WASHINGTON STATE BRIDGE PRESERVATION AND ASSET MANAGEMENT

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Abstract

Washington State Department of Transportation (WSDOT) employs various strategies to extend the service life of its bridge assets, while minimizing life cycle costs. These strategies include performing day-to-day maintenance repairs as well as bridge preservation work to ensure it does not deteriorate to a condition that is beyond repair. Bridge preservation strategies include rehabilitation, pairing, replacing bridge elements, repainting steel bridges, repairing concrete bridge decks, and seismic retrofit. WSDOT's highest priority for constructing, inspecting and maintaining bridges is to ensure that all bridges are safe for the traveling public.

Introduction

WSDOT's highest priority for constructing, inspecting and maintaining bridges is to ensure that all bridges are safe for the traveling public. Strategic asset management of bridges with timely maintenance and preservation maximizes their useful service life. WSDOT manages bridges through inspection, maintenance, rehabilitation, and replacement. These are essential aspects of bridge management to prolong their service life, keep costs down and maintain bridge safety. A bridge is considered for replacement when the problem causing the structural deficiency may reduce the load-carrying capacity of the bridge, and the cost of rehabilitation is more than 50 percent of the replacement cost.

Bridge preservation strategies could be used to extend the service life of bridges and structures, while minimizing life cycle costs. These strategies include performing day-to-day maintenance repairs as well as bridge preservation work to ensure it does not deteriorate to a condition that is beyond repair. Bridge preservation strategies WSDOT uses include rehabilitation (repairing and replacing bridge elements), repainting steel bridges, and repairing concrete bridge decks.

Bridge seismic retrofit program is to address bridges that do not meet current seismic response design standards. The program is divided into three phases: Phase 1 addresses simply supported bridges and bridges with in-span hinges; Phase 2 addresses Major bridges and bridges with single column supports; Phase 3 addresses bridges with multiple columns.

WSDOT Bridge Inventory

The Washington state-owned bridge inventory that WSDOT manages includes 3,829 structures as of June 2014. These add up to 46.6 million square feet of deck area, about 1.7 square miles. Of these structures, 3,098 carry vehicles and are 20 feet or longer, with a total of 45.5 million square feet of deck area. The average age of WSDOT's vehicular bridges is 44 years. WSDOT has 283 bridges that are 75 years old or older, totaling 1.95 million square feet of deck area. WSDOT bridge inventory increases by 35 in year 2014. Table 1 shows the Inventory of WSDOT bridges as of June 2014

Table 1: Inventory of WSDOT bridges as of June 2014

	Number
Total WSDOT bridge structures	3,829
Vehicular bridges longer than 20 feet	3,098
Structures less than 20 feet long	402
Culverts longer than 20 feet	131
Pedestrian structures	76
Ferry terminal structures	68
Tunnels and lids	43
Border bridges maintained by border state	6
Railroad bridges	5

Bridge Asset Management Plan

The Bridge Asset Management Plan focuses on achieving the greatest return through available investments. WSDOT uses the of lowest life cycle cost (LLCC) model, which uses incremental preventative maintenance activities to preserve the life of the asset while avoiding more costly repairs. The bridge asset management goals are based on the following critical categories, ranked from highest to lowest priority:

1. Border bridges: These are interstate responsibilities with Oregon or Idaho, which are the highest obligation held by WSDOT in bridge asset management.
2. Scour critical bridges: "Scour" describes the erosion of stream bed material from under bridge foundations; bridges are classified as "scour critical" if they have the potential for scour depth to be lower than the foundation. Scour failure is the most common reason for bridge collapse in Washington and the U.S. Addressing scour critical bridges is a high priority due to safety concerns and to avoid an emergency repair.
3. Bridge repairs, including anchor cable replacements on floating bridges and repairs to keep movable bridges functional.
4. Bridge painting: is intended to paint a bridge when it is due, before serious deterioration of the coating system occurs. Waiting until significant corrosion attacks the steel is more expensive.
5. Bridge deck repair and overlays.
6. Replacement and rehabilitation of structurally deficient bridges.
7. Seismic retrofits: All planned projects are under contract or have been completed. Due to current bridge preservation needs and a lack of funding, no new projects are planned.
8. Miscellaneous structures (sign bridges, walls, etc.)
9. Timber bridges: WSDOT's long-term plan is to eliminate all timber bridges due to the long term maintenance concerns and the difficulty in inspection.
10. Functionally obsolete bridges: A bridge is functionally obsolete if its design is not suitable for current traffic needs. This category is completely unfunded. More than a quarter of the bridges in Washington are classified as functionally obsolete.

