DESIGN DEVELOPMENT AND CONSTRUCTION OF I-5 GATEWAY PEDESTRIAN BRIDGE EUGENE / SPRINGFIELD, OREGON, USA

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ABSTRACT:

As a part of a major highway interchange improvement project at Beltline Highway and Interstate 5 in Eugene, Oregon, an innovative cable-stayed pedestrian bridge was constructed primarily of precast concrete structural elements. The cable-stayed pedestrian bridge uses segmental precast concrete deck panels, precast concrete main tower, and precast concrete MSE wall approaches. The precast concrete structural elements are combined to allow rapid construction over the busy interstate freeway, provide extremely good stability at all stages of construction, and eliminate forming for the composite cast-in-place topping slab. This innovative use of precast concrete structural elements, especially the deck panels, has also successfully been used by the designers in stress-ribbon, through arch, and suspension bridge types, as well as the cable-stayed bridge presented in this paper. The background and development of the general bridge concepts used in previous projects serve to improve the understanding of the design of the I-5 Gateway Pedestrian Bridge and show the versatility of the methodology.

Keywords:

Pedestrian Bridges, Precast Concrete Deck Panels, Precast Concrete Deck, Cable-stayed bridge, Segmental

INTRODUCTION

OBEC Consulting Engineers has designed a number of innovative long-span pedestrian bridges in association with Dr. Jiri Strasky, PhD, P.E., Consulting Engineer, since 1993. During this time, Gary Rayor, P.E., S.E., Principal Engineer for Specialty Structures with OBEC, and Dr. Strasky have successfully completed four long-span pedestrian bridges in Oregon including Willamette River (DeFazio) Bridge, Grants Pass (Rogue River) Bridge, McKenzie River (Wildish) Bridge, and Springwater (McLoughlin Boulevard) Bridge. Currently, our fifth pedestrian bridge collaboration, the I-5 Gateway Pedestrian Bridge, is under construction and scheduled for completion in December 2008.

The purpose of this paper is to present the design and construction of the I-5 Gateway Pedestrian Bridge project. This bridge includes many unique details and innovations developed by Dr. Strasky and OBEC using the opportunities and cost efficiencies presented by the use of precast concrete structural elements. This project also demonstrates how precast concrete construction allows for rapid and safe bridge construction over a busy interstate freeway without traffic interruption.

The I-5 (Gateway) Pedestrian Bridge was a needed pedestrian and bicycle transportation element at the Interstate 5 and Beltline Highway interchange, which is undergoing major expansion in Eugene, Oregon.

Photo 1. I-5/Beltline Interchange–Phase 1 (Photo: Oregon Department of Transportation [ODOT])

Photo 2. I-5 (Gateway) Pedestrian Bridge under construction (Photo: ODOT)

Throughout this paper, all photos are by OBEC Consulting Engineers, Eugene, Oregon, unless otherwise noted.

The background and development of the general bridge concepts used in previous projects serves to improve the understanding of the design of this bridge and show the versatility of using very light segmental precast concrete deck panels. The panels are generally erected on internal prestressing strand "bearing cables" for the stress ribbon type bridge or externally on cables or suspenders for the suspension, through arch, and cable-stayed type bridges.

The precast concrete deck panels are either monolithic or serve as a form for a composite cast-in-place topping slab on the precast concrete deck panels. In addition, in all of our bridges the main spans are longitudinally post-tensioned to provide asymmetrical live load bending resistance, to provide stiffness for user vibration comfort, to prestress the panel joint closures, and to pre-compress the deck section against cracking for enhanced longevity.

The deck system has proved to be extremely versatile in all bridge types considered so far. In the case of the I-5 Gateway Pedestrian Bridge, the precast concrete deck panels are used in the cable-stayed structure type. Other precast concrete structural elements were also used for the main tower and mechanically-stabilized earth (MSE) wall approaches to the bridge. The commonalities of our five Oregon pedestrian bridges include use of precast concrete deck panels, long cable-supported main spans, slender profile, cost effectiveness, and pleasing aesthetics. The following Table 1 summarizes some of the interesting statistics of the bridges:

Table 1. Summary of interesting statistics of the OBEC/Strasky precast deck pedestrian bridges (all located in Oregon, USA).

