View from below the Tacoma Narrows Bridges; the older westbound span on the right (Photo: Paul Knaebel WSDOT)

TRAVELLING LIGHT

A new underbridge traveller system for the Tacoma Narrows Bridge in the USA has just been brought into service. **Scott Snelling**, **Mark VanDeRee**, **Paul Knaebel** and **Matt Rochon** report on its design and installation

Long-span bridges benefit from the improved inspection and maintenance access made possible by permanent traveller systems that are installed under the deck. In addition to providing a moving working platform, travellers make it possible to provide utilities such as compressed air and electricity to mid-span work locations, while allowing traffic and navigation to continue unimpeded.

At the end of last year, the design, installation and commissioning of a new underbridge traveller for the Tacoma Narrows Bridge in Washington State was substantially completed.

The current configuration of the Tacoma Narrows Bridge crossing consists of twin bridges connecting the city of Tacoma with the Kitsap Peninsula, over the Tacoma Narrows of Puget Sound. The older of the two is the replacement for the original, infamous Tacoma Narrows Bridge, which opened to traffic in July 1940 and collapsed just four months later due to wind-induced vibration.

The replacement bridge was built in 1950 to its current configuration with a deep stiffening truss, hydraulic dampers, and vented deck. In 2007 a second bridge was built next to the first one, and traffic flow reconfigured so the older bridge now carries westbound traffic and the new bridge carries eastbound traffic.

The traveller system on the older bridge had provided access for maintenance and inspection of the suspended spans for more than 65 years and was well regarded by the maintenance staff, but it did not meet modern safety standards. In 2012 Parsons Brinckerhoff was hired by the owner, Washington State DOT, to inspect the traveller and carry out a study to investigate options for rehabilitating or replacing it.

The new traveller, just like the one it replaces, is designed to service the full length of the suspended deck; the 853m-long main span and the two 335m-long side spans. One challenge for the project was to provide continuity of the traveller rails over the expansion joints at the towers. The rails that serve this function use a series of accordion-like links to provide 1.2m of movement over their 6.1m length.

Reliability can be a major issue with underbridge travellers; on other bridges problems such as jamming of the traveller, and rapid deterioration of sophisticated mechanical-electrical systems often arise. Jamming can be caused by skew and/or inadequate rail alignment tolerances.

This was never a problem on Tacoma – the original traveller did not jam and it was driven by a very simple but effective mechanical operating system which had a diesel engine and hydraulic pump and motor adapted from a farm tractor. Over the life of the traveller, the bridge maintenance staff had improvised various rehabilitations and adaptations. The retrofitted electrical system was simply a car battery which was used to start the diesel engine and power a fuel gauge – there was no electrical control system or lighting to maintain. This improvisation was effective in keeping the traveller running and ensured that the bridge maintenance staff were comfortable operating and maintaining the equipment, but it did not meet modern safety standards. The brakes were ineffective and unconventional, and considering that the rails are on a 3% gradient, the risk of a runaway traveller was serious.

Additional safety issues with the previous equipment included the fact that it was significantly heavier than its original design weight, and that the patented rails upon which it rode had been recalled by the manufacturer due to in-service fatigue-fracture failures in industrial crane applications.

Furthermore, the four expansion rails had seized up, due to an inability to accept lubrication, and the resulting corrosion was imposing excessive out-of-plane loading on the floor trusses adjacent to the towers.

Although the two travellers on the newer bridge function well, they did not serve as a model for the design of the replacement travellers. One specific complaint was that the skew-sensing limit switches installed at each corner of the traveller were vulnerable to be unknowingly tripped. This risked rendering the traveller inoperable until the offending switch could be identified.

In June 2014, the Washington State Department of Transportation, which owns and operates the bridge, awarded a US$7.4 million contract to PCL Construction for a new traveller for the westbound bridge. WSP/Parsons Brinckerhoff served as designer and engineer of record. The new traveller was manufactured by American Crane and the traveller and rails were erected and aligned by PCL Construction.

Key lessons that were applied to the new design included favouring simple mechanical systems, avoiding complex and fragile electrical controls and sensors, and using a wide wheelbase and stiff traveller structure to prevent skewing and jamming.

This resulted in design of a traveller that is quite different in configuration compared to systems built in recent years. Modern systems often use a narrow wheelbase, a flexible 'kingpin'-supported structure to accommodate significant skewing and sophisticated electrical control systems to monitor skewing and synchronise several independent mechanical drives.

Tacoma's new traveller has 1.3m-deep Warren trusses fabricated from high-strength structural tubes of 345MPa yield strength with shop-welded connections. The floor is fibre-reinforced polymer grating supported at the elevation of the lower truss chords, allowing the upper chords to serve as the handrail. Due to the limited load capacity of the existing structure, it was important to keep the weight of the new traveller within 11,300kg. This was accomplished while more than doubling the usable working space within the traveller from 20m^2 to 45m^2.

The mechanical drive system uses two 3.7kW electric gear motors, front and rear. Each gear motor drives two drive wheels which are transversely connected using drive shafts and no differential. The drive wheels use a solid elastomeric tyre and are spring-loaded onto the underside of the rails. Separate wheel truck assemblies support dead and live loads using steel wheels running on the top of the lower rail flange; the truck assemblies also include horizontal guide wheels. A 36.5kW air compressor is provided for powering tools, and is also available to operate the traveller using auxiliary air motors in case of failure of the electrical system.

The electrical system is powered by a 33kW diesel generator. The motor drives are synchronised flux vector variable frequency drives with dynamic braking. The traveller is controlled with a programmable logic controller with some hard-wired relay controls and hard-wired emergency stops. The operator controls the traveller using a joystick mounted upon a pedestal. Emergency stop buttons are provided at opposite sides of the traveller.

