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The State Route 520 Floating Bridge in Seattle, Washington

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ABSTRACT

The four longest floating bridges in the world are located in Seattle, Washington on the North West Coast of the United States of America. At 2.3 km long and 35 m wide, the Evergreen Point Floating Bridge, also known as the State Route (SR) 520 Bridge, is the longest floating bridge in the world.

Home to around 3.5 million people, the metropolitan area of Seattle is divided by Lake Washington and the SR 520 transports 115,000 vehicles across Lake Washington on a daily basis. At depths reaching 61 m [1] a suspension bridge would require a bridge tower of over 183 m; thus a floating bridge is necessary. Constructed in 1963, this bridge however is now approaching the end of its lifespan and will be replaced by an even longer and wider floating bridge by 2014.

This paper will investigate why the bridge must be replaced, the past and current reasons for selecting a floating bridge to cross Lake Washington, what it takes to make a concrete bridge float, and how the new bridge will vary from the existing bridge.

1 INTRODUCTION

The city of Seattle, located in the State of Washington on the North West Coast is the 22nd largest city in the United States of America. While hosting the headquarters for big Information Technology companies such as Microsoft and Amazon, it is no surprise that the metropolitan population of Seattle has increased from 1.4 million to 3.5 million from the years 1960 to 2012. The Seattle metropolitan area, including Bellevue and Kirkland, supply thousands of workers to the city centre on a daily basis. Lake Washington however, at over 30 km long [2] and 2.4 km wide, divides the eastern metropolitan area of Seattle from the city centre.

Figure 1: Lake Washington

The bridge shown in Figure 1 above that is marked 520, is known as the State Route (SR) 520 Floating Bridge. At the time of its completion in 1963, the bridge was to carry an estimated 65,000 vehicles a day to and from the city centre. Due to the dramatic increase in population, the bridge now carries an average of 115,000 vehicles per day. This increased congestion displays the dire need for a reliable bridge across Lake Washington.

2 REASONS FOR REPLACEMENT

3.1 Repair Work

The 50 year old SR 520 Floating Bridge is approaching the end of its lifespan and it is beginning to show. In 1989 and 1991, for no known reason, one of the 33 concrete pontoons supporting the bridge cracked open. Strong winds in 1999 split the bridge in two. Between 1993 and 2013 over 9,100 linear meters of cracks were repaired on the concrete pontoons. In 2006 anchor bolts within the draw span were sheared off during a severe storm, and in 2000 emergency repairs had to be made to a damaged column.

3.2 Closures

Residents of Seattle are always on high alert while driving to determine if their main route home, the SR 520 Floating Bridge, is closed to traffic. If 40 mph gusts are sustained for one minute a warning alarm is sounded and crews are summoned to inspect and monitor the bridge. When 50 mph gusts are sustained for over 15 minutes, the bridge is closed and the drawspan is opened in order to relieve the pressure on the bridge from the wind and wave action.[3] The drawspan is a retractable concrete pontoon that allows for larger vessels to pass through the SR 520 Bridge, and as stated, can be opened to relieve pressure. Below is an image of the drawspan retracted during a storm.

Figure 2: Retracted drawspan on the SR 520 Bridge to relieve pressure during a storm

These closures are an obvious inconvenience to commuters, and many citizens are eagerly awaiting the day when they can count on a more reliable route across Lake Washington.

3 FLOATING BRIDGE CONSTRUCTION

3.1 Bridge Selection

M. Myint Lwin of the Washington State of Department of Transportation has stated, "For a site where the water is 2 to 5 km wide, 30 to 60 m deep and there is a very soft bottom… a floating bridge is estimated to cost three to five times less than a long-span fixed bridge, tube or tunnel." [4] The mean depth of Lake Washington is 33 m [5] and the bottom is composed of highly compressible silt. Also, the corridor in which the bridge needs to be placed is not straight. This depth would require a suspension bridge with an impractical tower over 183 meters high. Also, suspension bridges can only be built in a relatively straight line. In addition, the poor soft bedding would not easily support a conventional bridge. It is thus evident that in order for vehicles to traverse of the 2.3 km wide Lake Washington, a floating bridge must be constructed.

3.2 Pontoons

A floating bridge is generally consisted of concrete pontoons joined together continuously, or of separate concrete pontoons spanned by a steel or concrete superstructure. A continuous pontoon floating bridge may or may not have an elevated super-structure. The new SR 520 floating bridge will be constructed with an elevated super-structure and consist of three different types of concrete pontoons that are joined together continuously, as shown in Figure 3 below.

