REPORT:
STATUS OF FRACTURE CRITICAL TRUSS BRIDGES

King County Department of Transportation
Roads Services Division

June 2013

Introduction

On Thursday, May 23, the Skagit River Bridge on Interstate 5 partially collapsed after being damaged by an over-sized truck, taking with it two vehicles and their passengers. The bridge was identified as being a "fracture critical" truss bridge, meaning that the truss structure of the bridge did not contain any redundancies that would keep the bridge standing if a single critical member failed. The incident rightfully heightened awareness of these types of structures in the region.

King County Executive Dow Constantine directed the Department of Transportation's Road Services Division (RSD) to identify and report on the status of fracture critical truss bridges in unincorporated King County.

This report is in response to the Executive's request and contains the following information:

- Overview of Road Services Bridge Program
- Truss Bridge Inventory and Status by Type
- Safety/Precaution Recommendations for the Stossel Bridge
- Additional Resources and Conclusion

Overview of Road Services Bridge Program

King County owns and manages an inventory of 180 vehicular, county-owned bridges throughout the unincorporated county as part of an organized bridge program. Since 1971, this program has proactively inspected, cataloged and rated the condition of the bridges, and made recommendations for repair and replacement of each bridge at least once every two years.

The rating system used for bridge conditions is known as Sufficiency Rating (SR). The average SR of the entire inventory provides a comparative look at the health of the inventory from one year to the next. The SR is a score calculated for each bridge using a multitude of ratings the inspector assigns to the bridge based on the condition of the various components of the bridge. The geometric layout, safety, traffic volume, and the length of the detour route in the event of a closure are also factored into the SR. The SR ranges from zero to 100, with zero being the worst rating and 100 being the best rating.

Common repairs include replacing cracked concrete, rotted timber, corroded steel and/or otherwise deteriorated components of bridges. Detailed repair instructions are provided to maintenance crews as part of the bridge priority maintenance program for scheduling and implementation. Over the past ten years, many bridges were repaired or rehabilitated, and 32 were replaced.

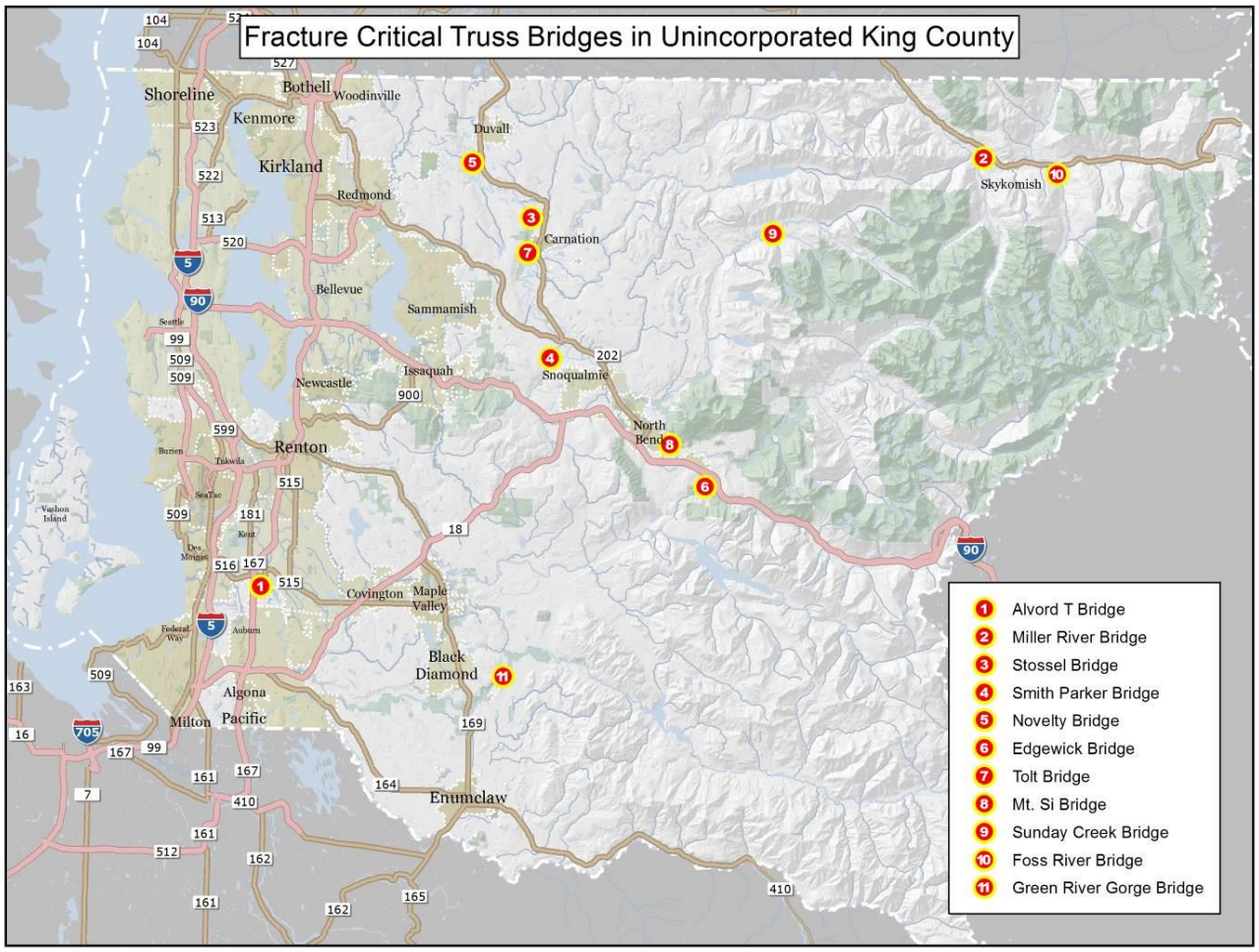
Cover photo: The Edgewick Bridge near North Bend was built in 2004 and has been regularly inspected by King County engineers since.