Figure 1 shows the bridge replacement candidates.

Figure 1 shows the bridge replacement candidates

Bridge Condition Evaluation and Preservation

Measuring bridge conditions by deck area provides a more comprehensive measure because it factors in bridge size. Counting the number of bridges does not distinguish whether bridges are small or large, which makes it difficult to determine the correct size in each condition category.

Statewide, 92.1% of bridges measured by deck area are in fair or better condition; 7.9% are structurally deficient. Measured by deck area, 9.3% of bridges on the National Highway System in Washington are structurally deficient. WSDOT estimates that the number of state-owned structurally deficient bridges will increase by 12% between 2014 and 2018. Table 2 shows the number of bridges and percent of bridges by deck area by condition category. The percentage in fair or better condition is greater in terms of the number of bridges compared to the percentage of deck area because several large and are classified as structurally deficient and are currently being replaced with a tunnel and a new bridge. Combined, these bridges account for 2 percent of the state-owned bridge deck area in Washington. WSDOT Bridge structural condition is summarized in Table 2.

Table 2: Bridge Structural condition

STRUCTURAL CONDITION	By bridges	By area
GOOD/VERY GOOD - Bridges in good condition range from those with no problems to those having some minor deterioration of structural elements.	2,855	80.1%
FAIR - All primary structural elements are sound; may have minor section loss, deterioration, cracking, spalling or scour. This is the most cost-effective time to rehabilitate, before the underlying structure is damaged. By doing this, the agency manages to the Lowest Life Cycle Cost.	290	11.7%
POOR - A bridge in poor condition has advanced deficiencies such as section loss, deterioration, scour, or seriously affected structural components, and may have weight restrictions. A bridge in poor condition is still safe for travel.	141	8.2%

There are 7,600 bridges across Washington on city streets, county roads, and state highways. Of these, more than 4,000 are locally owned and support an average of 10 million crossings per day. Approximately 4 percent of Washington's local bridges are considered to be in poor condition in 2014, a decline from 5 percent in 2013. However, keeping them in good repair will be required to avoid much larger replacement costs in the future.

Bridge Rehabilitation Program

There are various performance reporting requirements that include bridge condition measures, goals and targets. The federal transportation legislation, Moving Ahead for Progress in the 21st Century (MAP-21) aims to transition to a performance-and outcome-based federal aid program. Washington State set a target of no more than 10 percent of National Highway System bridge deck area being classified as structurally deficient (poor

condition). The percentages of Washington State bridges on the NHS that are structurally deficient (by deck area) are 9.1% for State-owned and 11.8% for locally-owned bridges.

Bridge rehabilitation projects address specific bridge elements needing repair; the most common types of repairs include expansion joint replacement, concrete column repair, and anchor cable replacements on floating bridges. Figure 2 shows the expansion joint rehabilitation for a floating bridge on Lake Washington.

Figure 2: Expansion joint rehabilitation Project

Replacing deteriorated bridge elements is a strategy that WSDOT uses to improve a bridge with a low condition rating is to perform major preservation repairs by addressing specific bridge elements. The most common types of repairs include floating bridge anchor cable replacement, expansion joint replacement, and concrete column repair.

Repainting steel bridges with a protective paint coating is essential to prevent corrosion, extend the bridge's service life, and keep the bridge in fair or better condition.

Repairing concrete bridge decks is a strategy to rehabilitate concrete bridge decks to extend their service life.

WSDOT Bridge Inspection Program

The bridge inspection program ensures that bridges open to public are safe. The Federal Highway Administration (FHWA) mandates that all publicly-owned bridges be inspected at least once every two years. WSDOT performs federally mandated inspections on all state-owned bridge structures as outlined in the National Bridge Inspection Standards to determine bridge conditions, and preservation and maintenance needs. While the majority of WSDOT's bridges are inspected on a two-year cycle, there are eight bridges with specific watch items that are inspected annually.

Concrete bridges in good condition that meet defined FHWA criteria are inspected on a four-year cycle, currently a total of 453 bridges. The criteria to allow a bridge to be inspected every four-years includes that it is in good condition, has a span length of less than 100 feet, has maximum average daily traffic less than 100,000 vehicles and average daily truck traffic less than 10,000, is not a scour critical bridge, and has had no major maintenance within the last two years.

