SR 400 (I-4) Project Development and Environment (PD&E) Study

FM No.: 432100-1-22-01

SR 400 (I-4) Over US 17-92 and St. Johns River

Structural Evaluation Study

SR 400 (I-4) OVER ST. JOHNS RIVER STRUCTURAL EVALUATION STUDY

TABLE OF CONTENTS

I-4 Veterans Memorial Bridge Over St. Johns River Structural Evaluation

1. Executive Summary

In 2000-2001, The St. Johns River Veterans Memorial Bridge was designed and constructed with provisions to accept a future interior (median) widening as part of the future I-4 Ultimate corridor project. The existing structure provides a 132'-11" open median between the Eastbound and Westbound bridges available for widening. For the purposes of this study, this future widening will be referred to as the "Original Widening." The Original Widening was to carry a roadway consisting of a 10' inside shoulder, one 12' managed lane, and a 12' outside shoulder on the Eastbound and Westbound bridges. Recently, as part of the SR 400(I-4) Project Development and Environment (PD&E) Study, multiple alternatives for providing more than one managed lane in each direction are being investigated:

- Alternative 1: Provide a 6' inside shoulder, two 12' managed lanes, and a 10' outside shoulder via an interior bridge deck widening.
- Alternative 2: Provide a separate bridge in the median carrying three managed lanes with a reversible lane located in the center of the section.

The investigation of Alternative 1 is presented in Sections 2 and 3 of this report and the investigation for Alternative 2 is presented in Section 4 of this report.

The Alternative 1 Widening requires several changes to the original widening design. Firstly, the beam layout will need to be revised to support the increase in the roadway width from 36 feet to 42 feet to add a second managed lane. This will require larger beam spacing and an extra beam line in some spans. Also, the Florida Bulb-T 78 beams selected in original widening will be replaced by current Florida I-78 beams. The result is an estimated additional 4,310 linear feet of Florida I-78 beams required to carry the proposed widening over the original widening configuration. Furthermore, a 6 feet increase in the widening width will also require wider end bents and pier caps.

Based on our preliminary investigation, the existing River Piers appear to have adequate foundation capacity as installed to handle the proposed widening without modification to the pile supported foundations. The not-yet-constructed pier caps and columns at these piers will likely require additional reinforcing than what was anticipated in the original widening design as well as revised connection details to the existing foundations to assure safe transfer of loads. However, based on the relatively small level of increased load demand from the proposed widening, it will be feasible to develop constructible details in the final design phase.

None of the “Ultimate” Land Pier foundations, except for Pier 5 WB foundation, were constructed during the original construction. Due to the increase in the ultimate bridge width, it is expected that these piers will experience higher loads than it was previously anticipated. However, the new design will accommodate the load increase in these future ultimate land piers. Additionally, due to a shared pier cap between the existing and ultimate land piers, the existing land piers will see higher loads. Therefore, these existing footings will require modification such as adding a row of piles and extending the footing. As for the existing land pier 5 WB, the “Ultimate” footing has already been installed at this pier location due to its proximity to the river. Analysis shows that the proposed widening will generate a 192% increase in demand on the existing “Ultimate” footing. Unlike the river piers where combined footings were used between WB and EB bridges to support ultimate widening, at land pier 5 WB, the existing footing is an isolated footing located under WB bridge only. Therefore, in order to accommodate the increased demand on this footing, the footing will require major strengthening/reconstruction.

Pier 2 WB was analyzed due to its skewed orientation and adjacent span configurations. Also, its location in the median of US-17/92 was taken into consideration since modifications to the foundation elements could impact traffic on US-17/92. The analysis shows the as-built foundations are adequate and the proposed foundations can be installed with minimal impacts to traffic.

Pier 12 EB was analyzed due to its skewed orientation and larger levels of loading on the pier relative to other piers. The analysis shows that the as-built foundation is adequate.