Bridge	**Picture**	**Type**	**Main Span/ Overall Length/Width**	**Bid/ Completion**	**Bridge Cost/SF (2009 Dollars)**
DeFazio (Willamette River) Bridge		Suspension	338/606/14 (ft) 103/185/4.2(m)	1996/1999	\$550/ sq ft \$5900/ sq m
Grants Pass (Rogue River) Bridge		Stress Ribbon	278/658/14 (ft) 85/201/4.2(m)	1999/2000	\$275/ sq ft \$2900/ sq m
McKenzie River (Wildish) Bridge		Suspension (Self Stiffened)	430/670/19 (ft) 131/204/5.7(m)	1999/2001	\$375/ sq ft \$4100/ sq m
Springwater Trail (McLoughlin Blvd.) Bridge		Through Tied Arch	241/302/12 (ft) 73/92/3.7(m)	2004/2006	\$480/ sq ft \$5200/ sq m

I-5 Beltline (Gateway) Bridge		Cable-stayed	203/503/14 (ft) 62/153/4.2(m)	2006/2008	$375/ sq ft $4100/ sq m

A brief background of the precast concrete pedestrian bridges leading to the design of the I-5 Gateway Pedestrian Bridge is presented herein.

BACKGROUND OF PRECAST CONCRETE DECK PANEL PEDESTRIAN BRIDGES

STRESS RIBBON BRIDGE TYPE

Dr. Strasky and a team of engineers developed the stress ribbon bridge using segmental precast concrete deck panels in the former Czechoslovakia in the 1970s. A very cost-effective long-span cable-supported bridge type, stress ribbon bridges are extremely slender with typical depth to span ratio between l/200 and 1/500. Also the bridges are very strong during load testing, as shown in Photos 3 and 4.

Photo 3. Stress ribbon pedestrian bridge in Prague-Troja being load tested with 38 vehicles – 1980. (Photo: J. Strasky)

Photo 4. Stress ribbon pedestrian bridge in Brno-Komin being load tested with military vehicles – 1982. (Photo: J. Strasky)

The precast concrete deck panels are erected on "bearing cables" that consist of prestressing strand bundles anchored at abutment blocks to resist the high horizontal force associated with a suspension structure with very little sag. The method of erection and basic configuration of the stress ribbon precast concrete deck panels are shown in Photos 5 and 6.

Photo 5. Erection of a stress ribbon bridge deck panel on bearing cables over the Sacramento River in northern California, USA – 1989. (Photo: J. Strasky/ C. Redfield)

Photo 6. Erection of a stress ribbon bridge deck panels on bearing cable over the Rogue River, Grants Pass, Oregon, USA – 1989.

The bearing cables support the precast deck panels, forming a completely solid deck from which further stages of the construction are facilitated. In general, full length post-tensioning is then installed after the deck panels are fully erected, composite cast-in-place deck closure/topping slab cast, and full length post-tensioning is applied. The result is that the bridge deck acts as a tension structure; however, it is completely pre-compressed across the entire deck section, making it a very stiff structure. Calculation, user experience, and wind tunnel testing confirm that the bridges meet U.S. and European bridge codes for vibration and comfort.

SUSPENSION BRIDGE TYPE

Dr. Strasky pioneered the use of precast concrete deck panels in a long-span suspension bridge, the Lake Vranov Bridge, in the Czech Republic in 1988. OBEC, in association with Dr. Strasky, has extended this pioneering effort in the design and construction of precast concrete deck panel suspension bridges in the United States, having designed two similar projects in Oregon: Willamette River (DeFazio) Bridge in Eugene, Oregon, completed in 1999; and the McKenzie River (Wildish) Aggregate Ore Conveyor Bridge near Coburg, Oregon, completed in 2001. The Willamette River, McKenzie River, and the Lake Vranov Bridges have main spans of 338, 430, and 840 feet (103, 131, and 256 meters), respectively. The Willamette River (DeFazio) Pedestrian Bridge was federally funded by the Federal Highway Administration (FHWA), and the innovative aspects of the design and construction were subjected to thorough review by FHWA Washington Structures Office and Oregon Department of Transportation (ODOT) Bridge Section.