Bridge engineers also perform specialized work to determine the condition of selected elements of a bridge such as fracture critical members and mechanical elements on movable bridges, along with the routine inspections. Bridge engineers work closely with Maintenance Office to address repair needs on the bridges. Engineers identify a repair need and recommend a time frame for when the repair should be addressed. WSDOT performs 1,892 bridge inspections in 2014. Table 3 shows the number of inspections by structure type.

Table 3: Bridge inspections types

Type of inspection	Number
WSDOT routine bridge inspection	1,504
WSDOT under bridge inspection truck (UBIT) bridge inspections	267
WSDOT routine ferry terminal inspections	24
Fracture critical ferry terminal inspections	20
Local agency UBIT inspections	69
Local agency routine inspections	8

Bridge Inspection types

1. Inventory Inspection: An inventory inspection is the initial inspection of a bridge as it becomes part of the bridge inventory or after a major rebuild when the year rebuilt is coded greater than zero. Inventory inspections provide structure inventory and appraisal data along with bridge element information and baseline structural condition.

2. Routine Inspection: A routine inspection is performed at regular intervals not to exceed twenty four months. Inspection intervals of greater than twenty-four months, not to exceed forty-eight months, may be approved when past inspection findings and analysis justify increased inspection intervals. Written FHWA approval is required when increasing inspection intervals to greater than twenty-four months.

3. Fracture Critical Member Inspection: A fracture critical inspection is an in depth evaluation of critical bridge components performed in accordance with procedures developed for that structure. A fracture critical member is defined as a steel member in tension, or with a tension element, whose failure would probably cause a portion of or the entire bridge to collapse. Inspect fracture critical members at intervals not to exceed twenty four months.

4. Underwater Inspection: An underwater inspection is performed on bridges with structural elements that are not accessible for inspection otherwise. Underwater inspection procedures shall be developed to identify, locate, and describe underwater elements for each bridge requiring an underwater inspection. Inspect underwater structural elements at regular intervals not to exceed sixty months. A scour evaluation is required for bridges over water. The purpose of a scour evaluation is to determine susceptibility of the bridge's foundation to the erosive actions of flowing water removing material from the bridge's foundation. A bridge is considered scour critical if its foundation is determined to be unstable for observed or calculated scour conditions.

5. Special Feature Inspection of Complex Bridges: A special inspection is required on complex bridges that have unique or special features requiring additional attention.

Inspection procedures shall be developed that identify specialized inspection requirements and additional inspector training and experience necessary to inspect complex brides. Complex bridges include: Movable Bridges, Floating Bridges, Suspension Bridges, Redundant Pin and Hanger Bridges, Precast Segmental Bridges, Ferry Terminal Structures, High Strength steel Bridges, and Cable-stayed Bridges. Table 4 shows the inspection types and frequency.

Table 4 Inspection types and frequency (Months)

Timber	24
Steel Trusses	24
Steel Bridges with pins and hangers	24
Non-fracture Critical Steel Bridges	48
Concrete Bridges with movable bearing in the interior spans	48
Concrete Bridges with fixed bearing or no bearings maximum	72

A variety of other inspections may be required on a bridge during its service life. The types of inspections can include but are not limited to damage inspections, in-depth inspection, and interim inspections. These other inspections are not usually performed on a set frequency but are performed as needed. They provide added information and detail to the routine bridge inspection. Other inspection types include damage, scour, and in-depth inspections.

The safety inspection is required for Non-State owned bridges crossing over state routes, and bridges under construction that are not "substantially complete" yet open to traffic. The maximum inspection frequency in this case is 12 months.

A bridge or structure is classified as fracture critical if it contains any fracture critical support members (a tension member piece of the bridge structure whose failure will probably cause a portion of or the entire bridge to collapse). The specific actions to address for cleaning fracture critical bridges are to identify a prioritized list of state-owned fracture critical member bridges needing to be cleaned, and to institute and fund a bridge cleaning program to clean state-owned bridges prior to performing a bridge inspection. During the first year of the program (FY2014), WSDOT completely cleaned 44 bridges and partially cleaned six. Despite the current bridge cleaning backlog, WSDOT expects to be caught up by 2017.