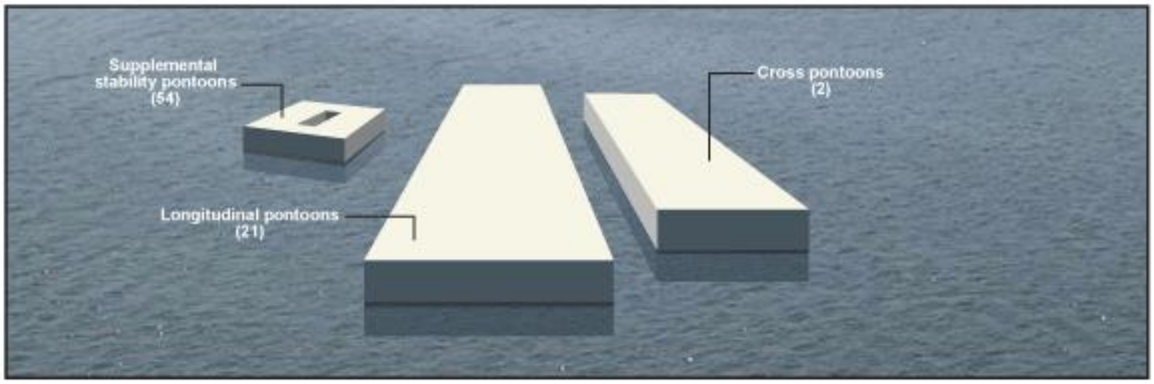

Figure 3: The SR 520's three types of concrete pontoons

The largest pontoons, labelled as the longitudinal pontoons, measure approximately 110m long and weigh over 9,980 tonnes. Two cross pontoons will be placed at each end of the new bridge on the East and West Approach structures. Their weights will range from 9,163 to 9,571 tonnes. The new bridge will vary from the existing bridge with the addition of a third type of pontoon called the supplemental stability pontoon. These 54 pontoons will help stabilize the bridge and support the weight of the new and larger floating bridge. They will weigh between 2,268 and 2,558 tonnes. The three pontoons will be assembled as shown in Figure 4 below.

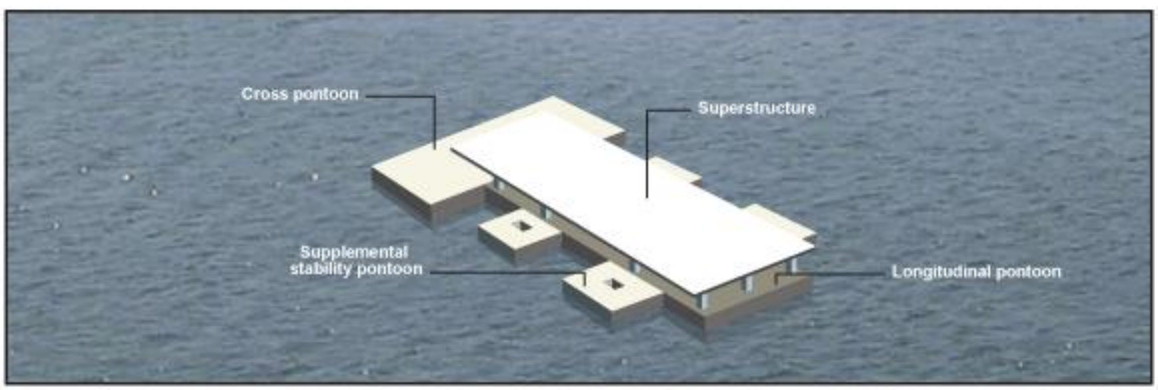

Figure 4: The SR 520's pontoons assembled

The pontoons are constructed on dry land adjacent to a waterway within a watertight basin. Once construction is complete, the basin is then flooded to allow the pontoon to float. Once it is high tide, the gates of the basin are lifted and the pontoons are towed by tugboat to a mooring location approximately 2.8 km from the shoreline. The moorage area is about 1.6 km long, 213 m wide, and deep enough to give the pontoons at least 2 m of clearance from the harbour bottom during all tides. It is from here that the 21 longitudinal pontoons are towed one at a time by tug boat to Shilshole Bay, approximately 260 nautical miles (482 km) away. This journey is expected to take over three days. The pontoons must then pass through the Hiram M. Chittenden Locks and towed through a channel to the construction site of the new bridge. The Hiram M. Chittenden Locks divide the sea from the Lake Washington and maintains the lake's water level between 6.1 to 6.7 m above sea level.

3.3 Concrete

The natural law of buoyancy of water causes an object to float when the volume of water displaced by the object weighs more than the object itself. This allows water to support the dead and live loads of a floating bridge. The issue with constructing concrete pontoons is concrete's natural tendency to crack. Once a pontoon cracks, water is capable of leaking into the pontoon, compromising the structural integrity of the pontoon and increasing the pontoon's weight.

One measure introduced to reduce cracking involved heating the concrete. When concrete is poured its temperature ranges from 50 to 60 degrees Celsius. As it cools it shrinks. The walls and the bottom panels are connected via rebar but the panels are poured in different stages. Pipes were placed in the bottom panels to heat the previously set concrete to the same temperature as the concrete being poured. This causes both panels to cool and shrink in unity, thus reducing the amount of cracks.

The pontoons are closely expected and have crack restrictions of 6/1000 of an inch (0.1524mm). Cracks larger than this must be injected with an epoxy resin and waterproof membrane. This treatment is to ensure the crack will not widen under the constant wave action during the bridge's 75 year life expectancy.

