INNOVATIVE USE OF PRECAST CONCRETE FOR THE ELLIOTT BAY SEAWALL REPLACEMENT PROJECT

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ABSTRACT

The Elliott Bay Seawall protects Seattle's downtown waterfront from waves and the erosive forces of Puget Sound and Elliott Bay. It serves to protect the core waterfront commercial district and the Alaskan Way arterial corridor, as well as major regional utilities and access to the busy Colman Dock ferry terminal.

Originally constructed in the early 1900's, the seawall requires replacement due to its deteriorating condition and seismic vulnerability. When completed, the new seawall will feature an expanded cantilevered sidewalk with a light penetrating sidewalk surface that serves to promote improved marine habitat along the project's 3,700 foot length. The new seawall structure will be supported on a jet grout-improved cellular soil mass to mitigate soil liquefaction effects in a seismic event.

The new seawall structure makes extensive use of modular precast concrete components to speed construction, reduce project costs, and minimize impacts to adjacent properties. Precast elements include custom precast face panels fitted with precast habitat shelves, precast zee-shaped superstructure segments, and precast light penetrating sidewalk panels. This presentation will provide an overview of the Elliott Bay Seawall project and focus on the key design and construction considerations associated with use of precast concrete components for the new structure.

Keywords

Precast Concrete Construction, Creative/Innovative Solutions, Accelerated Construction, Seawalls

INTRODUCTION AND BACKGROUND

The Seattle waterfront along Elliott Bay originally consisted of beaches, marshes, mud flats and sand that the met forested hills and bluffs upon which the City of Seattle was built. As Seattle grew in the late 1800's and early 1900's, the demands on its waterfront increased as it became a major shipping and industry hub for the Northwest region and as a launch point for the growth and development of Alaska and points north. Railroad lines were built along the waterfront Railroad Avenue along with numerous piers - each with a railroad spur and shed buildings to facilitate storage and movement of cargo to and from ships. The existing Elliott Bay seawall was constructed to protect this industry hub and the growing downtown Seattle from wind-driven storm waves and from the erosive tidal forces of Puget Sound and Elliott Bay.

Railroad Avenue and Original Seawall Under Construction Showing Precast Wall Panels (historical photo from waterfrontseattle.org)

The existing Elliott Bay Central Seawall structure to be replaced is approximately 3,700 feet in length. The seawall retains and supports the waterfront Alaskan Way roadway, major utility infrastructure, and adjacent upland areas; provides protection from the tidal waters of Elliott Bay; and provides access to adjacent pile-supported pier structures along the waterfront. The existing seawall is in poor condition in many locations, and is vulnerable to significant damage and potentially catastrophic failure during a major earthquake.

The Elliott Bay Seawall project area is defined by several distinct Zones based on their current predominant waterfront usage as shown in Figures 1 and 2 and Table 1 below:

Figure 1 - Elliott Bay Central Seawall Project (graphic from Elliott Bay Seawall Project)

Figure 2 - Aerial View of Elliott Bay Seawall Project Area (graphic by authors)

Table 1 - Elliott Bay Seawall Project Zones

	ZONE	NAME	BOUNDARIES	INCLUDES
CENTRAL SEAWALL	1	Pioneer Square/ Washington Street Boat Landing	S. Washington Street to Yesler Way	Washington Street Boat Landing, Proposed Beach
	2	Colman Dock Ferry Terminal	Yesler Way to Madison Street	Washington State Ferries (Colman Dock) and Seattle Fire Station No. 5
	3	Central Commercial Piers	Madison Street to just north of University Street	Historic Waterfront Commercial Piers 54, 55, 56, and 57
	4	Waterfront Park/ Seattle Aquarium	North of University Street to Virginia Street	Waterfront Park, the Seattle Aquarium, and public Pier 62/63

While there are numerous unique areas along the projects 3,700 foot length, this paper will focus on the typical design solutions that represent the majority of the projects design conditions.