Steel Bridge Painting Program

Repainting steel bridges keeps bridges in fair or good condition. A protective paint coating on a steel bridge is essential for preventing corrosion, extending the bridge's service life, and keeping the bridge in fair or better condition. WSDOT's 10-year steel bridge painting needs total nearly $700 million. Continuing to keep up with painting can prevent the number of bridges in poor condition from increasing. On average, a steel truss bridge is considered in poor condition if it has been due for painting for at least five years, or 10 years for steel girder bridges. Figure 3 shows the condition of steel bridges and need for repainting.

Figure 3: Condition of steel bridges and need for repainting

Bridges are prioritized for repainting based on the amount of corrosion and the route on which they are located. Bridges on primary freight routes are given top priority. Steel truss bridges should be repainted every 20 to 25 years on average and newer steel girder bridges should be painted approximately every 40 years. Bridge painting is a major repair project with significant costs due to the complexity of safety, environmental regulations, and containment system requirements.

WSDOT owns 323 steel bridges of which 110 are currently due or past due to be repainted. The estimated cost to paint these 110 bridges is $467 million. Forty-three additional bridges are expected to become due for painting in the next 10 years with a total estimated cost of $282 million. This work keeps bridges safe and serving the public for the least cost. One third of steel bridges are due for painting. Table 5 shows the bridge painting summary.

Table 5: Bridge Painting Summary

Painting needs	Number of bridges	Cost to repaint
Currently due or past due	110	$467.0
Projects planned for 2013-2015 biennium	8.5	$54.8
Remaining backlog	101.5	$412.2
Due within the next 10 years	43	$282.0
10-year total need	144.5	$694.2

Bridge Cleaning

Keeping bridges clean to allow for structural inspections and the belief that keeping coatings cleaned of debris accumulations extends the life of the coating and serves as the basis for bridge washing programs around the country.

In partnership with the University of Washington, WSDOT conducted research to quantify the benefits of cleaning steel bridges versus the costs associated with the expected deterioration if a bridge is not cleaned. In light of the lack of clear cost-benefit information, the research project made recommendations on criteria that could be used for long-term monitoring of pairs of bridges. The research would allow half of a set of bridges to be washed annually, and the other would not be washed, to develop some cost-

benefit information. Critical needs related to washing bridges for structural inspections drove to expand washing to all steel truss bridges.

Bridge Deck Repair

A concrete overlay is a repair to an existing concrete bridge deck that provides corrosion protection for the steel reinforcing. Crews routinely provide temporary repairs in the form of quick-cure patching materials to keep bridges in service. These repairs normally have a service life of a few years. A full bridge deck rehabilitation and concrete overlay provides a longer service life of at least 25 years and is more cost effective for bridge decks that have repeated deterioration, yet is less expensive than replacing the entire deck or bridge.

Concrete deck overlay program began in the mid 1980s. A significant number of bridge decks are protected against winter de-icing salts. Protective overlays are required on those identified with deck deterioration. Figure 5 shows the bridge deck deterioration projects.

Figure 5: Bridge Deck Deterioration

Load Rating

Load rating calculations shall be performed on all NBI bridges to determine live load carrying capacity. An updated load rating calculation is required whenever the capacity of the bridge changes due to the condition of the structure, impact on the bridge due to approach roadway or deck deterioration, or if the dead load of the bridge has been increased.

A bridge must be load posted whenever the legal load exceeds the bridge capacity. Load posting consists of signs indicating the load limit in advance of the applicable section of highway or structure at points where prohibited vehicles can detour or turn around. Of the 3,286 bridges WSDOT manages, 137 are load-posted or load-restricted, a decline from 140 in 2013.

Bridge Seismic Retrofit Program

Washington State has a long record of major earthquakes and is considered to be one of the five states facing the greatest seismic hazards in the United States. California and Washington are the two states at greatest risk. Earthquakes can happen in Washington State at any time, and past history indicates there may be substantial shifting of land during a seismic event. Due to the available funding level, the program prioritized the retrofit needs into four stages: (1) link the superstructure together with earthquake restrainers; (2) major bridge retrofit and single column bridge retrofit; (3) multiple column bridge retrofit and (4) foundation retrofit. Up to 2003, restrainers have been installed to all the highway bridges and 90% of the single column bridges have been retrofitted with steel or composite material jackets. Using this phased approach WSDOT calculated "retrofit units". Figure 6 shows the seismic rehabilitation projects.

