PRECASTING THE WORLD'S LONGEST FLOATING BRIDGE - SR520 FLOATING BRIDGE

Jason B. K. Pang, P.E., KPFF Consulting Engineers, Seattle, WA
W. Gregory Hess, P.E., S.E., KPFF Consulting Engineers, Seattle, WA
Benjamin D. Nelson, P.E., Kiewit/General/Manson, A Joint Venture, Bellevue, WA

ABSTRACT

Construction of the new SR520 Floating Bridge maximized the use of precast concrete to address the challenges of limited access, overwater work, and an accelerated schedule. Thousands of different structural and architectural precast elements comprise the new floating bridge that spans 7,710 ft across Lake Washington in Seattle.

77 watertight precast concrete pontoons joined end-to-end form the floating foundation. The largest pontoons, weighing 11,000 tons and measuring 360 ft long, 75 ft wide and 29 ft tall, were cast in a specially constructed dry-dock and towed nearly 400 miles to site. Precast gravity and fluke anchors, in addition to cast-in-place shafts, provide permanent moorage.

The center mile of roadway is a unique lightweight elevated deck system comprised of 776 match-cast panels post-tensioned into 360 ft long segments supported directly on columns. The remaining portions leading up to the transition spans are supported on 331 precast-prestressed girders, supported on cast-in-place substructure. Pairs of precast box columns, some as tall as 70 ft, support the transition spans on each end.

Ends of the bridge are flanked by architectural sentinels. These steel frame towers clad in precast stand 124 ft above the water. Precast belvederes and other architectural precast adorn the bridge. This paper discusses the extensive use of precast concrete throughout the new floating bridge.

Keywords: Pontoon, Floating Bridge, Precast Concrete, Prestress Concrete, Post-Tension, Segmental Construction, Accelerated Bridge Construction

INTRODUCTION

The SR520 Floating Bridge, commonly known as the Evergreen Point Floating Bridge and officially known as the Governor Albert D. Rosellini Bridge, is a floating concrete pontoon structure that carries State Route 520 across the northern half of Lake Washington. The new and old bridges are shown in Figure 1. The bridge links Seattle to its eastside neighbors of Medina, Bellevue, Redmond, and Kirkland. Its western end is located in the neighborhood of Montlake, near the University of Washington. Its eastern end is located in Evergreen Point, in the City of Medina.

Figure 1 - The new SR520 Floating Bridge nearing completion, adjacent the original bridge.

Construction of the new SR520 Floating Bridge maximized the use of precast concrete to tackle the challenges of limited access, overwater work, and an accelerated schedule. Thousands of different structural and architectural precast elements were prefabricated at different sites across Washington State and transported to Lake Washington to construct the new floating bridge. The pontoons, the largest of the precast elements, were constructed nearly 400 miles away on the Pacific Ocean in Aberdeen, Washington in a specially designed casting basin. Pontoons were towed by tug boat to the bridge site in Lake Washington. Other elements were precast miles away in Tacoma, Kenmore, and Redmond, Washington.

The original bridge, built in 1963, outlived it useful service life and was determined to be in poor condition and vulnerable to storm and seismic damage. Continued upkeep of the exiting 53 year old pontoons and draw span was costly. In 2011, construction began on the new SR520 Floating Bridge replacement. The new bridge was designed to be safer and more stable and resilient. It provides the growing region added capacity for transit and high-occupancy vehicles, new access for pedestrians and bicycles, and the potential for future light-rail expansion. In April 2016 the original bridge closed to traffic and new bridge opened.

At 7,708.5 feet long the new SR520 Floating Bridge is the longest floating bridge in the world. It broke the record of its predecessor by 30 feet more. With the large amount of precast elements comprising the structure, it also should qualify for the world's longest precast floating bridge.

BRIDGE CONFIGURATION

The bridge's floating foundation is comprised of 77 watertight precast concrete pontoons. 21 longitudinal pontoons joined end-to-end, with two cross pontoons at each end, form the 7,708.5 feet long back-bone of the bridge. 54 smaller supplemental stability pontoons, also known as SSP's, serve as outriggers to provide additional stability and buoyancy. The total bridge pontoon width measures 75 feet across at a typical pontoon, 195 feet across the SSP’s, and 240 feet across at the cross pontoons. Figure 2 shows a typical cross section of the bridge. The largest pontoons are the longitudinal pontoons, which measure 360 feet long, 75 feet wide, and 29 feet deep, weighing over 11,000 tons.

