

Specialty Precast Solutions

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ABSTRACT

Prestressed concrete components have been routinely used by the railroads for short-span bridge solutions over the past several decades. These components are typically comprised of standard shapes with standard lengths, such as the 30-foot double cell box beam, 20-foot solid slab, and include miscellaneous cap and wingwall components. In recent years, engineers and owners have advanced innovative solutions using precast prestressed concrete products to span longer distances. In Oregon, several projects have taken advantage of these technological capabilities, using longer-span precast prestressed concrete girders.

The Radiant Drive project in Salem, OR, utilized side-by-side box beams to span 63'-0" to carry heavy haul trains over a popular vehicular road. The section included three interior 4'-0" deep voided box beams and two 5'-6" voided box beams. A total of (16) transverse tie rods tensioned to 50 kips were located at five points along the span to sufficiently connect the five beams together.

The OMSI Viaduct Bridge is a Streetcar-only bridge that carries passengers riding the Portland Streetcar over multiple railroad lines. This bridge features four spans of a bulb tee girder that is 5'-0" in depth. Span 2 is a modification of the standard girder and has built-in camber to match the site's steep crest vertical curve, which was a unique solution to meet the railroad clearances below and the overhead powerlines above.

Several TriMet expansion projects have been completed in the Portland, OR, area over the past 15 years. These projects have utilized long-span precast prestressed concrete bridge girders to carry Portland's light rail traffic over various crossings. Span lengths in some cases are at 175'-0", with girder depths at 7'-6". The combination of using a deep section and long girder spans have allowed the owner more flexibility in planning routes and locating bridges.

INTRODUCTION

This paper focuses on three projects that highlight unique solutions using precast prestressed concrete products for rail crossings. The first project is the Radiant Drive Bridge, which carries heavy freight trains across it. It used side-by-side pretensioned voided box beams to span a distance of 65'-0". The three interior box beams had a section depth of 4'-0", while the two exterior box beams had a section depth of 5'-6". The second project is the OMSI Viaduct Bridge, which carries the Portland Streetcar across multiple railroad tracks. This one is a 425-foot-long 4-span precast prestressed concrete girder bridge. Site constraints included clearing the railroad tracks below and avoiding the many overhead powerlines, which required a steep crest vertical curve alignment. The solution was to fabricate a girder with built-in camber. The final project includes several expansions of TriMet's light rail MAX system. This system uses various bridge types, including numerous precast prestressed concrete girder bridges. Span lengths in some cases reach 175'-0", with section depths at 7'-6". All three projects highlight a unique solution to meet the requirements of various railroad loading and crossing criteria.

PROJECTS

Radiant Drive Bridge

Located in Keizer, Oregon, the Radiant Drive Bridge was constructed in 2005 to carry Portland and Western Railroad trains over Keizer Station Blvd. The bridge parallels a vehicular bridge to the east (Stadium Dr. over Keizer Station Blvd.) and sits just south of a large shopping center and baseball stadium. Keizer Station Blvd. is the main access road to the shopping center from the city and from Interstate 5 traffic. Figure 1 shows an aerial view of the site and the bridge location in relationship to the freeway, the shopping center, and the baseball stadium.



Figure 1: Aerial View of the Radiant Drive Bridge Site

The key to this project was eliminating the at-grade crossing. The land occupied by the shopping center and the baseball stadium was almost entirely undeveloped prior to the bridge being constructed. High volumes of traffic were anticipated to access the new development, and therefore, an at-grade crossing was not a viable solution. The idea to use a longer box girder section with transverse post-tensioning came from a similar project that was completed on the Arbor Rail Line near Nebraska City, Nebraska, for the Omaha Public Power District (1).

Figure 2 shows an exterior box beam being set on the temporary steel caps. The box beams were tied together using (16) high-strength post-tension threaded bars conforming to ASTM A722. Each bar was 1.375" diameter in size, with an ultimate strength of 150 ksi, and tensioned to 75% of ultimate strength (~112 ksi). The high transverse post-tensioning force from the double tie rod system ensured that the five beams would act together as a unit to resist the design loads, namely, AREMA's Cooper E-80 live load.