The bridge program also takes a proactive approach to retrofitting bridges for safety purposes. In 2008, the bridge program concluded a 14 year seismic retrofit, improving 115 bridges at a cost of $22 million. These retrofits were designed to prevent bridges from collapsing during a major earthquake and to leave any earthquake-damaged bridges in a state where they could be repaired.

Truss Bridge Inventory and Status by Type

Of the 180 bridges in King County's inventory, 11 of the bridges are fracture critical truss bridges. Of those 11, 8 are through truss bridges similar to that of the Skagit River Bridge, two are pony truss bridges, and one is a deck truss bridge.

The average age of the 11 fracture critical truss bridges is 42 years, and the average Sufficiency Rating is 63. The following map identifies the approximate locations of each fracture critical truss bridge in the King County inventory.



Through Truss Bridge Inventory

Of the 11 truss bridges, eight are through truss bridges, meaning traffic drives through a box-like structure with bridge truss members on both sides of the roadway as well as overhead. These

truss bridges are of the same design as the I-5/Skagit River Bridge and have both horizontal and vertical clearance restrictions.

Of those eight through truss bridges, five are new (built since 1998) and constructed to modern standards. Those standards include having vertical clearances ranging from the minimum (per federal standards) of 16 feet 6 inches up to 20 feet. The bridge decks have ample width, meeting today's standards, with 11-foot wide traffic lanes and 4- to 8-foot wide shoulders depending upon the roadway classification and the amount of traffic served. In addition, these trusses have stronger truss members, more robust rail systems and were designed to meet current codes for seismic stability.

Two of the eight though truss bridges are more than 90 years old and have vertical and horizontal clearances below current standards. One of these bridges, the Alvord T Bridge, is closing on June 5, 2013. The other bridge, the Miller River Bridge, is already closed.

The eighth bridge in the through truss bridge category is the Stossel Bridge, which has several similarities to the I-5/Skagit River Bridge. A separate discussion on the Stossel Bridge is included later in this report.