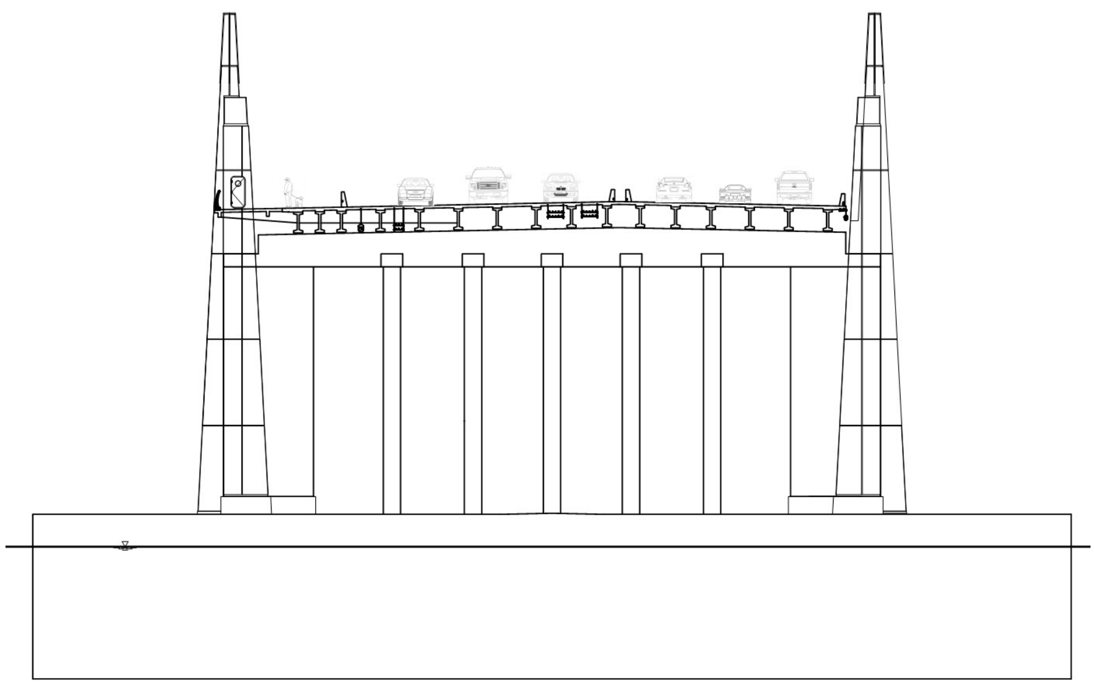

Figure 2 – Cross section view.

The floating bridge is essentially a permanently moored floating structure, anchored to the sea floor of Lake Washington. A total of 58 steel cables, 3-1/8 inch in diameter, as long as 800 feet, and tensioned up to 60 tons, tie the floating bridge to three different types of anchors. 45 precast concrete fluke anchors, 8 precast concrete gravity anchors, and 5 cast-in-place concrete drilled shaft anchors ensure the bridge remains in place and stable under wind and wave action. The floating bridge was designed to sustain a 100-year wind and wave storm event, which is defined as a storm having 98 mph winds and 6-foot waves.

The floating bridge superstructure is elevated above the pontoon foundation and consists of two different types of structures, the "low-rise" and "high-rise". The center mile is a unique segmental precast concrete ribbed deck panel system called the "low-rise". Figure 3 shows a portion of the low-rise structure under construction. A typical low-rise segment is 360 feet long, 114 feet wide, and varies in depth from 2 feet 10-1/2 inches to one foot 8-1/2 inches. A segment consists of 50 separate match-cast panels post-tensioned together transversely and longitudinally. The panels are cast complete with the traffic barriers and final roadway surface. The low-rise segment is supported directly on 42 circular cast-in-place columns rigidly connected to the pontoon. 776 panels comprise the low-rise structure.

Figure 3 - Low-rise section under construction.

The east and west portions that lead up to meet the transition spans and land structures are known as the "high-rise". The east high rise structure is shown in Figure 4. These structures resemble more conventional concrete bridges. 60 inch deep precast prestressed girders, spanning approximately 90 feet from pier to pier, support a 7-1/2 inch thick cast-in-place deck. The precast girders are supported on cast-in-place crossbeams and columns. In the west high-rise, cantilever crossbeams are post-tensioned.