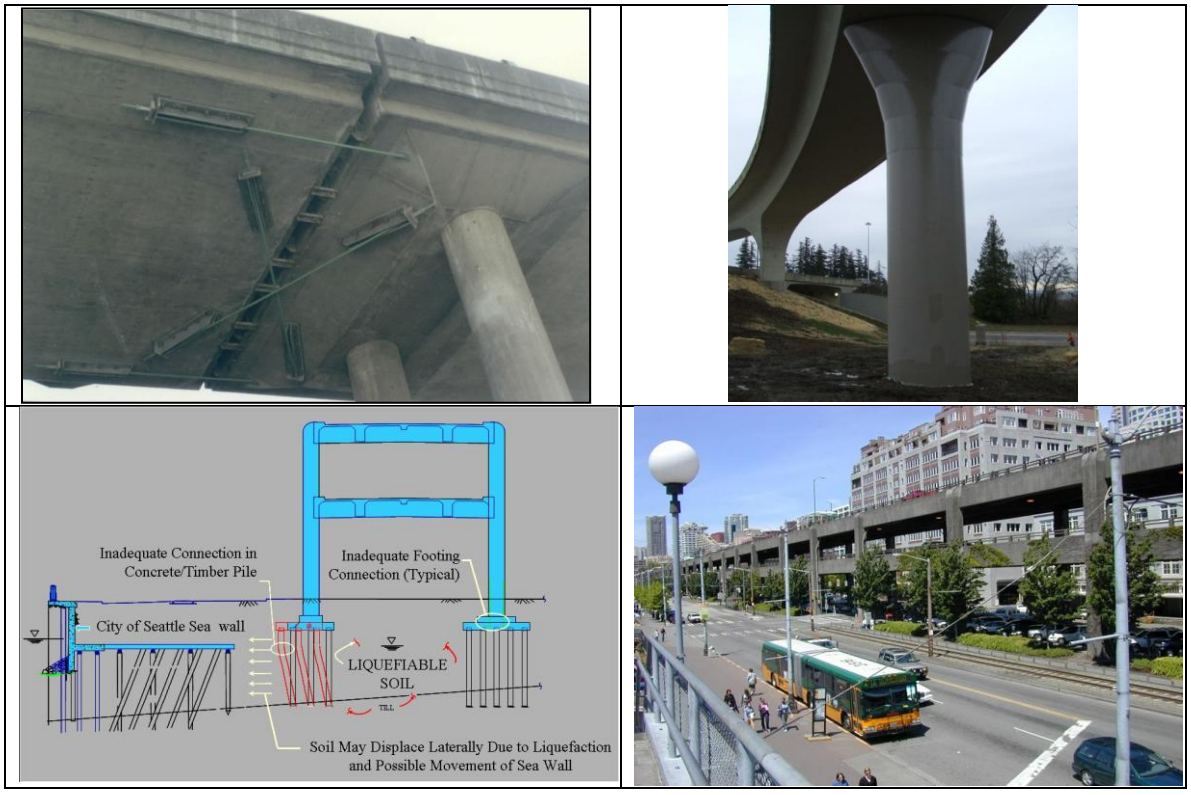

Figure 6: Seismic Rehabilitation Projects

Since WSDOT's seismic retrofit program began in 1991, WSDOT has invested nearly $150 million to strengthen bridges to withstand earthquakes. Approximately 1600

retrofit units are either completed, identified that no retrofit is required, or the retrofit is deferred. Most deferred structures will be replaced in the near future. Approximately 35 retrofit units are either partially complete or in progress. Just fewer than 500 retrofit units remain to be retrofitted.

WSDOT identified a network of routes that can provide the critical corridors needed to get emergency responders into damaged areas rapidly and the state economy (freight and goods) moving again as quickly as possible. Figure 7 shows the Seismic Lifeline routes map in the corridors needed to provide these essential services.

Estimated costs are $100 million to implement the lifeline component of phase three which secures the lifeline in both directions. The Legislature funded $50 million (as of July13, 2013) for the continuation of phase three which is well underway and will continue to decrease the risk of damage from earthquakes. This network will offer safe travel routes for vehicles and trucks during and after a catastrophic event. Figure 7 shows the seismicity of Washington State, earthquake sources, liquefaction and lifeline maps.