Figure 2: Box Beam Erection



Figure 3: Superstructure Assembled & Waiting to be Moved

To maintain rail traffic, the foundations were installed underneath the line and the new bridge was constructed adjacent to the existing line. A weekend change-out allowed the contractor to remove the existing line and slide the new bridge into place. Figure 3 shows the constructed bridge sitting on temporary steel bent caps, ready to be slid into its final spot.

Once the bridge was moved into place, the contractor excavated the ground below and continued with construction of the roadway. Figure 4 shows the tracks crossing the bridge prior to excavation, and Figure 5 show the bridge in use by a Willamette & Pacific train just after the line reopened.



Figure 4: Operational Bridge after Change-Out



Figure 5: Train Crossing Bridge Prior to Excavation

The bridge spans 65'-0" and consists of three 48"-deep interior voided box beams and two 66"-deep exterior voided box beams. The interior box beams used (30) strands and the exterior box beams used (44) strands. The strands were $\frac{1}{2}$ " diameter, low relaxation, grade 270 prestressing strands per ASTM A416. The strands were stressed to 31,000 pounds each at jacking for a total jacking force of 1.3 million pounds for the exterior box beam and just under 1 million pounds for the interior box beams. Figure 6 shows construction of the roadway below the bridge. The completed bridge is shown in Figure 7.



Figure 6: Roadway Construction Underneath Bridge



Figure 7: Completed Structure

OMSI Viaduct

In Oregon, the Portland Streetcar is a transportation system that serves riders in and around the downtown Portland area. It was opened in 2001, has been gradually upgraded and expanded over the past 15 years, and see roughly 20,000 riders per day. The Streetcar system is operated by Tri-County Metropolitan Transportation District of Oregon (TriMet). It is owned by the City of Portland and is managed by Portland Streetcar Incorporated.

In 2009, the Portland Streetcar expanded their line along the east side of the Willamette River in Portland, OR, with a loop extension. The loop begins in the Pearl District, travels across the Broadway Bridge on NE Broadway Street, connects with NE Weidler Street and then travels to the Lloyd Center at NE 7th Avenue. It then heads south on Martin Luther King Jr Boulevard to the Oregon Marine Science Institute (OMSI), and then returns North on Grand Avenue to Broadway.

Part of this expansion project included a new Streetcar-only bridge, referred to here as the OMSI Viaduct Bridge. It was constructed from Martin Luther King Jr Boulevard, over the Union Pacific Railroad (UPRR) tracks to Water Street, which is adjacent to OMSI. The bridge is a 425-foot-long 4-span precast prestressed concrete girder bridge. It was designed to accommodate one or two streetcar vehicles producing maximum force effects on the structure (longitudinally, transversely and vertically). Loading combinations included single vehicles passing on adjacent tracks and two vehicles on one track with a minimum distance of 27.17 feet between the last axle of one vehicle and the first of another. Figure 8 shows the 94-kip streetcar live load vehicle. Span 2 crosses over two UPRR main line tracks and a siding. Span 3 crosses over the Oregon Pacific Railroad (OPRR) main line track. Each span consists of four girder lines for a total of 16 concrete girders (see Figure 9).