To minimize the corroding effects of salt water, a concrete mixture composed of fly ash and microsilicia was selected. Although the bridge will be located on the freshwater Lake Washington, the pontoons are constructed, moored, and towed in salt water.

3.4 Anchors

In order to resist the forces in the transverse and longitudinal direction produced by winds, waves and currents, an anchoring system is required. Anchors can be composed of concrete gravity based anchors, or driven H-piles. The new SR 520 floating bridge will have 58 reinforced concrete anchors weighing 70 tonnes each. These new anchors will attach to the concrete pontoons via steel cables almost 3 inches (76 mm) thick. The existing bridge has 62 anchors of similar weight connected by cables ranging from 27 to 70 mm diameters (the cables closest to shore require thicker cables). Along the bridge, the anchors use their own gravity to sink into the soft lake bottom and at each end of the bridge the anchors are drilled directly into the ground. These anchors provide lateral stability through tension and prevent the bridge from swaying.

3.5 Old vs. New

The original SR 520 Floating Bridge is currently 18.3 m wide and sits about 4 m above the water and supports 4 traffic lanes. The new bridge will be over 35 m wide, and will initially have 6 traffic lanes plus a pedestrian and bicycle lane. The deck will be elevated from the pontoon to allow wiring and piping to pass below the roadway, as well as to allow a maintenance area and stormwater treatment system to be accessed without closure of the highway. A diagram of the existing and new SR 520 Floating Bridge is displayed below.

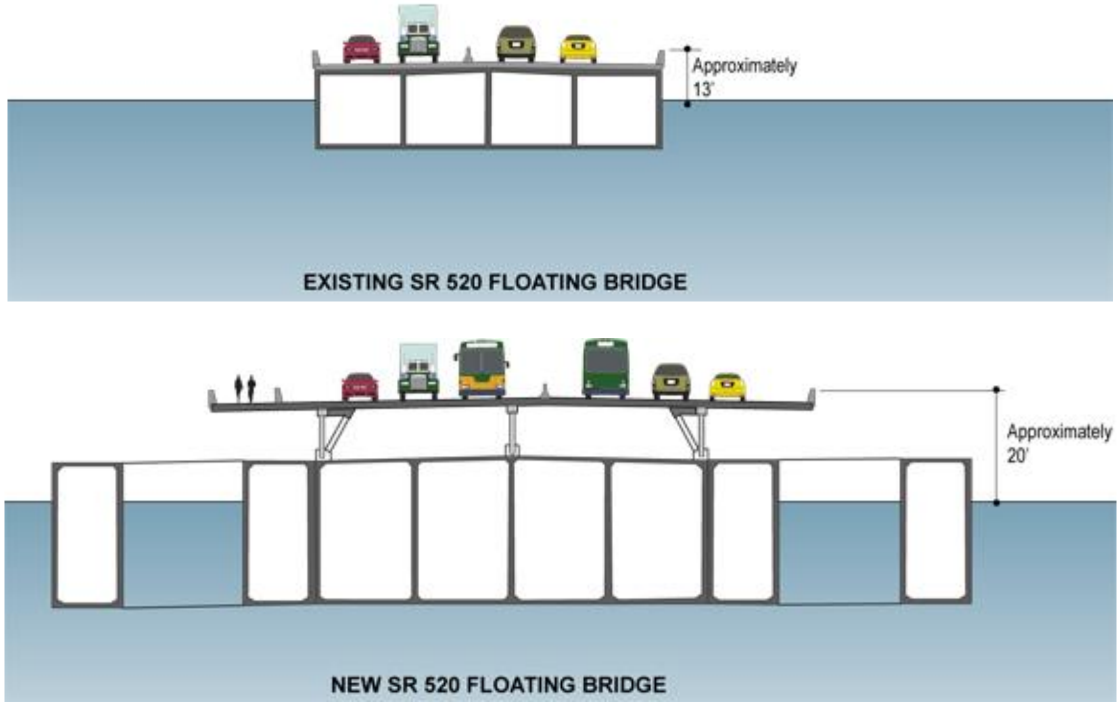

Figure 5: The SR 520 Floating Bridge's existing and new section view

In addition to these convenient changes, the new structural design has increased the wind design speed from 133 to 143 km/h. The new SR 520 Floating Bridge is also designed so 30 additional supplemental pontoons may be added to fully support a wider elevated support structure that would accommodate a light rail in each direction. It should also be noted that the existing bridge was not designed for earthquake loads and the new bridge is designed to withstand a 1,000-year earthquake.

4 CONCLUSIONS

Due to the increased traffic, frequent road closures and repair work, as well as insufficient earth quake resistance design, it is apparent that the SR 520 Floating Bridge must be replaced. A floating bridge must be the selected due to the poor soil conditions of Lake Washington, as well as its great width and depth. A variety of concrete pontoons were designed to support the SR 520's roadway, and special measures were taken to ensure the structural integrity of each pontoon was not compromised by cracking. The new bridge should meet the needs of the residents of Seattle and easily accommodate any required expansions.

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