End Bent 21, located at the North end of the bridges, is located close to the Lake Monroe Outlet Midden. However, since the bridge components are within the Right-of-Way of I-4, modification to this End Bent is deemed feasible. The proposed modifications will involve four commonly-used steps to widen an existing end bent: (1) driving one additional pile to the interior of the bridge, (2) extending the cap and backwall approximately six feet to the interior of bridge, (3) reconstruction of beam seats, and (4) adding a cheekwall to the interior of the end bent. End Bent 1 will require similar modification. Minimal additional earthwork will be required since a wrap-around MSE wall is used to provide soil retention around the existing end bents.

Additionally, prior to driving the additional pile at the end bents, the existing MSE wall straps will need to be located using vacuum excavation.

In addition to the widening Alternative 1, a separate analysis was carried out to determine the feasibility of Alternative 2 consisting of one managed lane in each direction with a reversible center managed lane, carried on a separate superstructure. The most viable solution for this configuration consists of constructing straddle piers spanning between existing pier footings at river pier locations. Furthermore, entirely new end bents need to be constructed at the North and South ends of the bridge. Due to the existing MSE walls in these locations, the potential for conflicts between end bent piles and existing MSE wall straps need to be investigated. For land pier locations, new multi-column piers can be constructed in the median to carry the proposed bridge section. According to As-Built plans, old piles and foundations at Pier 2 may still be intact and need to be field verified before carrying out substructure design at that location. Alternative 2 also presents the possibility of dealing with construction during design and record high water levels, which places the existing river pier footings underwater. Vessel collision also needs to be addressed to assure new collapse mechanisms do not present themselves due to the linking of the river pier footings. Finally, the overall construction cost of this alternative has been estimated to be similar to Alternative 1. However, the widening Alternative 1 provides more roadway usage per dollar spent.

2. Methodology

2.1. Assumptions

Based on limited availability of design calculations and information on the as-built plans depicting the details of original widening, several assumptions were made to perform our preliminary investigation:

- Simple spans
- Future ITS component loads assumed negligible
- Full width of deck available for the placement live loads
- Live load and braking loads generated via RC-Pier are considered conservative
- Widening shown in the plans in Appendix A-3 is included in the Factored Design Loads and subsequent Nominal Bearing Resistance values shown in the Pile Data Tables found in the plans in Appendix A-2

2.2. Establishment of Design Controls

Key locations along the bridge were analyzed. These locations were chosen based either on their likelihood to be critical design components or their uniqueness from other typical components. The selected locations are as follows:

- Superstructure: Span 1 WB, Span 2 WB, Span 4 WB, Span 5 WB, Span 11 EB, Span 12 EB, Span 20 EB
- Substructure: Pier 2 WB, Pier 5 WB, Pier 12 EB, End Bent 21 EB

The adequacy of each component is based on not exceeding pile loads for which the installed foundations were originally designed. This implies that if those pile loads are not exceeded, there should not be any issue with strength or serviceability demands. Due to the environmentally sensitive nature of the pier footings located within the St. John's River, modification to said footings is not considered to be feasible. Other components, such as pier columns and caps, that have not yet been constructed, can therefore be designed as necessary to accommodate the higher loads.

2.3. Input Calculations & Software

Conspan was used to carry out analysis of the superstructure. The beams were designed using the program's Auto-Design feature to determine whether the superstructure for the proposed widening could be reasonably designed and detailed. By default, Conspan computes live load distribution factors via LFD formulas. These factors can be conservative or unconservative depending on the superstructure cross-section. When the manually computed live load distribution factors per LRFD were compared with the Conspan computed live load distribution factors per LFD, a close correlation was observed. Therefore, the distribution factors were allowed to be computed internally within Conspan for expediency.

The substructure elements (both piers and end bents) were analyzed via RC-Pier. Dead loads were input from Conspan analyses while live, braking, wind, and vessel collision loads were generated via the program's Auto-Generation feature.