Through Truss Bridge Inventory Details

Bridge Name	Year Built / Rebuilt	Bridge Length	Total Lanes	Vertical Clearance	Average Daily Traffic	Avg. Daily Truck Traffic	Curb to Curb Width	Speed Limit	Last Inspected	Sufficiency Rating
THROUGH TRUSSES										
TOLT	2008	962'	2	20'-0"	2,950	148	40'-0"	35	3/25/2013	91.06
MT. SI	2008	365'	2	17'-2"	3,000	150	40'-0"	35	10/17/2012	75.00
EDGEWICK	2004	213'	2	17'-0"	938	38	34'-0"	35	5/9/2013	81.25
NOVELTY	2000	623'	2	16'-9"	9,580	479	39'-4"	35	5/15/2013	87.35
SMITH PARKER	1998	125'	2	16'-6"	1,375	41	34'-0"	25	4/24/2013	94.81
STOSSEL	1951	330'	2	15'-0"	1,520	76	24'-0"	35	4/23/2013	43.24
MILLER RIVER (Closed)	1922	228'	2	13'-6"	100	5	16'-6"	35	8/14/2012	16.23
ALVORD "T" (Closing June)	1914/1970	275'	2	13'-8"	2,580	284	18'-6"	25	5/20/2013	4.00

End portal of the Stossel Bridge over the Snoqualmie River near Carnation.

Pony Truss Bridge Inventory

Two truss bridges in the county inventory are pony truss bridges. The trusses on these bridges are located on each side of the roadway, and therefore there are horizontal restrictions, but no vertical restrictions. One of these bridges, the Sunday Creek Bridge, was built in 2010 and meets modern requirements for width, robust member strength and seismic stability. The older of the two, the Foss River Bridge, is very low risk since it has no overhead restrictions, a relatively low speed limit and low traffic volumes.

Pony Truss Bridge Inventory Details

Bridge Name	Year Built / Rebuilt	Bridge Length	Total Lanes	Vertical Clearance	Average Daily Traffic	Avg. Daily Truck Traffic	Curb to Curb Width	Speed Limit	Last Inspected	Sufficiency Rating
PONY TRUSSES										
SUNDAY CREEK	2010	105'	1	unlimited	54	3	18'-0"	25	6/12/2012	78.91
FOSS RIVER	1951	120'	1	unlimited	35	2	14'-6"	25	6/14/2012	49.14

The Sunday Creek Bridge from 2010 is a pony truss bridge without height restrictions because of its open design.

Deck Truss Bridge Inventory

One King County truss bridge is a deck truss, meaning the truss is located under the roadway. These truss bridges have neither horizontal nor vertical clearance limitations. The Green River Gorge Bridge was recently rebuilt, and has virtually no risk of collapsing from vehicle damage since all truss members are below the roadway. There is no roadway or navigable waterway below the bridge that could result in contact with the truss.

Deck Truss Bridge Inventory Details

Bridge Name	Year Built / Rebuilt	Bridge Length	Total Lanes	Vertical Clearance	Average Daily Traffic	Avg. Daily Truck Traffic	Curb to Curb Width	Speed Limit	Last Inspected	Sufficiency Rating
DECK TRUSSES										
GREEN RIVER GORGE	1914/1991	437'	1	unlimited	850	43	14'-0"	signal	5/13/2013	72.00

The Green River Gorge Bridge is King County DOT's only deck truss bridge.

Notable findings and Planned Work

As part of the bridge program's routine inspections, a detailed analysis of each bridge is documented. Some of the typical findings from these inspections are noted below. These typical findings are long-term maintenance issues that are common among the entire bridge inventory and do not require immediate action. These findings are prioritized and a schedule is developed for addressing the top priorities on an annual basis.

- Stossel Bridge
    a. Scheduled to be painted in 2014
    b. New high load hits on 6 out of 7 overhead members (discussed further below)
    c. Corrosion on truss floor beams
    d. Widespread paint failure and debris accumulation
- Sunday Creek Bridge
    a. Built in 2010
    b. No concerns
- Smith Parker Bridge
    a. Built in 1998

    b. Minor isolated paint failures
    c. Minor expansion joint problem
- Novelty Bridge
    a. Built in 2000
    b. Minor isolated paint failures
    c. Deck joints leaking
- Green River Gorge Bridge
    a. Originally built in 1914 and rehabilitated in 1990
    b. Last painted in 2001
    c. Seismic retrofit in 2008
    d. Frequent drain clogging
    e. Minor areas of rust
- Tolt Bridge
    a. Built in 2008
    b. No concerns
- Mt. Si Bridge
    a. Built in 2008
    b. Transverse white leaching cracks on deck
- Foss River Bridge
    a. Timber deck worn
    b. Several rotten timber stringers- some stringers were replaced in 1994, 1997 and 2012
    c. Minor corrosion and paint failures – last painted in 1994
    d. Scour hole on intermediate pier forming
- Edgewick Bridge
    a. Built in 2004
    b. Minor expansion joint problem
- Alvord T Bridge (bridge is closing June 5, 2013)
- Miller River Bridge (bridge is currently closed)

