Kansas City Downtown Streetcar Transit System
Condition and Load Rating Assessment of Structures

An important part of the Advanced Conceptual Engineering (ACE) phase of the streetcar project is to perform a more in-depth investigation of the three bridges on the Main Street alignment to accommodate streetcars. These three bridges include:

1. Main Street Bridge over KC Terminal Railway – City Structure
2. Main Street Bridge over I-670 – MoDOT structure
3. Delaware Street Bridge over I-35/I-70 – MoDOT structure

Our first task was to obtain and review as-built drawings, rehabilitation plans, bridge inspection reports and load rating calculations for all of the bridges. After reviewing the existing data, a general condition inspection of the bridges was performed in February of 2012. While some deterioration has occurred to all of the bridges, the condition inspections did not identify any structural issues that would reduce the current load ratings. For the most part, we agreed with the NBI condition ratings given for each of the bridges in the inspection reports.

Our next task was to perform load rating calculations for the streetcar vehicles. The calculations were not performed on all spans, girders and units of each bridge. Given the time and budget constraints, our intent was to use engineering judgment to identify those elements that would likely control the load rating of the structures. A complete analysis of the bridges should be performed in a future phase.

Load Rating Design Assumptions:

1. Streetcar loading is more similar to the AASHTO HS truck loading than to the Cooper E80 railroad loading cited in the AREMA code. Therefore, the 2002 17th Edition of the AASHTO Standard Specifications for Highway Bridges was used to review each structure.
2. The Load Factor Design method was used to rate the bridges, except for the Main Street Bridge over I-670. Allowable Stress Design was used for the rating of this bridge.
3. Dead Load – Existing dead load plus an additional superimposed dead load due to the 3.5-inch infill pavement and rail in elastomeric grout. The minimum unit weight of infill pavement shall be the weight of concrete, 150 lb. per cu ft. The weight of rail shall be 112 lb. tram rail (112 lb. per yd.)
4. Live Load:
    a. United Streetcar 100 – 45 Tons
    b. Ameritram Streetcar – 50 Tons
    c. Cincinnati Streetcar – 55 Tons

    The total live load is based on vehicle weight plus maximum passenger crush load except for the Cincinnati Streetcar which is for the AW3 load condition.
5. A Dynamic Load Allowance of 30% maximum, in accordance with the AASHTO Standard Specifications for Highway Bridges, was applied to the streetcar vehicles. This should be a conservative allowance for impact due to the low speeds anticipated for the streetcars.

Load Rating Results:

Positive moment, negative moment and shear were checked at various superstructure locations. No substructure investigations were completed. Below is a summary of the locations investigated and corresponding load rating factors.

Main Street Bridge over KC Terminal Railway:

Unit 1N of the southbound roadway, a four span voided slab structure, was investigated for the designated loading. The calculated inventory rating factors for the Cincinnati Streetcar are 1.02 for flexure, with positive moment in Span 1N controlling, and 1.46 for shear at Bent 4N. The rating factors for the Ameritram Streetcar are 1.23 for flexure and 1.38 for shear.

The 2012 AASHTO LRFD Bridge Design Specifications states in Article 5.14.4.1 that slabs and slab bridges designed for moment in conformance with Article 4.6.2.3 may be considered satisfactory for shear. For the purpose of this Article, cast-in-place voided slab bridges may be considered slab bridges.

The controlling location for shear in slabs is defined in Article 5.13.3.6.1. The more critical of the following conditions shall govern:

1. One-way action, with a critical section extending in a plane across the entire width and located at a distance taken as specified in Article 5.8.3.2 (d_v from the face of the support).
2. Where the slab thickness is not constant, critical sections located at a distance not closer than $0.5d_v$ from the face of any change in the slab thickness.

Based on the above design recommendations from AASHTO, the shear capacity in the voids does not need to be evaluated and the shear capacity can be considered sufficient based on the design check performed at the bent. The structure has performed adequately for many years and no shear cracks have been found during inspections.

Main Street Bridge over I-670:

The Main Street Bridge is a two span voided slab structure. The calculated inventory rating factor for the Cincinnati Streetcar is 1.30 for flexure and 1.25 for shear near Bent 2. The rating factors for the Ameritram Streetcar are 1.54 for flexure and 1.25 for shear.

Delaware Bridge over I-35/70:

The Delaware Bridge is a six span prestressed I-girder bridge. The controlling location for flexure was in the positive moment region of Span 6. The calculated inventory rating factor for the Cincinnati Streetcar is 1.22 and 1.35 for the Ameritram Streetcar.