Photo 7. Willamette River (DeFazio) Bridge

Photo 8. McKenzie River (Wildish) Bridge

Photo 9. Lake Vranov (Swiss Bay) Pedestrian Bridge (Photo: J. Strasky)

Details of precast concrete panel erection are similar to the stress ribbon bridges in that the deck panels are delivered into position on temporary erection cables that act in a similar way to bearing cables.

Photo 10. Erection of precast deck panels on the McKenzie River Bridge by use of temporary erection cables and wheeled trolley.

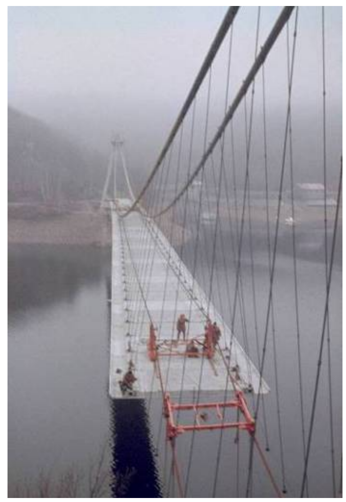


Photo 11. Erection of precast deck panels on the Lake Vranov Bridge by use of temporary erection cables and wheeled trolley. (Photo: J. Strasky)

THROUGH ARCH BRIDGE TYPE

In association with Dr. Strasky, OBEC more recently developed the use of precast concrete deck panels in a tied through arch bridge on the McLoughlin Boulevard Bridge. The precast concrete deck panels can be used in the tied or true arch form. By the simple addition of bearing cables an arch tie is formed with the additional benefits of being able to deliver the panels into position during erection, and the foundation can consist entirely of vertical support elements. The resulting structural system is very constructible and redundant as shown in Figure 1. The slenderness and beauty of the final bridge is expressed in Photo 12.

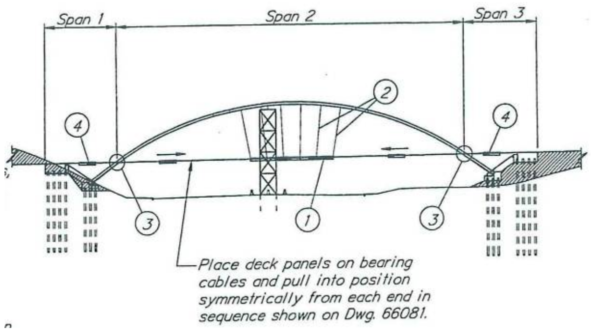


Figure 1. The bridge structural system using bearing cables and precast deck panels presents concise and logical load paths. (Graphic: OBEC design drawings)

Photo 12. The resulting structural arrangement clearly shows the bridge to be slender and aesthetically-pleasing.

CABLE-STAYED BRIDGE TYPE

Extending the use of precast concrete deck panels to other structures types, Gary Rayor and Dr. Strasky designed a gateway/signature cable-stayed pedestrian bridge, which is currently under construction, for Oregon DOT. The resulting structural system is, again, extremely simple and constructible[1]. The simplicity of erection is expressed in Figure 2 and Photo 13.

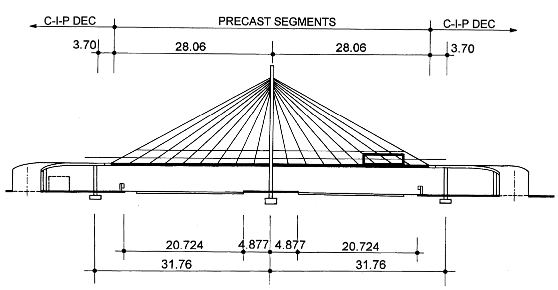


Figure 2. The bridge structural system using precast deck panels represents an extremely simple structural solution to the typically complicated cable-stayed bridge form. (Graphic: J. Strasky)