Safety/Precaution Recommendations for the Stossel Bridge

As mentioned earlier, this two-lane bridge is the oldest fracture critical through truss bridge in the King County inventory that is open to the public. It is also the bridge closest in type and era to the I-5/Skagit River Bridge. The Stossel Bridge, built in 1951, carries Carnation Farm Road over the Snoqualmie River near the town of Carnation, and has King County Landmark status.

In brief, similarities with the I-5/Skagit River Bridge include:

- Type, through truss
- Fracture critical structure
- Same era (1950s)

- Vertical and horizontal clearances below today's standards, making it Functionally Obsolete
- High speeds possible on approach roadways
- Truck traffic present
- History of high load hits

In more detail, the Stossel Bridge has a vertical clearance of 15 feet, which is below the 16 feet 6 inches of clearance required by today's standards. Its roadway width of 12 feet per lane, including shoulders, is narrower than today's standards requiring anywhere from 14 feet to 20 feet per lane depending on the population growth assumptions for this rural collector route.

The approach roadway is posted at 35 MPH and the average daily traffic is 1,520 vehicles. About 5 percent or 75 vehicles a day are trucks. The bridge is not load restricted, but has a load rating factor for a two-axle truck of 1.05, meaning the bridge has only 5 percent load capacity above the minimum required to carry legal loads. This capacity limit restricts the ability of the bridge to be retrofitted with traffic barriers due to their significant weight. For example, if the bridge were modified with a stronger rail system or stronger truss members, the bridge would likely be reduced to a single lane because the added weight and geometrical restrictions of the additional structure would not allow two lanes of traffic.

The bridge has a Sufficiency Rating of 43.24 and was last inspected April 23, 2013. A fracture critical inspection was performed and an Under Bridge Inspection Truck (UBIT) was used to reach all areas of the bridge with attention to fracture critical members.

The Stossel Bridge has a through truss design similar to the span on the Skagit River Bridge.

High Load Hits and Vulnerability

Given the low clearance, the Stossel Bridge is subject to vehicular damage. The bridge was damaged by a high load hit on two overhead members in May 2005. Overhead portals were bent several inches out of plane. Damage was limited to the overhead members only. Bridge mechanics repaired the members using heat straightening in July 2005. Heat straightening is a widely-accepted practice that brings bent members back into their original position and utility.

New high load hits were detected again on six of the seven overhead members during the April 23, 2013 fracture critical inspection. Damage was limited to the overhead members. It ranged from minor dents to members that were bent ½ to 2 inches out of plane.

Like all through truss bridges, the end portals – the overhead members at each extreme end of the bridge – are connected to the upper chords of the truss, which are in compression. A substantial force from a high load or wide load hit imposed on either the end portal, the diagonal end posts (the first members encountered at the ends of the truss on the right and left sides of the roadway), or any truss member between the end posts could conceivably buckle the member and cause the bridge to fail.

Given the low clearance and signs of impacts from traffic using the bridge, the immediate measures outlined below will be taken to reduce the likelihood of an oversize vehicle damaging the truss structure.

High load hits, such as this one on the Stossel Bridge, bend members out of place.
Heat straightening realigns the members to their original geometry without compromising strength.

Signage

As part of RSD's recent inspection, engineers evaluated Stossel Bridge to identify features and possible modifications that could be put in place to lessen the bridge's overall risk factor.

Currently, there are no vertical clearance signs posted at the Stossel Bridge. The bridge has a 15-foot clearance at the centerline of the bridge deck, which slightly increases in height at the shoulders. The overhead structure at each end of the bridge is flat, unlike the Skagit River Bridge's elliptical, downward-sloping members above the shoulders that increase the risk of vehicular contact.