Figure 4 - East high-rise section under construction.

In the low-rise, the roadway is elevated approximately 20 feet above the water. In the east and west high-rises it raises to 80 and 54 feet above the water to meet up with the transition spans. The elevated roadway is an improved feature from the original bridge and other Lake Washington floating bridges, where motorists otherwise ride directly on the pontoon deck. Elevating the roadway above the pontoon provides maintenance crews continuous access to the pontoons, reducing the need for lane closures and dangerous shoulder work. The additional height also provides additional safety to motorists during storms where waves and spray would otherwise splash up and onto the roadway.

The moveable floating bridge connects to the stationary approach structures with 190 foot long transition spans. The 8 foot deep steel plate girder transition spans are designed to accommodate fluctuations in lake elevation and movements of the floating bridge. The end piers on the floating bridge support the transition spans and a mezzanine area to access its modular expansion joint and sliding spherical bearings. Theses unique piers are flanked by two large 25 feet long by 21 foot wide precast concrete box columns and have 5 pairs of intermediate cast-in-place circular columns. The box columns provide lateral resistance for the transition span and houses stair cases for pontoon access. On the east end, the pier rises more than 70 feet above the water. On the west end, the pier stands 40 feet above the water.

Each box column is ornamented with architectural precast concrete major elements, called sentinels. They stand as a gateway to the floating bridge and serve as major architectural element. The sentinels have a steel framed skeleton clad in a multi-faceted arrangement of precast concrete panels, which extend 44 feet above the roadway and drape down to the pontoon deck. They are tallest on the east end, standing 124 feet above the water. Each is comprised of 26 different precast panels. On the west end, they stand 97 feet above the water and each has 24 different precast panels. The sentinels are crowned with a pair of illuminated reflective stainless steel mesh boxes and an obelisk shaped lantern towering above the precast. Along the bridge are 48 smaller precast concrete minor elements that mirror the larger sentinels and carry out the architectural rhythm of the corridor across the floating bridge.

Figure 5 - Nearing completion.

In its final configuration, the new bridge has two 11 foot wide general purpose lanes, one 12 foot wide high-occupancy vehicle lane, and full width shoulders in each direction. A 14 foot wide "regional shared use path" (RSUP) on the north side of the bridge provides pedestrian and bicyclist a second cross lake route. Figure 5 shows the bridge nearing completion. Along the path are 5 semi-circular rest areas, called belvederes, which were constructed using precast concrete and made integral with the bridge superstructure via closure pours. At its widest point, the bridge deck measures 130 feet across. At is narrowest point, the bridge deck measures 114 feet across.

PRECAST CONCRETE ELEMENTS

PONTOONS

The pontoons are the largest precast elements on this project, and the largest in Washington State. They are massive hollow cellular concrete boxes that serve as the floating foundation for the bridge.

Longitudinal Pontoons:	21 total 360 feet long, 75 feet wide and 29 feet deep 11,000 tons 90 precast wall panels
Supplemental Pontoons:	54 total Varies, typically 98 feet long, 60 ft wide and 28 feet deep 2,500 to 2,820 tons 9 precast wall panels

Cross Pontoons: 2 total
240 feet wide, 75 feet long and 35 feet deep
10,500 tons
57 precast wall panels

33 of the 77 pontoons were precast in a specially built 4 acre casting basin, shown in Figure 6, constructed on a 55 acre site in Aberdeen, Washington, on the Pacific Ocean. 21 longitudinal pontoons, 2 cross pontoons, and 10 SSP's were constructed at this site in 6 cycles over the course of 4 years. The remaining 44 SSP's were constructed at an existing casting basin in Tacoma, Washington on the Puget Sound.

Figure 6 -The white truss is the flood gate for the casting basin in Aberdeen, WA. On the left is a pontoon being constructed.

The pontoons were constructed using a combination of precast concrete tilt-up wall panels and form-cast concrete, as seen in Figure 7. The interior wall panels were precast flat and then lifted into the vertical position and set in the keel slab forms. A longitudinal pontoon used 90 precast wall panels. The keel slab, exterior walls, and wall joints were formed and cast in different stages. At the final stage, the pontoons were post tensioned.