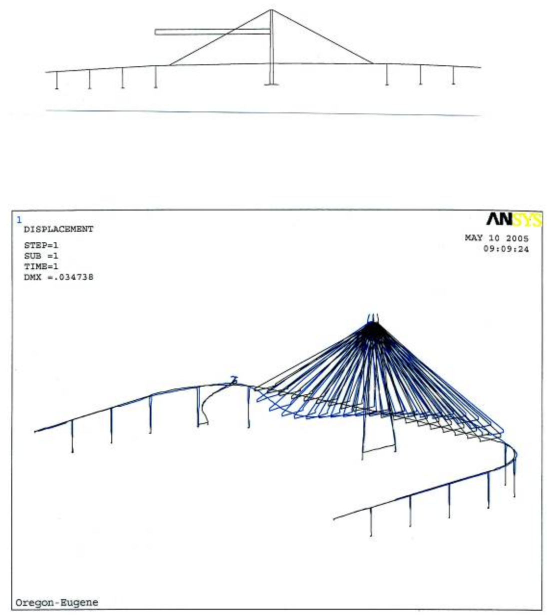
Photo 13. The precast concrete deck panels are erected over Interstate 5 in three evenings with no impact to the freeway traffic.

PRECAST DECK PANELS AND STRUCTURAL INTEGRATION INTO THE SUPERSTRUCTURE

In all of the pedestrian bridges discussed, the common element is the precast concrete deck panels as the major element of the superstructure. The use of the precast deck panels for segmental placement of the superstructure allows relatively small equipment to be used to set the panels. In cases where shoring or equipment is not possible or economical to locate, such as over large rivers, the panels can be pulled into position on bearing cables or temporary erection cables. In the case of bearing cables, these can also act as a self stiffening structure tie element or provide a portion of the required longitudinal prestressing force in the structure.

Where bearing cables are incorporated into the structure, the precast concrete deck panels are hung from the bearing cables and the other supporting elements, such as suspenders. A continuous composite topping slab is then generally placed on the precast deck panels, bonding the bearing cables into the structure. The panels serve as formwork/falsework for the topping slab. The topping slab itself allows additional opportunities to install full length post-tensioning to be cast into the structure, and when post-tensioned the entire structure becomes monolithic for live and lateral loading, such as wind and seismic. The full length post-tensioning pre-compresses the entire deck section including panels and topping slab. The final full length deck post-tensioning serves to resist bending in the deck under various load cases and stiffens the structure to the extent that user vibration and comfort on the slender structures has never been a problem.

The typical controlling design case for superstructures using the precast deck panels/cast-in-place topping slab/bearing cables and full length post-tensioning is the asymmetrical live load case where full pedestrian loading—typical 85 psf (4.1 kPa)—is applied to half of the main span[2]. Several figures illustrate this loading case for the cable-stayed and through arch bridge types.