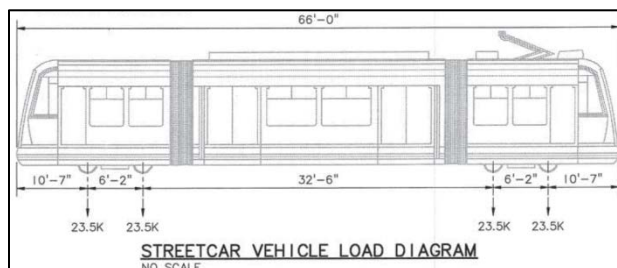


Figure 8: Portland Streetcar Loading Diagram

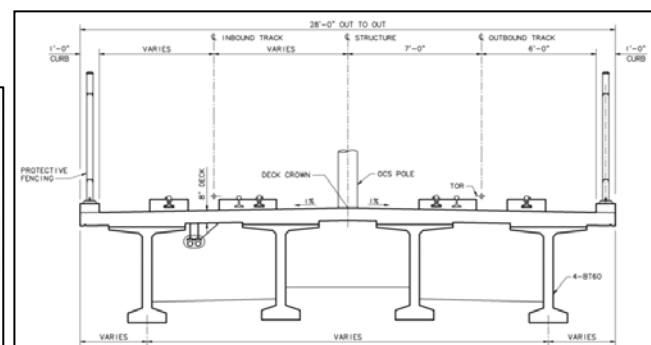


Figure 9: Typical Bridge Section

The site had several challenging constraints to contend with, including a tight vertical clearance window over the UPRR tracks, as well as numerous overhead powerlines. A steep crest vertical curve was required to avoid conflicts with these two constraints. The grade transitioned from +2.7% to -7.0% in 120

feet. The engineer and the precast manufacturer developed a solution that utilized a bulb tee girder with built-in camber. The elevation profile shown in Figure 10 emphasizes the built-in camber of the span 2 girders in comparison with the standard girders in spans 1, 3, and 4.

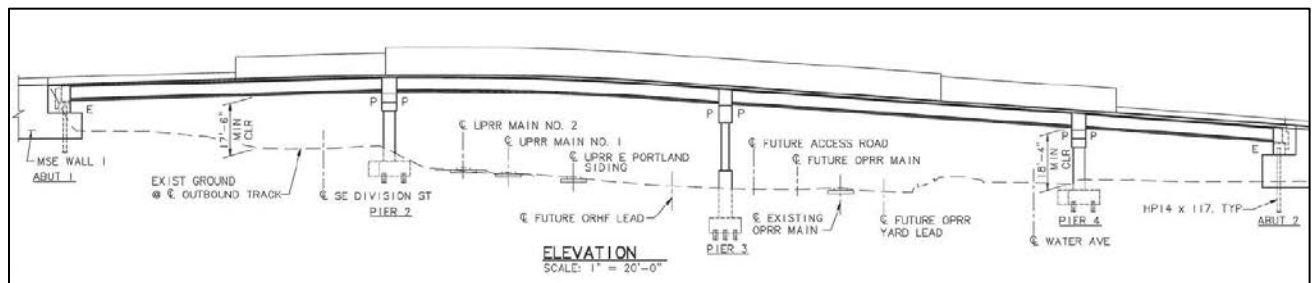


Figure 10: Elevation View of the OMSI Viaduct Bridge

The precambered girders in span 2 were developed using Oregon Department of Transportation's (ODOT) standard 5'-0" deep bulb tee section (BT60). The section includes a 4'-0" top flange, a 2'-0" bottom flange, and a 6" web. They were approximately 115' long and were produced with 1'-11/4" of built-in camber. The design specified a transfer concrete strength of 7000 psi and a 28-day concrete strength of 8000 psi. The girders had (48) 1/2" diameter, low relaxation, grade 270 prestressing strands per ASTM A416. The strands were stressed to 31,000 pounds each at jacking for a total girder jacking force of just under 1.5 million pounds. The strand pattern detail is shown in Figure 11.