3. Results

3.1. Superstructure

The table below summarizes which spans will likely need an additional beam to carry the proposed widening along with estimated beam lengths:

Span (As-Built)	Span Length* (ft.)	No. Spans	No. Girders for Original Widening	Spacing of Girders for Original Widening (ft.)	No. Girders for Prop. Widening	Spacing of Girders for Prop. Widening (ft.)	Add'l No. of Girders Required	Add'l Girder Length Required (ft)
Typical Spans	134.46	18	3	12.0	4	10.5	18	2,420
1EB & 1WB	90.00	2	3	12.0	4	10.5	2	180
2EB & 2 WB	118.00	2	4	9.0	4	10.5	0	0
3WB	152.41	1	3	12.0	4	10.5	1	152
4WB-6WB	129.08	3	3	12.0	4	10.5	3	387
11EB & 13WB	150.93	2	4	9.0	4	10.5	0	0
13EB &11WB	91.41	2	3	12.0	4	10.5	2	183
12EB & 12WB	142.33	2	4	9.0	4	10.5	0	0
3EB	83.59	1	3	12.0	4	10.5	1	84
4EB - 10EB	129.08	7	3	12.0	4	10.5	7	904
Total Additional Beam Length (feet)								**4,310**

*Average span length assumed for spans with variable beam lengths

Table 3.1 – Summary of Additional Girders

3.2. Substructure

3.2.1. Piers

The following table summarizes the pile reactions computed for the original and proposed widening design.

Table 3.2 – Summary of Pier Pile Reactions

Pier	Pier Type	Footing	As-Built ϕ-Factor	As-Built Max. Factored Load (kip)	As-Built Max. Factored Load (tons)	As-Built Ultimate Bearing Capacity[1] (tons)	Proposed Design Max. Factored Load (kip)	Proposed Design Max. Factored Load (tons)	Proposed Design Ultimate Bearing Capacity (tons)	Difference[3] (%)
2WB[2]	Land	1	0.65	570	285	438	500	250	385	-12%
		2	0.65	570	285	438	635	318	489	12%
		3	0.65	570	285	438	334	167	257	-41%
5 WB	Land	1	0.65	486	243	340	379	190	292	-14%
		2	0.65	486	243	340	795	398	612	80%
		3	0.65	486	243	340	933	467	718	111%
12 EB	River	1	0.65	340	170	263	242	121	223	-15%

Notes:

1. Ultimate Bearing Capacity taken as minimum As-Built value (sheet C-78A of As-Built plans) where applicable
2. Pile loads for Pier 2 WB, Footing 3 assume a 16'x16' footing with 9 piles
3. Differences > 0% indicate an increase in load, Differences <0% indicate a decrease in load