The controlling location for shear was in Span 2 near Bent 3 with a calculated inventory rating factor of 1.13 for the Cincinnati Streetcar and 1.11 for the Ameritram Streetcar.

(Note: The designer used f'c = 6,000 psi for the girders. It is not clear looking at the drawings if this is correct for all spans. However, the Virtis file provided by MoDOT used f'c = 6,000 psi.)

Condition Assessments:

Main Street Bridge over KC Terminal Railway:

This bridge is a 19 span, 5 unit structure composed of prestressed concrete I-girders and reinforced concrete voided slab spans. The structure was built in 1980 and a major rehabilitation was performed in 2001. The bridge has an inventory rating of 31 tons and a sufficiency rating of 77.1%.

The overall condition of the bridge is good. The 2010 bridge condition ratings are:

- Deck 7
- Superstructure 7
- Substructure 6

We found some minor deterioration during our inspection, but believe the ratings above are appropriate.

Below are photos of the Unit 1 voided slab spans. The voided slabs appear in good condition with very little deterioration shown. Some spalling and corrosion was noted on a few substructure elements in the voided slab spans under the expansion joints. However, there was nothing found that would affect the load rating capacity.

West Face of Voided Slab Spans

East Column of Bent 2N

Units 2 – 5 are prestressed concrete girders and all elements of the superstructure and substructure were in very good condition. No significant issues were noted.

West Face of Prestressed Girder Spans

The concrete deck over all units is also in good condition. Some minor transverse cracking in the deck was noticed over the piers and they had been sealed.

Strip Seal Joint

Repair work will be needed to the expansion joints. Some of the strip seal joints have large spalls behind the armoring and have become loose. We expect these can be patched and repaired. A good, durable detail will be required for the streetcar rails passing over these joints.

Main Street over I-670:

This bridge is a two span voided slab structure built in 1963. New sidewalks and an epoxy polymer overlay were added in 2007. The 2011 SI&A sheet has the following condition ratings:

- Deck 8
- Superstructure 8
- Substructure 6

The deck and superstructure condition ratings seem high for a structure of this age and given there is some deterioration along the lower edges of the slab. The substructure rating is appropriate, but further deterioration of the columns and abutment walls will soon reduce this rating. The structure has an inventory rating of 30 tons. The sufficiency rating is 80.0%.

Spalls along West Face

The majority of the voided slabs appear in very good condition. There are numerous spalls and exposed reinforcing steel along the west edge of the slab. However, there is no water saturation or staining visible under the deck. The epoxy overlay is in excellent condition.

There is significant spalling and exposed reinforcing steel on all of the columns at the intermediate bent. Under most of the bearings at the abutments there is cracking and corrosion staining. There are also some large spalls in the abutment walls.

West Face of Bridge

The substructure deterioration does not currently affect the load rating capacity of the bridge. However, in the future significant substructure rehabilitation will be required to keep the bridge in service.

Estimated remaining service life of the structure is 10 – 15 years if no additional work is done to the bridge. With a significant rehabilitation 20 – 25 years is estimated remaining service life.

Large Spall in South Abutment

Delaware Bridge over I-35/70

This bridge is a 6 span prestressed concrete girder structure built in 1985. The current inventory rating is 46 tons and the sufficiency rating is 90.4%. The 2011 SI&A sheet has the following condition ratings:

- Deck 8
- Superstructure 7
- Substructure 8

We believe the condition ratings above are appropriate. Some minor deck cracking was noticed, especially near the south end bent, but overall the concrete deck is in good condition. The prestressed girders and substructure elements are also in good condition.

West Face of Bridge

The only significant issue we found was the settlement of the approach slabs and deterioration of the joint between the end bents and the approach slabs. The approach slab joints at the bridge have been a constant maintenance item. Significant settlement has occurred under the approach slabs and the sidewalks. At

the south end bent water is getting behind the abutment and significant staining of the concrete is occurring on the front face of the diaphragm and bent cap.

The bridge is fairly long with integral abutments and a 24 degree skew. The temperature movement combined with the skewed abutments may be contributing to the settlement and deterioration of the approach slab joints. These joints need to be stabilized for the streetcar rails.

South End Bent

Approach Slab Joint at South End Bent

We recommend replacement of the bridge approach slabs and repairs be made to the embankment behind the abutment and wings. The approach slabs need to be dowelled into the end bents to prevent the joints from separating.

Settlement of Sidewalks at Approach Slab