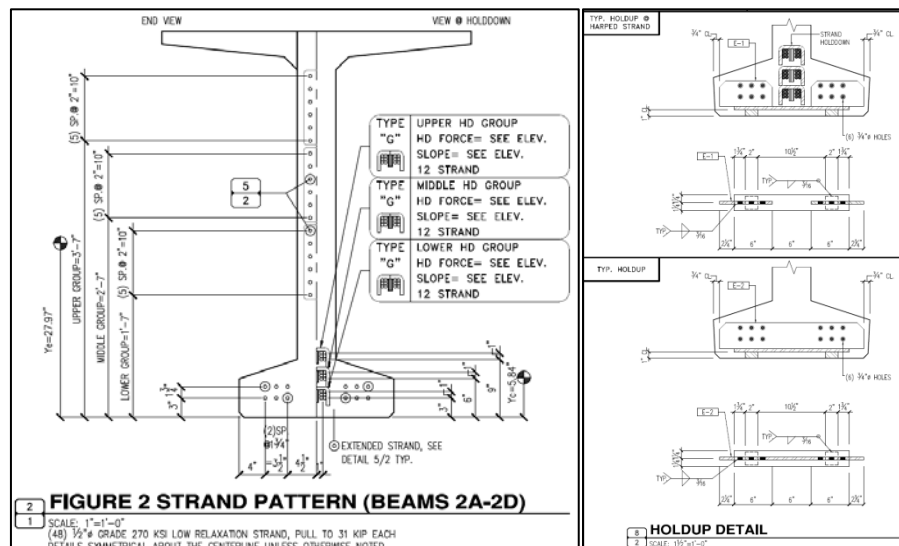


Figure 11: Strand Details and Hold-Up Device Cross-Section

The form was constructed of segmented straight sections connected via pie shaped wedge pieces. This approach was utilized to mimic a radius profile and keep form costs down. The pattern included (36) harped strands and (12) "straight" strands. Figures 12 and 13 show the form profile and the strand pattern geometry.



Figure 12: Form Profile with Cage & Strands



Figure 13: Strand Profile

The “straight” strands followed the segmented profile and required hold-up hardware at each of the pie shaped wedge form pieces to transfer forces to the ground. Hold-down hardware was required at each end of the form to deflect the strands back up towards the reaction posts. Figure 11 shows the detail of the hold-up device and Figure 14 shows it in the form. Figure 15 shows the hold-down device (painted orange and bolted to the ground).



Figure 14: Strand Hold-Up Device



Figure 15: Strand Hold-Down Device

Unique stirrups were detailed at the hold-up devices to resist the downward forces from the strands. Compared with the standard strand pattern in a BT60 girder, the modified strand pattern in the precambered girder, combined with the section's varying center of gravity, resulted in additional design considerations regarding deflection and camber calculations. In addition to the 13.25" of built-in camber, the section also had a design camber of 4.50".

Storing, handling, shipping, and erecting the girders required extra care. Stresses along the top and bottom fibers of the girder were checked during all stages of construction. Figure 16 shows the girder just after the prestressing force was transferred to the member.



Figure 16: Girder Just After Release of Prestressing Force

Figure 17 shows several of the girders bunked on trucks ready for transport. The girders were bunked 12'-0" from each end. The large overhang was needed to navigate the turns from the production facility to the jobsite. The stresses in the top fiber of the beam at its centerline were checked prior to shipping to ensure adequate capacity. The as-built 28-day strength of the concrete was 12,600 psi.



Figure 17: Girders Bunked on Trailers Ready for Shipping

Figure 18 shows the erection crew installing the second girder in span 2. Each of the girders were tied down to the cap and braced to the adjacent beam for adequate stability. The cranes had to keep the girder below the overhead powerlines and above the train envelope.



Figure 18: Girder Being Erected Onsite

Figure 19 shows a UPRR train passing underneath after the girder erection, diaphragm casting, and deck casting.



Figure 19: UPRR Train Passing Underneath Span 2

Figure 20 shows the OMSI Viaduct Bridge in use by the Portland Streetcar after all construction had been completed (2).



Figure 20: The Portland Streetcar Crosses the Completed Bridge (2)

TriMet Light Rail

TriMet – in addition to operating the Portland Streetcar – operates and maintains the light rail infrastructure in and around the Portland metropolitan area (known as the Metropolitan Area Express, or MAX). Passengers utilize the MAX lines daily for their commuting needs. Riders can either travel on lines in and around the downtown area, or travel on specific lines to the outlying communities. The Blue Line takes riders from Hillsboro in the west to Gresham in the east. The Red Line takes riders from Beaverton in the southwest to the Portland Airport in the north. The Yellow Line takes riders from Portland State University (PSU) and the downtown region north to the Expo Center. The Green Line takes riders from PSU and the downtown region southeast to the Clackamas Town Center. The Orange Line takes riders from the downtown region southeast to Milwaukie. Figure 21 shows each of the lines and their general route (3).