Figure 7 - Precast interior wall panels erected in pontoon formwork. Joints between panels would then be cast. At the rear are the post-tension anchor heads.

At completion of each cycle, the basin was flooded and the pontoons were floated out, as shown in Figure 8. Figure 9 shows pontoons moored in Lake Washington being assembled. Each pontoon was towed one-by-one with tugboats nearly 400 miles up the Pacific Coast, into Puget Sound, through the Hiram M. Chittenden Locks, and into Lake Washington. The 75 foot width of the largest pontoons was limited by the 80 foot width of the locks.

Figure 8 - A longitudinal pontoons being floated out from the casting basin in Aberdeen, WA.

Figure 9 - Pontoons being connected at the bridge site on Lake Washington.

ANCHORS

A fluke anchor, shown in Figure 10, consists of a flat precast concrete panel that measures 35 feet wide, 26 feet tall, and 17.5 inches thick, weighing 100 tons. A steel tetra-pod frame is fixed to the face of the slab and connected to a large pad eye, which is the connection point for a pontoon anchor cable.

The 45 fluke anchors were precast in specially constructed casting beds at the north end of Lake Washington in Kenmore, about 10 mile north of the bridge site. When cured, they were lifted from the bed by an overhead crane onto a barge and shipped to the bridge site.

The fluke anchors were designed to penetrate the soft mud at the deepest parts of the lake floor. Their size and shape ensure the bridge remains in place by creating drag through the soil. To strengthen the soil, ballast rock was dumped above and in front of each fluke anchor.

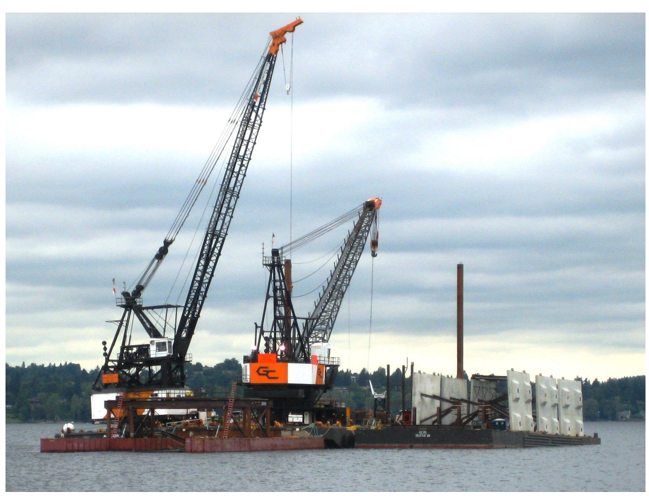

Figure 10 - Fluke anchors being installed.

A gravity anchor, shown in Figure 11, consists of a four chambered precast concrete box, measuring 40 feet wide, 40 feet long, and 24 feet tall, weighing 420 tons. Like the pontoons, these 8 gravity anchors float in their intermediate condition. Because of their massive weight a special crane, too large to enter the lake, was needed to lift the anchor. Instead of constructing them in a casting basin or on land, they were constructed 4 at a time on a barge docked in Kenmore. When completed they were transported out of the locks to Puget Sound where the D.B. General, a 700 ton floating barge crane, lifted the anchors and set them in the water.

Each anchor was pushed one-by-one back into the lake to the bridge site. Once in their location, the boxes were flooded, and lowered to the bottom of the lake. In contrast to the fluke anchors, they were set near shore on more solid soil. The gravity anchors weigh 587 tons after the chambers are filled with rock. They resist load by friction and dead weight. Ribs cast in the bottom slab enhance its frictional resistance.

Figure 11 - Gravity anchor being lifted from the barge to be set in the water in Puget Sound.

LOW-RISE SEGMENTAL DECK PANELS

The low-rise structure is a unique segmental precast concrete ribbed deck panel system consisting of 776 panels. Figure 12 shows the ribbed deck panel soffit and Figure 13 shows a typical panel. A typical panel measures 15 feet long (along the length of the bridge) and approximately 56 feet wide, and weighs more than 100 tons. A typical low-rise segment consists of 50 panels. The panels are joined longitudinally with match-cast epoxied joints, and transversely with a 2 foot wide longitudinal closure pour down the center, as shown in Figure 14. The segment is post-tensioned longitudinally along the entire length with profiled tendons in the 3 beam lines and with straight tendons distributed in the 10 inch slab. The section is also post-tensioned transversely in each rib and across the closure pour with post-tension bars.