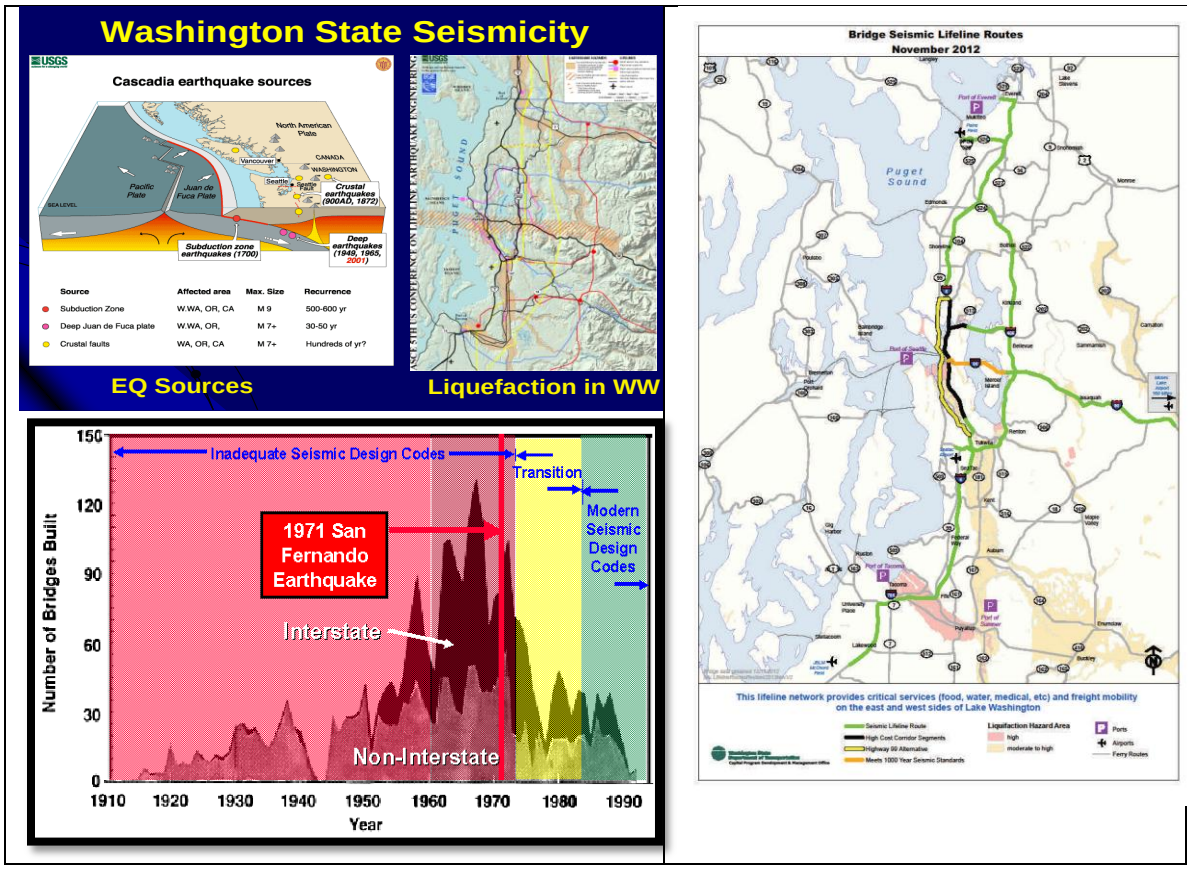

Figure 7: Seismicity of Washington State, EQ Sources, Liquefaction and Lifeline Maps.

Conclusions

Strategic asset management of bridges with timely maintenance and preservation maximizes their useful service life. WSDOT manages bridges through inspection,

maintenance, rehabilitation, and replacement. These are essential aspects of bridge management to prolong their service life, keep costs down and maintain bridge safety.

Seismic retrofit on highway bridges is a continuous effort, through "lesson learned", to upgrade the existing bridges to the current design standards. Due to the funding level, all the retrofit needs were prioritized to retrofit highway bridges that are in the immediate needs. Up to today, only the retrofits on Group 1 and Group2 have been completed. Washington State Department of Transportation is promoting several research projects to optimize the seismic retrofit design on multiple column bent bridges. Many seismic retrofit projects on highway bridges have been scheduled for construction this year.

References

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