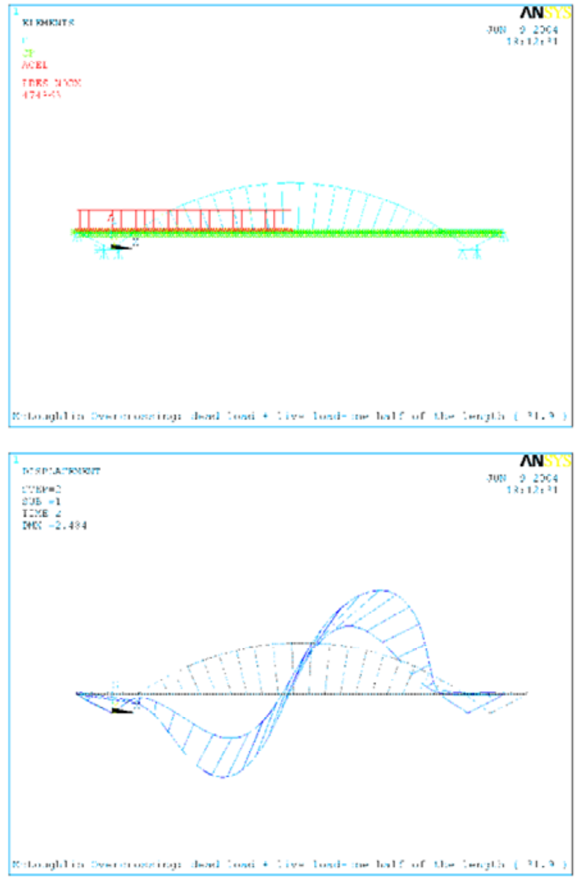
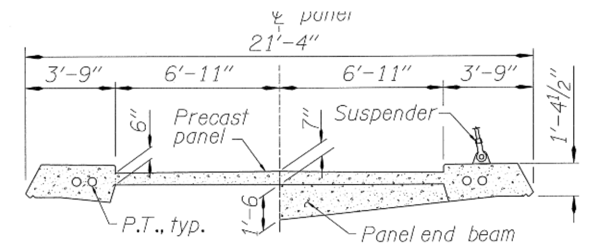
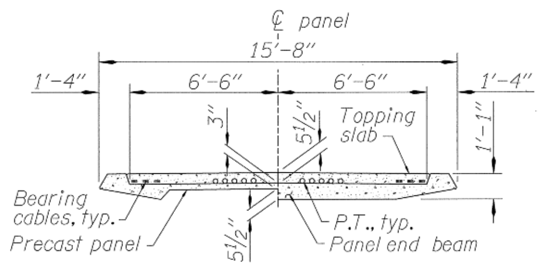
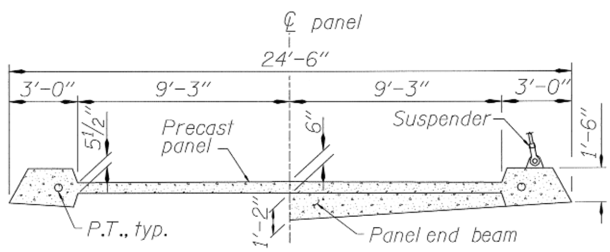
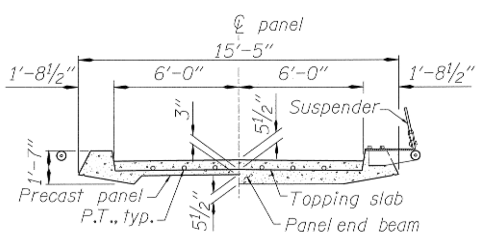
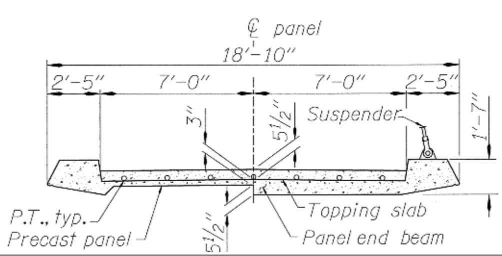


Figure 3. Asymmetrical live loading on I-5 Gateway Pedestrian Bridge. (Model: J. Strasky)

Figure 4. Asymmetrical live loading on Springwater (McLoughlin Blvd.) Pedestrian Bridge. (Model: J. Strasky)

PRECAST DECK PANEL SUPERSTRUCTURE COMPARISON

We have discussed the use of precast deck panels and integration into the superstructure for pedestrian bridges. The following Table 2 compares the superstructures of the five Oregon pedestrian bridges using the concepts discussed herein. As can be seen, the superstructures are extremely light allowing long spans, low superstructure (cable/suspender) demand, and more economical foundations.