A typical section is supported on 42 steel reinforced elastomeric bearings on cast-in-place columns anchored to the pontoons. Columns range in diameter from 18 inches to 30 inches. The size of the columns and bearings and their relative stiffness are tuned to apply load on the pontoon based on the capacity of the pontoon connection. Certain connection points were designed to resist higher loads. At these locations, the superstructure is secured to the bearings with a grouted pintle, where the bearings are sandwiched between two steel plates with retainer rings. At other locations bearings bear directly on grout pads on the soffit and embedded steel plates with a retainer rings on the column. Shear is resisted through friction and restraint from the retainer ring.

Figure 12 - The ribbed deck panel soffit in the low-rise section.

The panels were precast in Kenmore in two specially constructed casting beds, one for the north panels and one for the south. Panels were match-cast, complete with the traffic barriers and the final driving surface, against the previously cast panel. This allowed for adjustment to maintain geometry control and ensured they fit together. Steam curing allowed them to maintain a 24 hour casting cycle. Once they achieved strength, the panel was lifted from the bed and post-tensioned transversely. The panels were delivered to the bridge site by barge.

Steel false work was erected along each column line, for the entire pontoon segment. A barge crane then set the panels on the false work, which had PTFE pads beneath the panels to ease adjustment. High strength bars were used to temporarily hold the panels in place while the joints were epoxied. The north and south sections were temporarily post-tensioned longitudinally, while the longitudinal closure pour was installed and cured. Once cured, post-tension bars were installed transversely across the closure pour and the remaining post-tension tendons stressed. After the bearings were grouted the 360 foot segment was set on its columns. During peak construction, up to 18 panels were set in a day, lending to a rate of 135 feet of roadway per day. The entire 5,580 feet of low-rise was erected in less than one year.

Figure 13 - Setting a low-rise panel on the false work.

Figure 14 - Temporary bars holding panels in place while the center longitudinal closure pour is constructed.

HIGH RISE BOX COLUMN PANELS

The box columns consist of full height precast panels joined with closure pours, as shown in Figures 15 and 16. The largest panels measure 56 feet tall, 16.25 feet wide, and 9 inches thick, and weigh 55 tons. The panels were precast in beds at Kenmore and delivered to the bridge site on barges.

Because of their long thin shape, steel strong-backs were fastened to the panels to strengthen them for handling and installation. A barge crane, together with a special steel jig secured to the stern of the delivery barge, was used to tilt the panel into the vertical position and lift it into place on the pontoon, as shown in Figure 15. Two structural steel feet were fixed to the base to support the panel in the closure pour, while the panel was held vertical with pole braces. The panels were joined together with closure pours at the four corners and along the base, where the panel reinforcement lapped with bars extending from the pontoon.

Figure 15 - Pontoon W precast box column panel being tilt vertically.

Figure 16 - Pontoon A precast box column panels being erected.

PRESTRESSED GIRDERS

The east and west high-rise superstructure has a total 331 precast prestressed girders. Girders are standard WSDOT W58G I girders, typically 90 feet long. W58G girders were selected as the most efficient and economical member, balancing superstructure weight and cost. They were constructed at a precast plant in Tacoma, Washington, and barged to the bridge site. A single barge crane set the girders in place using a two-point pick configuration with a large spreader beam. A typical elevated structure girder span is shown in Figure 17.

Figure 17 - Precast girders set on a west high-rise post-tensioned cantilever crossbeam.

BELVEDERES

The belvederes along the RSUP offer pedestrians and bicyclist rest areas and outlooks to take in the views. They were constructed separately from the bridge superstructure, as independent precast units, and later connected with closure pours. Figures 18, 19, and 20 show the east high-rise belvedere at various stages of construction.

In the high-rise, belvederes are located near the ends of the floating bridge, adjacent to the sentinels. They cantilever 14 feet beyond the edge of the bridge deck and are 51 feet wide. An additional exterior girder and 6 lines of cast-in-place diaphragms, or ribs, were added to superstructure to support the cantilever. 16 - 2 strand tendons anchored at approximately the center of the deck extend through the deck to the edge of the belvedere.