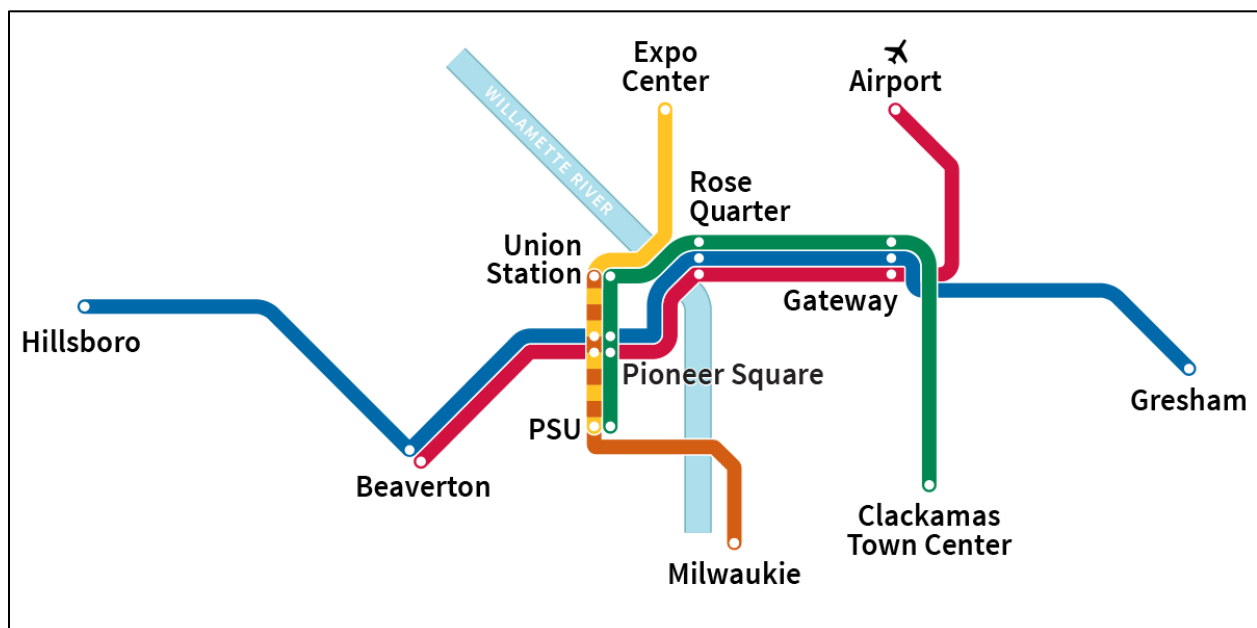


Figure 21: TriMet's MAX Line Routes (3)

The two most recently completed MAX projects include the Green Line, completed in 2009, and the Orange Line, completed in 2015. The largest section utilized was a 7'-6" tall bulb tee girder (BT90). The BT90 included (54) 0.6" diameter prestressing strands. The prestressing steel conformed to ASTM's A416 specification, and is 7-wire low relaxation, grade 270 strand. Each strand was stressed to 75% of fpu, or 43,900 pounds. For a typical (54)-strand girder, the total jacking force is just over 2.3 million pounds. The design concrete strength at transfer of prestress and at 28 days was 7,000 psi and 9,000 psi, respectively. The weight of a BT90 is 1,040 pounds per foot, or 180,000 pounds for a 173-foot beam. Each beam consisted of 42 cubic yards of concrete.

The bridges were designed to accommodate all combinations of one, two, three and four car trains of light rail live load that produce maximum force effects on the structure (longitudinally, transversely and vertically). The combinations include trains passing on adjacent tracks. The live load is per TriMet's light rail design criteria.