Table 2. Comparison of superstructures of five Oregon pedestrian bridges designed by OBEC/Strasky.			
Bridge	**Superstructure Deck Section**	**Description**	**Weight/Ft**
DeFazio (Willamette River) Bridge		Precast Panels with grouted joints with full length PT in panel curb sections	Panels 2.9 k/ft (42.3 kN/m) (No topping slab)
Grants Pass (Rogue River) Bridge		Precast panels with full length PT and bearing cables in the topping slab section	<u>Panels</u> 1.3 k/ft (19.0 kN/m) <u>Topping Slab</u> 1.1 k/ft (16.1 kN/m)
McKenzie River (Wildish) Bridge		Precast panels with grouted joints with full length PT in panel curb sections	<u>Panels</u> 3.2 k/ft (46.7kg/m) (no topping slab)
Springwater Trail (McLoughlin Blvd.) Bridge		Precast panels with full length PT and bearing cables in the topping slab section	<u>Panels</u> 1.3 k/ft (19.0 kN/m) <u>Topping Slab</u> 0.9 k/ft (13.1 kN/m)
I-5 Beltline (Gateway) Bridge		Precast panels with full length PT in the topping slab section	<u>Panels</u> 1.5 k/ft (21.9 kN/m) <u>Topping Slab</u> 1.0 k/ft (14.6 kN/m)

The precast deck panel weight includes edge curbs and ends beams. The edge curbs present a location for full-length deck post-tensioning and serve as a longitudinal stiffening element;

the end beams serve as transverse floor beams for suspender and other superstructure support.

The I-5 Gateway Pedestrian Bridge is a good example of the use of precast deck panels in our pedestrian bridges, as shown in Photos 14 and 15. The panels were produced at Knife River Precast, a PCI-certified plant.

Photo 14. Precast deck panel metal forms. Generally, one panel can be produced per day.

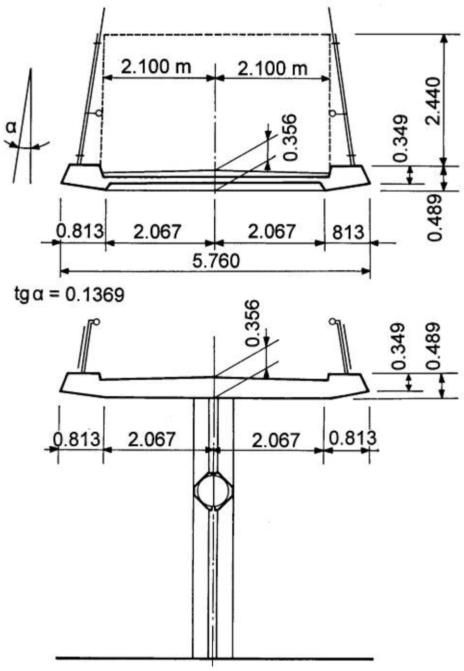
Photo 15. Precast panel with plain reinforcement in place.

DESIGN AND CONSTRUCTION OF THE I-5 GATEWAY PEDESTRIAN BRIDGE

The I-5 Gateway Pedestrian Bridge provides the bicycle/pedestrian transportation component for a $53 million interchange improvement located in Eugene, Oregon. The pedestrian bridge is located adjacent to the interchange where traffic volume and turning movements prevent placement of pedestrian and bicycle facilities. The pedestrian bridge cost is approximately $2 million. The bridge connects Eugene neighborhoods west of the freeway to a regional shopping center located east of the freeway in Springfield. The bridge is named for the Gateway neighborhood located on the northern edge of the metropolitan area.

In the preliminary study of bridge concepts it was confirmed that, while there is a small cost premium for the cable-stayed bridge type, it was nearly offset by the cost of additional approach ramp length required to meet Americans with Disabilities Act (ADA) standards for a much deeper and less innovative conventional deck girder type bridge. This is another major advantage in that slender superstructures are possible by the use of precast deck panels where gradeline constraints must be overcome.

The superstructure of the bridge consists of a series of 30-foot (9m) cast-in-place approach spans matching the deck section dimensions of the main spans. The main cable-stayed spans consist of segmental precast deck panels with composite topping slab. Figure 5 depicts the deck sections of the approach and main spans and the center tower is depicted in Figure 6.