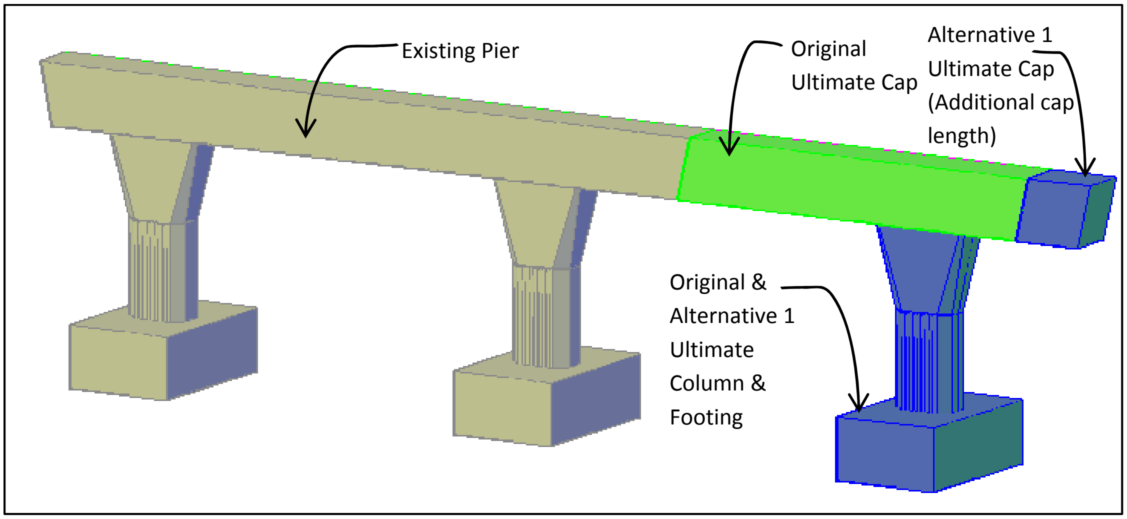

Fig. 3.1 – Typical Land Pier

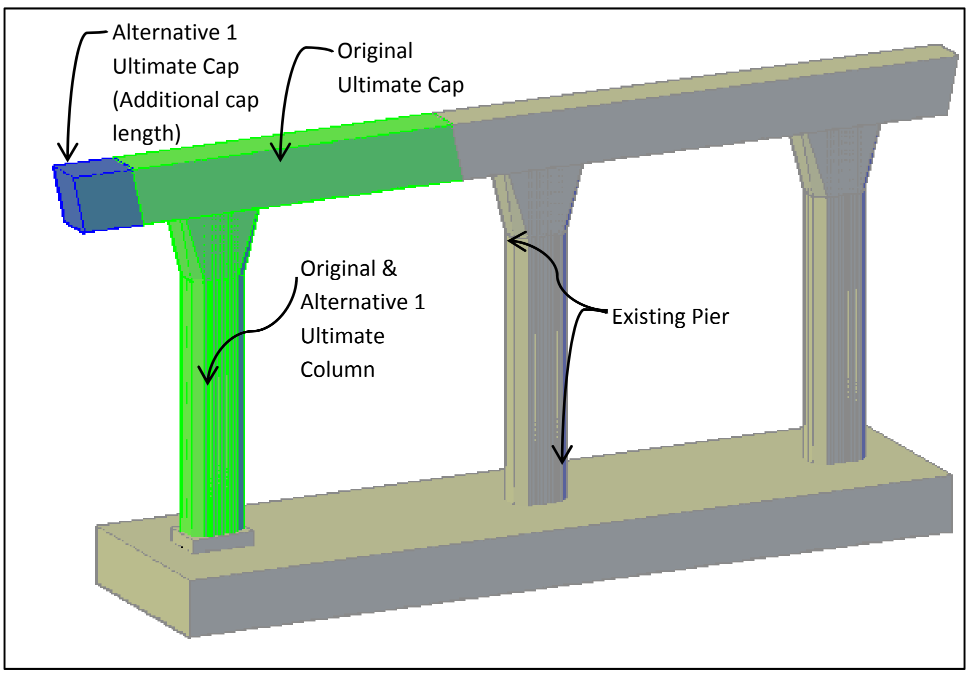

Fig. 3.2 – Typical River Pier

3.2.2. End Bents

Both End Bents 1 and 21 are constructed to accommodate the original widening with an MSE wall spanning the median between the eastbound and westbound bridge end bents. It is expected that the proposed widening will require one additional pile at each bridge end bent interior location. Since an MSE wall is already in place between the existing end bents, the location of the soil reinforcement straps will need to be probed and located before the driving of the additional piles. No adverse impacts are expected to the Lake Monroe Outlet Midden during the widening of the existing End Bent 21 which is currently located within the limits of the midden.

Fig. 3.3 – Existing End Bents

It is found that the pile reactions acting on the existing piles at the End Bents for the proposed widening will be lower than the pile reactions anticipated for the original widening based on redistribution of girder reactions over increased number of piles.

Pier	Pier Type	Footing	As-Built ϕ-Factor	As-Built Max. Factored Load		As-Built Ultimate Bearing Capacity[1]	Proposed Design Max. Factored Load		Proposed Design Ultimate Bearing Capacity	Difference[3]
				(kip)	(tons)	(tons)	(kip)	(tons)	(tons)	(%)
21 EB	End Bent	1	0.65	534	267	411	421	210	324	-21%

Notes:

1. Ultimate Bearing Capacity taken as minimum As-Built value (sheet C-78A of As-Built plans) where applicable
2. Differences > 0% indicate an increase in load, Differences <0% indicate a decrease in load

Table 3.3 – Summary of Pier Pile Reactions at End Bents 1 and 21

4. Alternative 2: 3 Managed Lanes

An alternative ultimate bridge widening carrying 3 managed lanes consisting of 2 uni-directional lanes and 1 reversible lane was also investigated. This widening would need to be carried on a separate superstructure located in the median area between the Eastbound and Westbound bridges. Several bridge options were investigated to carry this widening alternative over the St. John's River with regard to the environmentally sensitive nature of the location. Below is a brief summary of the most feasible option:

- Straddle Pier Option
  - Requires straddle piers to be constructed to span river between existing Eastbound and Westbound foundations.
  - Construction will be required over open water and below the Design High Water elevation of 8.11 feet and Historical High Water Elevation of Record of 12.33 feet.
  - Vessel impact would need to be accommodated in straddle bent design and construction.
  - Cost is similar to widening; however more risk for cost escalations is present due to design and detailing requirements for straddle piers, such as post-tensioning, construction methods in water, etc. and compensation for environmental impacts.

The proceeding section presents an analysis of this option.

4.1 Straddle Pier Analysis

For the purposes of analyzing the straddle pier alternative, only Pier 12 was considered critical due to the larger cap span resulting from the support skew angle combined with the taller pier height. The existing piers and proposed straddle piers were analyzed in separate RC-Pier models. The superstructure loads for the existing spans were computed via the Auto-Generation feature of RC-Pier. The superstructure permanent loads for the proposed span were computed via Conspan. Live Loads, Wind Loads, and longitudinal force effects were computed via the Auto-Generation feature of RC-Pier. The reactions at the bases of the columns were enveloped and then applied to the footing. Pile reactions are then computed based on a rigid footing assumption. A summary of the findings for this analysis is presented below.

Pier	Pier Type	Footing	As-Built ϕ-Factor	As-Built Max. Factored Load (kip)	As-Built Max. Factored Load (tons)	As-Built Ultimate Bearing Capacity[1] (tons)	Proposed Design Max. Factored Load (kip)	Proposed Design Max. Factored Load (tons)	Proposed Design Ultimate Bearing Capacity (tons)	Difference[3] (%)
12 EB	River	1	0.65	340	170	263	247	124	227	-14%

Notes:

1. Ultimate Bearing Capacity taken as minimum As-Built value (sheet C-78A of As-Built plans) where applicable

Table 4.1 – Summary of Pier Pile Reactions for Straddle Pier Alternative

Pier	Straddle Span[1] (ft)
6	88.583
7	88.583
8	88.583
9	88.583
10	88.583
11	88.583
12	91.708
13	91.708
14	88.583

Notes:

1. Straddle spans are computed CL column-CL column

Table 4.2 – Summary of Straddle Pier Span Lengths

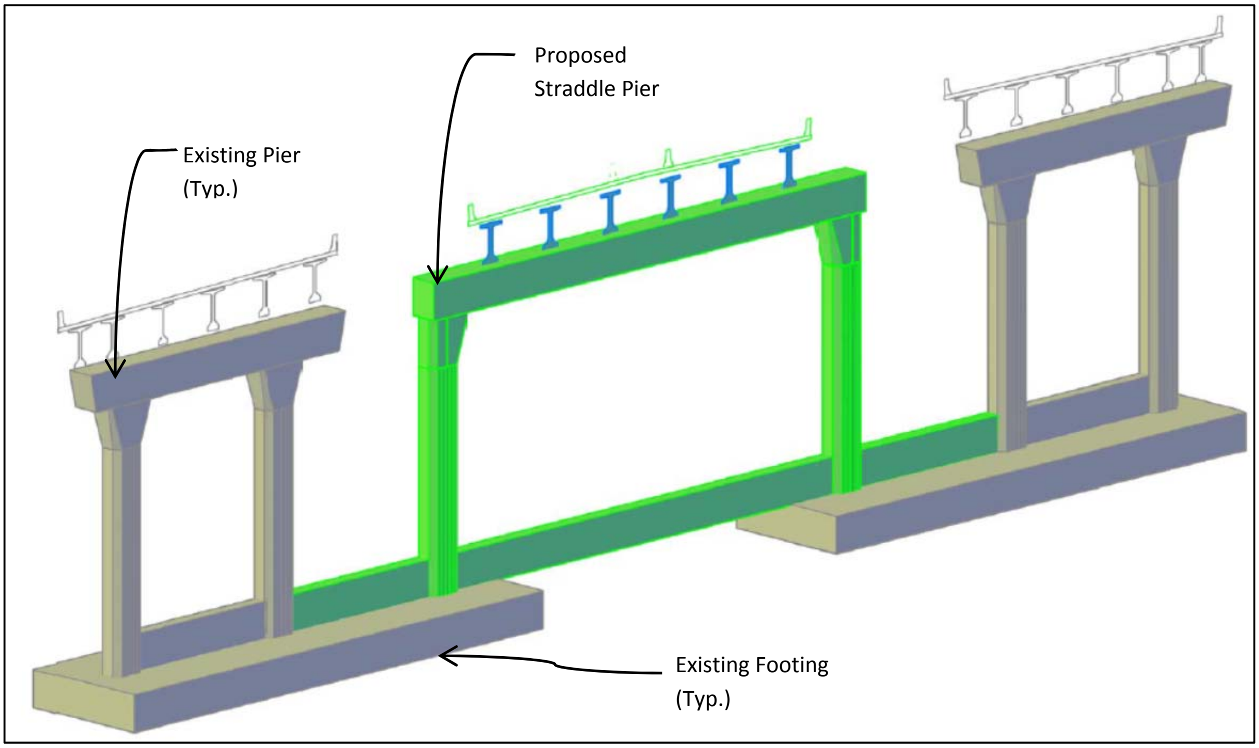

Fig. 5.1 – Typical Straddle Pier

In summary, the straddle pier alternative is expected to place roughly 2% more demand on the foundation piles compared to the widening option. However, the demand on the footings from the straddle pier is the threshold for necessitating modifications to the river pier footings. At the land pier locations, twin-column piers similar to the existing pier can be constructed within the median between the Eastbound and Westbound bridges. It is important to note that piles for the original bridge may still be in place near the centerline of US 17-92 and Pier 2 and, therefore, need to be located prior to development of a concept pier for this location.

New end bents need to be constructed for this alternative as well. The potential for pile conflicts with existing MSE wall straps is greatly increased with this option. The location of said straps will need to be investigated to confirm the feasibility of installing end bent piles near the center line of SR 400 (I-4). Otherwise, the existing MSE walls within the median area will need to be removed and reconstructed.

4.2 Vessel Collision

The preceding analysis has not included provisions for vessel collision. It is expected that axial demand on foundations should not increase substantially and lateral loads should be manageable due to the linking of the separate foundations via the straddle pier but effects on other structural elements may worsen. Therefore, a more detailed study on the vessel collision ramifications on constructing the straddle piers is recommended. Appendix C-4 contains a brief description of recommended vessel collision load cases.

5. Cost Estimation

For the purpose of comparing costs between the primary alternatives, a BDR-level quantity and construction cost estimate was carried out. The estimations are based on typical sections presented in Appendix A-1. Please refer to Appendices B-5 and C-5 for support calculations for the Widening and Reversible Lane alternatives, respectively. It should be noted that the cost presented for Alternative 2 does not include the cost of the moveable barrier system, or any related systems, or potential MSE wall work which may be required to install new abutments at the ends of the bridge. A summary of construction costs is presented below.

Alternative	Pier Type	No. Lanes Provided	Bridge Deck Area (SF)	Estimated Construction Cost ($ Million)	Estimated Cost per Square Foot ($/SF)	Estimated Cost per Lane ($M/Lane)
Widening	Single Column Widening	4	215,565	19.4	90	4.85
Reversible Lanes with Straddle Piers[1]	Straddle	3	190,108	17.7	93	5.90

Notes:

1. Cost estimate does not include moveable barrier system or MSE wall work which may be required.

Table 5.1 – Cost Summary

Based on the results of these analyses, the reversible lane alternative supported by straddle piers over the St. Johns River could provide a structurally feasible solution. Even though preliminary cost estimates are lower than the widening option, the potential for structural cost escalation is greater with the reversible alternative due to more unknown conditions at the end bents and Pier 2. Furthermore, the straddle piers will require significantly more time and effort in design and construction phases than the corresponding piers for the widening alternative.