Green Line

The Green Line – also referred to as the I-205 line – added eight new stations along the 6.5-mile section that parallels I-205. The line connects the Gateway Transit Center to the Clackamas Town Center, with most of the line using the grade-separated, previously unfinished I-205 Transitway. This line added nine bridges constructed with precast prestressed concrete girders, with lengths ranging from 35 feet to 168 feet. Table 1 summarizes the precast prestressed concrete bridges on the Green Line.

TABLE 1: Interstate 205 Light Rail Project - Green Line - Precast/Prestressed Concrete Girder Structures

Bridge	Girder Length	Product		Strands		Strength (psi)	
		Section	Depth	Size	No.	Transfer	28 Days
Johnson Creek Blvd	167'-2"	BT90	7'-6"	0.6"Ø	52	7000	9000
Johnson Creek	38'-1"	12" Slab	1'-0"	1/2"Ø	28	6000	7500
92nd Avenue	149'-5"	BT90	7'-6"	0.6"Ø	46	7000	9000
Foster Road	161'-2"	BT90	7'-6"	0.6"Ø	52	7000	9000
Harold Street	101'-3"	BT60	5'-0"	1/2"Ø	44	7000	9000
Powell Blvd	166'-3"	BT90	7'-6"	0.6"Ø	52	7000	9000
Stark Street	35'-10"	21" Slab	1'-9"	1/2"Ø	18	5000	4000
Washington Street	35'-10"	21" Slab	1'-9"	1/2"Ø	18	5000	4000
Springwater Trail	64'-7"	30" Slab	2'-6"	1/2"Ø	38	5000	4500

Orange Line

The Orange Line – also referred to as the Portland-Milwaukie Light Rail Project (PMLRT) – is 7.3 miles in length and travels from Union Station in downtown Portland to Park Avenue in Milwaukie. This project added five bridges constructed with precast prestressed concrete girders, with lengths ranging from 55 feet to 173 feet. Table 2 summarizes the precast prestressed concrete bridges on the Orange Line.

TABLE 2: Portland to Milwaukie Light Rail Project - Orange Line - Precast/Prestressed Concrete Girder Structures

Bridge	Girder Length	Product		Strands		Strength (psi)	
		Section	Depth	Size	No.	Transfer	28 Days
LRT Over Powell Blvd	149'-5"	WF83G	6'-11"	0.6"Ø	56	7000	9000
Harold Street	127'-5"	WF58G	4'-10"	0.6"Ø	46	6500	7000
Tacoma Branch	139'-9"	BT84	7'-0"	1/2"Ø	58	7000	9000
Tillamook Branch	172'-9"	BT90	7'-6"	0.6"Ø	54	7000	9000
Kellogg Branch	60'-2"	30" Slab	2'-6"	1/2"Ø	42	5000	6000

Johnson Creek Blvd Bridge

The Johnson Creek Blvd Bridge is a part of TriMet's Green Line and is the longest of the bridges between the projects mentioned in Tables 1 and 2. It includes (40) 7'-6"-deep bulb tee girders, with four girders per span. The longest girder on this structure was just over 167 feet. Figure 22 shows one of the girders being erected, and Figure 23 shows the deck casting.



Figure 22: Girder Erection on the Johnson Creek Blvd Bridge



Figure 23: Deck Pour on the Johnson Creek Blvd Bridge

The completed 1400-foot-long 10-span bridge is shown in Figure 24 with Interstate 205 to the right.



Figure 24: The Completed Johnson Creek Blvd Bridge

CONCLUSION

Prestressed concrete components have been routinely used by the railroads for short-span bridge solutions over the past several decades. Several projects have been presented showing how longer-span members have been used to carry railroad loads over greater distances. The Radiant Drive Bridge utilized voided box beams to carry heavy haul trains across a 65-foot span. A 5-foot-deep bulb tee with built-in camber was used to carry Portland Streetcar vehicles over UPRR mainline tracks. TriMet's recent expansions have included girder sections 7'-6" deep and spanning 175 feet to transport MAX trains with passengers throughout Portland and its surrounding areas.

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