneficial or Optimum Rating	Moderate Benefit	Beneficial or Optimum Rating	$$$$
6	New, 2-Lane, Concrete Girder w/ Arch Truss	Beneficial or Optimum Rating	Beneficial or Optimum Rating	Beneficial or Optimum Rating	Detrimental or Lowest Rating	$$$
7	New, 1-Lane, Through Truss	Moderate Benefit	Beneficial or Optimum Rating	Beneficial or Optimum Rating	Moderate Benefit	$$

Legend:
- ● Beneficial or Optimum Rating
- ◐ Moderate Benefit
- ○ Neutral
- ◐ Moderately Detrimental
- ● Detrimental or Lowest Rating

* Costs represent bridge removal and replacement only. Earthwork, roadway approach work, right of way acquisition, or utility relocation costs are not represented in this table.

Appendix A:

Discussion of Decision Tree Approach

The decision tree starts very generally and then branches out into more specific options with each level. The trunk of the decision tree begins by categorizing options into the “One lane bridge” option and “Two lane bridge” option. The one lane bridges were divided into four subcategories – no build, new truss bridge, new girder bridge, and rehabilitate existing truss bridge. The two lane bridges were divided into two subcategories – truss bridge and girder bridge. The subcategories were further divided into material type, girder type, and structure type as shown in **Figure 1: Bridge Options Flowchart**.

The decision tree approach provides the ability to investigate individual impacts of variations to each general option. Once a given variation is known not to be feasible, all subsequent branches containing that variation can be disqualified without further investigation. After careful consideration of engineering constraints, public input, cost, and structure type, the decision tree was narrowed down to seven bridge options.

Appendix B:

Discussion of Analysis for Bridge Rehabilitation Option

Rehabilitation Options

Because rehabilitation encompasses a multitude of options, this section describes the process used to analyze the feasibility of rehabilitating the existing 1912 truss.

Design Loads

This design loading addresses the fact that vehicles (such as fire trucks, snow plows, and delivery trucks) vary significantly in weight and axle configurations, and will produce different stresses in the bridge structure. Rather than attempting to design for each of the myriad of potential vehicles that could use the bridge, four standard AASHTO design loads were considered in the existing truss bridge analysis. The design truck configurations are:

a. AASHTO H-15 load (30,000 lbs., 2 axle vehicle)
b. AASHTO H-20 load (40,000 lbs., 2 axle vehicle)
c. AASHTO HS-15 load (54,000 lbs., 3 axle vehicle)
d. AASHTO HS-20 load (72,000 lbs., 3 axle vehicle)

For example: the Bigfork Fire Department fire truck is similar to the HS 20 design truck and a UPS or FedEx delivery truck is similar to an H-15 load.

Description of Bridge Rehabilitation Options

A matrix of bridge modifications and truck types was explored to determine an efficient combination of rehabilitation effort and design truck weight. The four design truck loads were analyzed under the following four truss bridge conditions.

a. Current bridge construction – In this analysis option, the four design truck loadings were individually applied to the existing truss bridge in order to determine the level of rehabilitation necessary to provide a structurally adequate bridge for each truck type.
b. Current bridge construction with the walkway removed – The existing truss bridge currently supports a cantilevered walkway. In this analysis option, the additional weight of the walkway was removed, and the bridge was analyzed with the four truck types.
c. Current bridge construction with the wood deck replaced with Fiber Reinforced Polymer (FRP) decking – The existing truss bridge currently has a wood deck. In this analysis option, the wood deck was replaced with a lighter-weight FRP deck, and the bridge was analyzed with the four truck types.
d. Current bridge construction with the wood deck replaced with FRP decking and the walkway removed (combine items b and c above) – In this analysis option, the weight of the walkway was removed and the wood deck was replaced with a lighter-weight FRP deck, and the bridge was analyzed with the four truck types.

Evaluation of Bridge Rehabilitation Options

The matrix of truss modifications and truck types was analyzed in AASHTOWare Bridge Rating software. Each of the four bridge conditions was analyzed using computer models for each of the four design trucks, and the results obtained indicated whether or not each individual component (member) of the bridge would be structurally adequate for the given load case.

In all cases considered, the existing steel stringers and steel floor beams are inadequate to support the design vehicles, and will need to be replaced. Likewise, the existing wood deck is inadequate to support all four of the design vehicles in the current configuration; however the existing wood deck can easily become structurally adequate for all four loadings by repositioning the stringers.

For all options considered, truss members need rehabilitation. The cost of material required to strengthen the truss members (steel plate and bar stock) is minor in relation to the cost of labor to perform the repairs. Therefore, the number of parts replaced is of greater significance to the project cost than the size or thickness of the replacement parts being used. In turn the cost of lifting, moving, and shoring the bridge during repairs is of greater significance to the project cost than the labor to replace a given truss part. The results of the matrix were evaluated primarily by comparing the number of truss members requiring rehabilitation.

The results of the analysis show that walkway removal and change in decking material do not significantly change the number of truss members that need to be rehabilitated. For a given truck type, the removal of the walkway or change in deck material results in a difference of two or three truss members needing rehabilitation. The savings of three truss members not requiring rehabilitation is minor in comparison to the entire construction cost. Therefore, removing the walkway and replacing the wood deck with FRP are not effective measures for increasing the load rating of the truss.

Although the lightweight FRP deck does not make a significant impact on the truss members' rating factors, it does offer a lower lifecycle cost in comparison to a wood deck. The transverse wood decking has an estimated lifespan of 15 years, and the wood running planks have an estimated lifespan of 5 years. The FRP decking has an estimated lifespan of 75 years. Even without accounting for inflation, the material cost of the wood deck replacement over the course of 75 years is approximately twice the cost of the FRP decking. The FRP decking will also reduce the amount of effort and cost associated with bridge deck maintenance by allowing Flathead County to use standard maintenance equipment (i.e. snowplow) and by eliminating the need to replace the running plank wearing surface every 5 years.

Removing the weight of the attached walkway does not have a significant effect on the number of truss members requiring strengthening. The stringers need to be replaced as previously discussed, and the new stringers can be designed to adequately support the cantilevered walkway. Cost analysis indicates that rehabilitating the walkway on the existing truss bridge will provide substantial savings over installing a new adjacent pedestrian bridge.

The results of the structural analysis also show that with an H 15 load, approximately 25% of the truss members (6 of 26) would need to be replaced, and with the HS 20 load, approximately 75% of the truss members (17 of 26) would need to be replaced. Although the number of truss members increases 50%, nearly the same costs and effort would be required to lift, transport, and temporarily shore the bridge for repairs whether 25% or 75% of the members require replacement. Therefore the marginal cost of replacing the additional parts does not continue to increase at the same rate once the bridge has been moved and shored. Based on the marginal cost of strengthening 75% of truss members versus 25% of truss members, it is recommended that the bridge be rehabilitated for the full HS 20 design vehicle.

All rehabilitation options would include abatement for lead based paint currently on the steel members of the bridge.