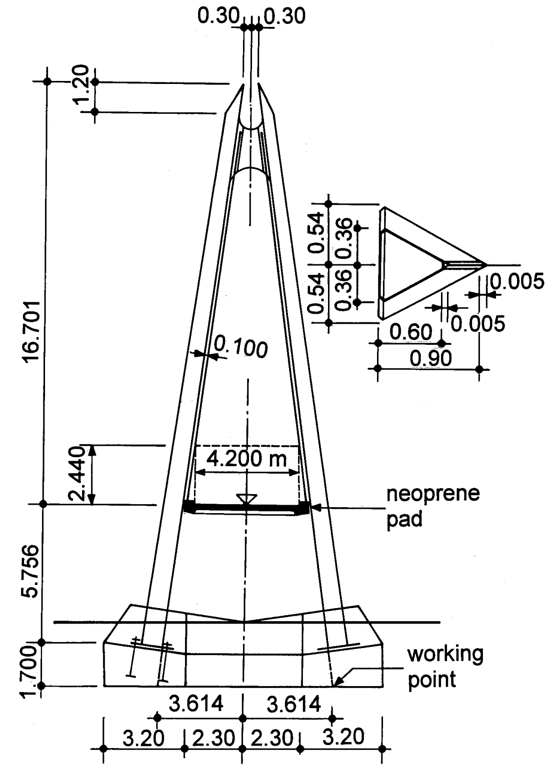


Figure 5. Upper: main spans, Lower: cast in place approach spans. (Graphic: J. Strasky)

Figure 6. Central tower for supporting the main cable-stayed spans. (Graphic: J. Strasky)

It was useful to fully render the bridge model for presentation purposes and to envision the design, aesthetics, and proportions, as seen in Figures 7 and 8.

Figure 7. Integration of approach and main spans, and spiral stairway from above the deck level. (Graphic: J. Strasky)

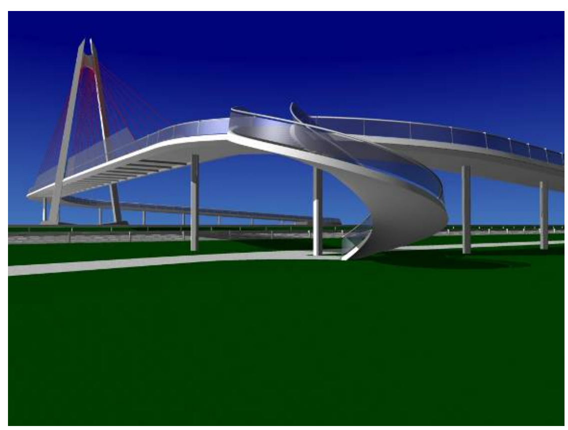


Figure 8. Integration of approach and main spans, and spiral stairway from below the deck level. (Graphic: J. Strasky)

Other major elements of the I-5 Gateway Pedestrian Bridge consist of precast concrete. The use of precast concrete for the central tower supporting the cable-stayed spans greatly minimized work within the freeway median. The central tower consists of two legs supporting a bolted structural steel cable-stayed anchorage at its top. Details of central tower construction are shown in Photos 16 and 17.

Photo 16. Structural steel cable-stayed anchorage with bolted splice.

Photo 17. Completed central tower ready for lifting into place. Legs are 71 feet (21.5 m) long.

Precast concrete was used in MSE approach fill walls to the cast-in-place approach spans. Details of MSE walls and approach slabs are shown in Photos 18 and 19.

Photo 18. MSE wall approaches to the bridge.

Photo 19. Cast-in-place approach spans match shape of precast deck panel main spans.

For construction of the main spans the precast tower was set by a 500-ton hydraulic crane in one piece into a temporary erection tower that provides overturning stability during erection. The temporary erection tower is designed to resist the imbalance in the main spans when one side has one more precast deck panel set than the other side. This allowed the main span to be set without the use of stabilizing falsework at the ends of the panels. When work was completed at the end of a shift, a temporary support was introduced under the end panel if it did not conflict with active freeway lanes. The setting of the tower within the temporary erection tower is shown in Photos 20 and 21.

Photo 20. Flying the central tower.

Photo 21. Setting the central tower in the temporary erection tower.

The next step in construction was to set the precast concrete deck panels. Setting of the panels for the main spans took place in three days. Several of those days included night work to allow the reduction of the normal three lanes of traffic in each direction to one lane. The contractor used a very light crane to set the panels in a balanced cantilever sequence.

Photo 22. Setting panels over freeway lanes.