To facilitate maintenance work, the traveller is provided with a 900kg-capacity electric winch and connection points for suspended scaffolding personnel lifts.

For the fixed rails, a W14x68 wide-flange structural steel rolled section was selected – almost 3km in total was required. Specification of a standard rolled shape allowed for competitive bidding, rather than the alternative of selecting a patented crane rail. Energy-absorbing elastomeric buffers are provided at the end of each rail, to guard against a runaway traveller.

The new expansion rails were reverse-engineered to a similar design as the previous system, but with improved lubrication provision, use of bronze bearing surfaces, instead of steel-on-steel contact, and increased bearing running clearances.

Construction and installation of a new traveller within the confines of the existing bridge is specialised work, hence the contract documents included rigorous pre-qualification requirements for the contractor, in particular as regards the traveller manufacturer.

Contractor PCL Construction provided an efficient construction procedure by temporarily erecting a scaffolding catwalk under the full length of each rail. Simple hand trolleys were used to convey each segment of old rail as it was removed and the new rail as it was erected.

No roadway or marine closures were required during the work; the contractor carried out all work, including delivering and removing material, from a staging area on the south end of the span where the suspended stiffening truss is at ground level. A small electric hoist was used to lower the existing rails and lift the new rails between the ground level and the temporary scaffolding level approximately 10m above.

Once new rail segments were in place, they were aligned to a tolerance of ± 4.8mm by using a laser range-finder to measure 9.4m to the opposite rail. Shims were used to align the joints flush with the abutting rails to a tolerance of ± 1.6mm, with a maximum allowable gap of 3.2mm. Oversize and slotted holes were allowed to facilitate field alignment.

Significant shop testing of the traveller and expansion rails was required before shipping to the bridge site. The traveller manufacturer temporarily erected rails in the shop, including a 3% slope, to enable testing to be carried out. Shop testing of the new traveller included weighing, operating at full speed for 10 seconds, operating at half speed and creep speeds, performing emergency stops, and operating with an asymmetric skewing load of 1,335N. Once the shop tests had been satisfactorily completed on dry rails, the rails were dampened to simulate rain and the tests repeated. After the traveller had been shipped to the bridge site and installed, similar operational tests were performed in the field.

The new traveller draws upon key lessons learned from the 65-year operation of the traveller it replaces, such as the value of using extremely simple mechanical and electrical systems and a wide wheelbase to limit problems with deterioration and jamming caused by skewing. The new traveller also complies with modern design and safety standards, resulting in a configuration that improves upon other travellers built in recent years

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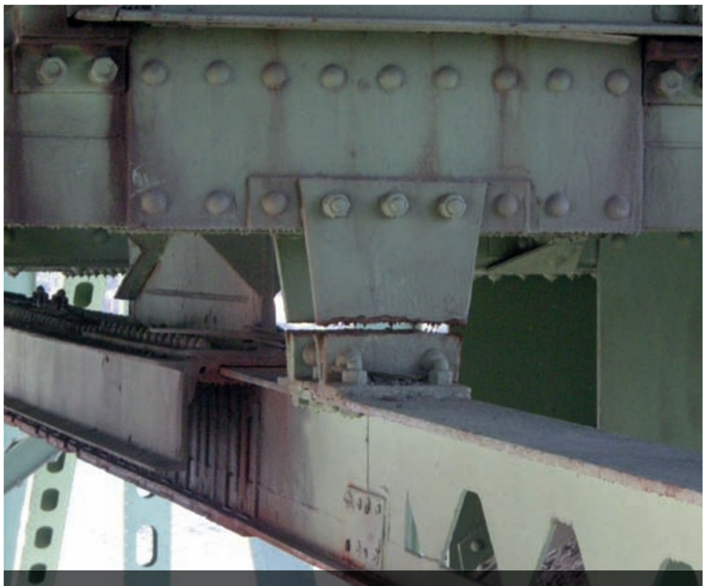
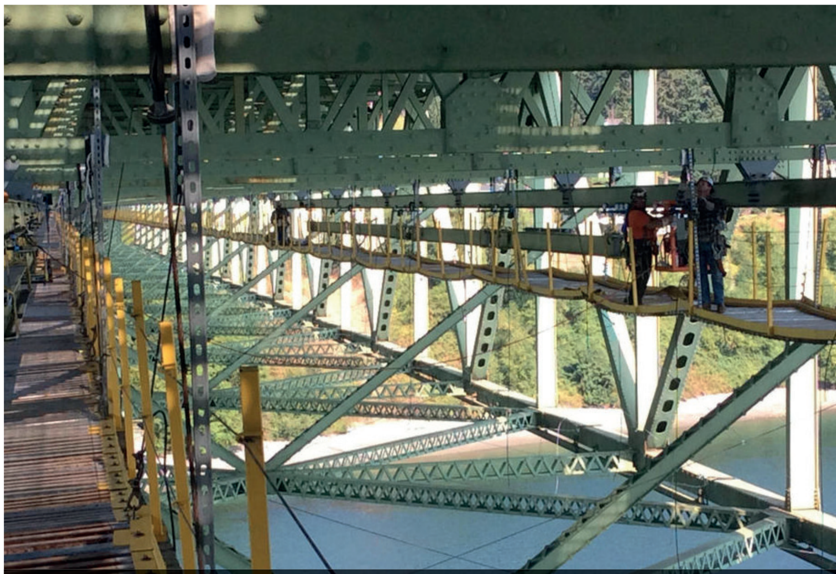


Previous expansion rails and fixed rails showing failed gusset plates caused by the corroded and bound expansion rails



Temporary scaffolding to provide access for removal of the existing rails and erection of the new ones; rails are hanging from trolleys in the process of being erected. *(Photo: Matt Rochon WSDOT)*