Per Revised Code of Washington, the maximum legal vehicle height permitted on public roads

and bridges is 14 feet. The WSDOT Bridge Inspection Manual requires posting signs for vertical bridge clearances less than 15 feet 3 inches, which is more restrictive than federal requirements. WSDOT also states that the posted clearance shall be 3 inches less than the actual clearance. To exceed federal requirements and to remain consistent with WSDOT standards, RSD will add new signs that will state a clearance of 14 feet 9 inches. Four new "Low Clearance" signs will be installed – one on each roadway approaching each end of the bridge and one mounted on each end of the bridge itself. Signs are expected to be in place by June 4.

To further warn over height trucks and discourage them from entering the approach roadways leading to the bridge, signs stating the bridge clearance will also be posted at the major intersections leading up to the approach roadways. Advisory speed limit signs will also be posted at each end of the bridge. Speed humps and other similar devices intended to slow traffic are not recommended in this location due to the arterial (higher volume) nature of the roadway, and potential conflicts with emergency vehicle response times. However, rumble strips or similar measures which signify to drivers the need to slow down, may be appropriate and will be investigated further.

As for horizontal clearances, there is currently one sign in each direction approaching the bridge notifying motorists of a narrow bridge ahead, which is sufficient given the lesser risk of significant damage from a horizontal impact.

Signage will be placed at the portal to the through truss on the Stossel Bridge.

Over Height Warning System

In addition to standard signage, a second method widely used to reduce the possibility of a high load hit on bridges is an over height detection system. This system sends a laser or infrared beam from one side of the road at the entrance to the bridge to a receiver at the same height on the other side. If the beam is interrupted by an over height vehicle, then the driver is warned of the over height condition with flashing lights and/or an audible alarm mounted on a sign.

These systems do not prevent over height trucks from damaging bridges, but do lessen the probability of an incident. For example, the City of Seattle has such a system in place for a low clearance bridge over Lake Washington Boulevard in the Arboretum. Despite this system being in place, the bridge is still hit twice a year on average.

Further investigation on the feasibility of installing this kind of detection and warning system is underway. The estimated cost is $300,000 to $500,000.

Over height warning systems have sensors that activate warnings signs when a vehicle is taller than allowed.

Further Engineering Evaluation

By design, truss members, such as those that make up the Stossel Bridge, have varying loads, both in tension and compression. RSD is planning to perform a structural analysis to determine if certain truss members can be modified to lessen the risk of truss members most vulnerable to impact damage.

Regulating King County Restricted Bridges

In order to inform the public of bridge restrictions, RSD currently uses the county's website, and also manages an "over legal" truck permit process. At the present time, the county web page currently lists six bridges with load and clearance restrictions. This web page is being modified to include the substandard clearances of the Stossel Bridge.

King County does an in-depth review of all over height and over weight vehicle permit applications. If load capacity and clearance issues are discovered, engineers condition the issued permit to restrict the size and/or weight of the vehicle, limit vehicle speed and use of the bridge by other vehicles at the same time, and/or mandate use of spotters.

Conclusion

The King County Department of Transportation Road Services Division maintains an inventory of eight fracture critical through truss bridges similar to the Skagit River bridge, but of those, only the Stossel Bridge is still open and of a similar era. In light of the heightened awareness surrounding the I-5/Skagit River Bridge incident, RSD re-evaluated the Stossel Bridge and will be installing additional signage and exploring truss strengthening as well as the potential for an electronic detection system that will exceed the notification requirements for height.

The engineering challenge of designing bridges involves balancing the critical needs of the users, responding to the surrounding environment, and analyzing the costs and associated benefits. With those priorities in mind, the RSD team strives to best meet the needs of the King County community through the efforts of the bridge program and bridge priority maintenance program.

However, it is also important to note that this report is not an exhaustive list of critical bridge infrastructure, and that despite the best efforts of the Division, generally speaking, bridges are not designed to be indestructible. Therefore, the RSD bridge program and bridge priority maintenance program were developed to keep bridges safe, preserve bridges by proactively performing repairs, and replacing or closing bridges when repair is not feasible.

Due to current funding challenges, RSD expects to close 35 bridges over the next 25 years that have exceeded their useful life and will no longer be safe for public use.

More information on the bridge program and the inventory of King County bridges can be found at www.kingcounty.gov/transportation/kcdot/Roads/EngineeringServices/Bridges.aspx.