Photo 23. End of a night shift. Panel cantilevered over freeway traffic.

The precast deck panels were quickly erected using logical and simple stay connections.

Photo 24. The panel mate with projecting structural tubes fit to adjacent precast deck panels. The forming of the panel closure joint is integral with the panel.

Photo 25. The solid bar stays are connected to the leading panel with standard AISC clevises. The panel joint and curb are cast with the topping slab.

After final grading of the panels by adjusting the stays to the calculated deflect shape prior to adding the topping slab, the deck reinforcement and full length deck post-tensioning is installed.

Photo 26. The full length deck post-tensioning extends well onto the curved cast-in-place approach spans so that the column bents adjacent to the central tower provide stability in the completed structure.

Photo 27. The full length deck post-tensioning is contained in the cast-in-place topping slab. The full length deck PT pre-compresses the entire deck section to eliminate cracking for live load, temperature, and other loadings.

The next step of construction is casting the deck over the post-tensioned section of the bridge, tensioning, and then casting the remainder of the approach span deck.

Photo 28. The deck was placed in balanced cantilever method from the central tower with two crews placing the topping slab in each direction away from the tower.

Photo 29. After the deck is cast, the concrete is cured and 20% of the post-tensioning is applied within 24 hours to prevent cracking during cure. At 14 days minimum the remaining post-tensioning is applied.

The fencing and rail will be similar to that for the Springwater Trail (McLoughlin Boulevard) Pedestrian Bridge as shown in Photo 32.

As the project is nearing completion at this time, the reader can see how the assembly of the various precast concrete and other components of the bridge creates the designer's desired effect of structural sculpture, even within a modest and economical bridge, giving it characteristics of landmark and signature status. The bridge is being extremely well received by the public, and that is the best outcome the Oregon Department of Transportation and the designers can ask for.

Photo 30. Completed bridge except for bridge railing and spiral stairway. The bridge is extremely stiff and comfortable for the user.

Photo 31. Spiral stairway at west end under construction. The stairway allows able-bodied users to avoid out of the direction connection to the path system below.


Photo 32. The rail and protective fence will be supported in the plane of the cable stays in a similar system to that used on the Springwater (McLoughlin Boulevard) Bridge.

The project is scheduled for completion in December 2008. The authors hope that they have presented the material in a concise manner and that the innovations and methods can be applied to other projects.

CONCLUSION

The authors feel that the use of precast deck panels and segmental erection, and sharing the description in detail for design and construction of our most recent pedestrian bridge, the I-5 Gateway Pedestrian Bridge, will assist engineers in visualizing and creating innovative long-span signature/gateway pedestrian bridges that are easy to understand, extremely cost-effective and simple to build.

The innovations using the precast construction described herein are summarized as follows:

- The slender deck section created by using precast deck panels allows gradeline constraints such as clearance requirements to be more easily overcome, improving the feasibility of the bridge under consideration.
- Use of precast concrete deck panels provides a very interesting and aesthetic architectural finish beneath the bridge.
- Use of precast concrete deck panels acts as a form for the continuous cast-in-place topping slab placed above the panels. Typical thickness of the mid-region of the panels is 3 inches (75mm); consequently, the panels are also very light.
- Use of precast concrete deck panels allows segmental erection of the deck across highways or rivers. The panels can be placed by light cranes where access is available or pulled into position on bearing or temporary erection cables.
- Erection of the panels, over highways for example, often occurs in a matter of days, usually only several evenings.

- The continuous topping slab facilitated by using the panels as a continuous form allows the placement of post-tensioning and bearing cables within the structure to serve as a stiffening tie for the overall structural action, longitudinal deck bending, crack control, and to limit vibration.
- The light weight of the deck system allows for efficiency in the supporting superstructure elements, such as arches, suspension cables, or cable stays, associated towers, and especially foundations.

ACKNOWLEDGEMENTS AND CREDITS

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- Precast concrete deck panel fabricator: Knife River Corporation, Harrisburg, Oregon
- Contractor: Mowat Construction, Company, Clackamas, Oregon
- Owner: Oregon Department of Transportation

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