The belvedere units were precast on the bridge deck and later lifted in place by a barge crane. It was temporary held in place beyond the bridge deck, by steel wide flange beams secured with high strength coil rods, as shown in Figure 19. After the closure pour was installed and cured, the post tension tendons were stressed and grouted, and false work removed.

The low-rise belvederes are 56 feet wide and extend 14 feet beyond the low-rise deck panel. They are supported on a circular column on the pontoon. These belvederes were also precast in forms located on the bridge deck. When cured, they were lifted in place, set on the column, and joined with a closure pour.

Figure 18 - Rebar and formwork assembled on the bridge deck getting ready to cast the belvedere.

Figure 19 - Steel false work supporting the precast belvedere while the closure pour and post-tension is installed.

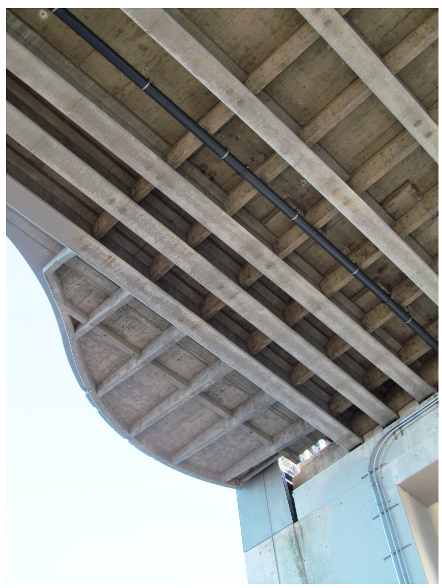

Figure 20 - Soffit of the belvedere with the additional girder and ribs.

ARCHITECTURAL SENTINELS

The sentinels are architectural features that mark the transition points between land and water. They stand as a gateway to the floating bridge and act as visual points of reference. Both users crossing the bridge and boaters or viewers from afar will recognize these prominent features. The sentinels also serve a structural function as they house stairwells that allow maintenance crews to access the pontoons. The sentinel is shown in Figures 21, 22, and 23.

At the center of the sentinel, is a tall slender pylon called the spire. The spire extends from the pontoons up above the roadway, towering as high as 124 feet above the water. At the top of the spire is a unique lantern with metal reveals that extend full height of the sentinel. On the shoulders of the sentinel are illuminated reflective stainless steel mesh boxes.

The tapered shape of the sentinel and its multiple facets means that each precast panel needed to be unique and most required compound angles and miters to be cast. The precast cladding is supported on a steel tower that is anchored to the box columns. The frame was designed to transfer nearly all of its loads back to the box column and impose minimal load on the pontoon below.

The precast concrete panels were constructed at a precast plant in Redmond, Washington and transported to the bridge site by truck. The panels are 5 inches thick and have a sand blasted finish and pigmented sealer finish.

Figure 21 - Nearly complete sentinel in the west high-rise.

Figure 22 - Sentinel steel framing to support the precast cladding, as seen at the roadway deck.

Figure 23 - East high-rise sentinels as seen during the grand opening day.

ARCHITECTURAL MINOR ELEMENTS

The minor elements, shown in Figure 24, are decorative lighting features that resemble the sentinels and continue the architectural rhythm of corridor across the floating bridge. They stand 10 feet above the roadway on the north and south traffic barriers. The base is constructed of precast concrete and sits on a steel post anchored in the traffic barrier. At the top of the precast is a stainless steel lantern similar to larger sentinels. The precast base was constructed at a precast plant in Redmond, Washington.

Figure 24 - Minor element with precast concrete base and stainless steel translucent panel fixture.

CONCLUSION – BENEFITS OF USING PRECAST

Construction of the new floating bridge maximized the use of precast concrete to address the challenges of limited access, overwater work, and an accelerated schedule. Site access is limited to just a few hundred feet of shoreline on the east end and was located in a residential neighborhood and down a steep grade. The only other access was via water. Using precast elements allowed multiple construction activities to take place simultaneously, accelerating construction, and also took advantage of the water access for delivery and erection. It also significantly reduced the amount of wet concrete needing to be cast in the lake and transported to site. Precast concrete provided huge benefits and efficiencies to the project.

The new SR520 floating bridge was open to traffic in April of 2016

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