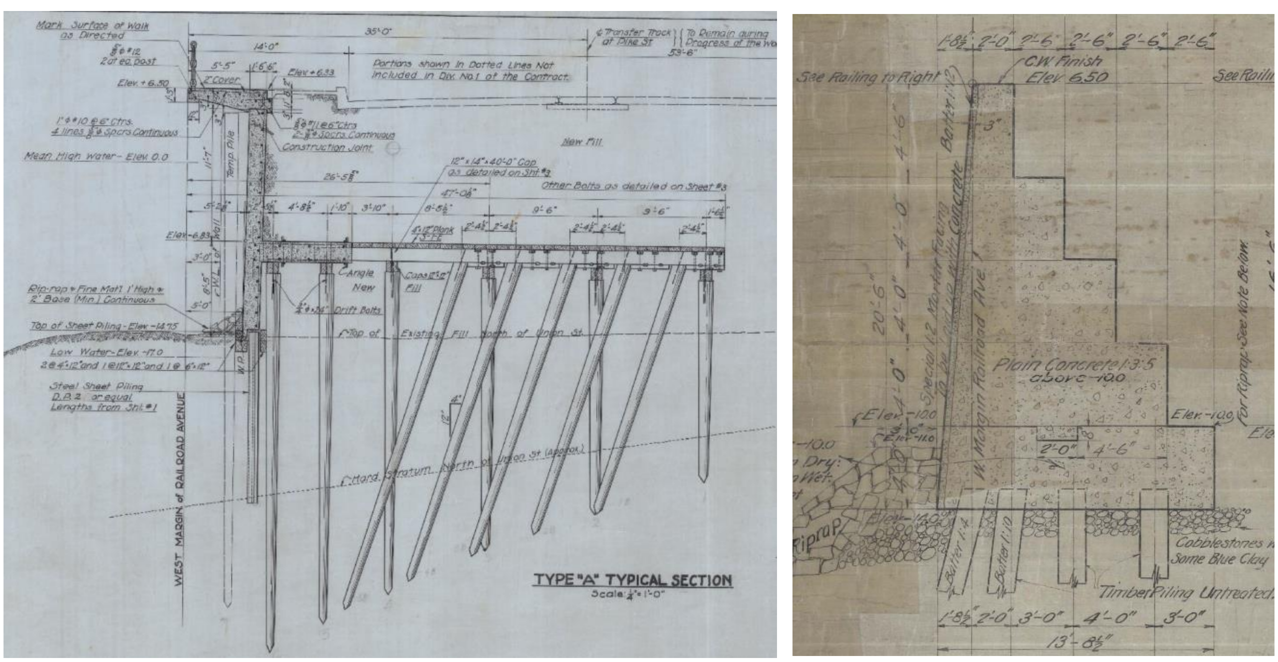
The replacement of the seawall will provide the foundation and structural support for downtown Seattle waterfront redevelopment. The project provides opportunities to restore marine habitat, and in conjunction with other elements of the planned Seattle Waterfront Program (including the Alaskan Way tunnel that involves removal of the existing Alaskan Way Viaduct), will reconnect people to the Seattle waterfront.

Currently in the early stages of construction, the project is planned to be completed by 2016. The new seawall consists of a concrete gravity structure supported on a jet grout improved cellular soil mass. The jet grouted mass serves to mitigate soil liquefaction risks at the site and provides for the global seismic slope stability of the system. The structural elements feature extensive use of precast concrete components, tied together with field-cast closure pours to make up the completed system.

SUMMARY OF EXISTING CONDITIONS

The existing Central Seawall structure consists of several distinct structure types, as shown below in Figure 3 and summarized in Table 2. Wall Types A and B are similar in construction but have differing geometry.

Figure 3 - Typical Cross Sections of Existing Type A and Gravity Seawall



The Type A and B walls constructed in the 1930's are of particular interest in that they were one of the earliest known uses of large precast concrete elements for a major public infrastructure project in the

Northwest. The concrete portions have performed well over the years, and show only limited deterioration. However, the timber relieving platform has experienced significant damage in some areas from marine borers, and the steel sheet piles below the concrete panels have deteriorated due to corrosion where they are exposed. Due to its deteriorating condition, the existing seawall is mostly being removed as part of the project, though some portions are being abandoned in place.

Table 2 - Summary of Existing Seawall Structure Types

WALL TYPE	ZONES	CONSTRUCTION DATE	COMPONENTS
A	3, 4	1934	Sheet-pile supported, reinforced concrete face panel tied back to a buried timber relieving platform supported by vertical and battered timber piles.
B	3, 4	1934	Steel master-pile supported, reinforced concrete face panel tied back to a buried timber relieving platform supported by vertical and battered timber piles. Master piles are connected to the relieving platform using angled tie-rods at some locations.
C	1, 2	1915	Timber-pile supported unreinforced concrete gravity wall.

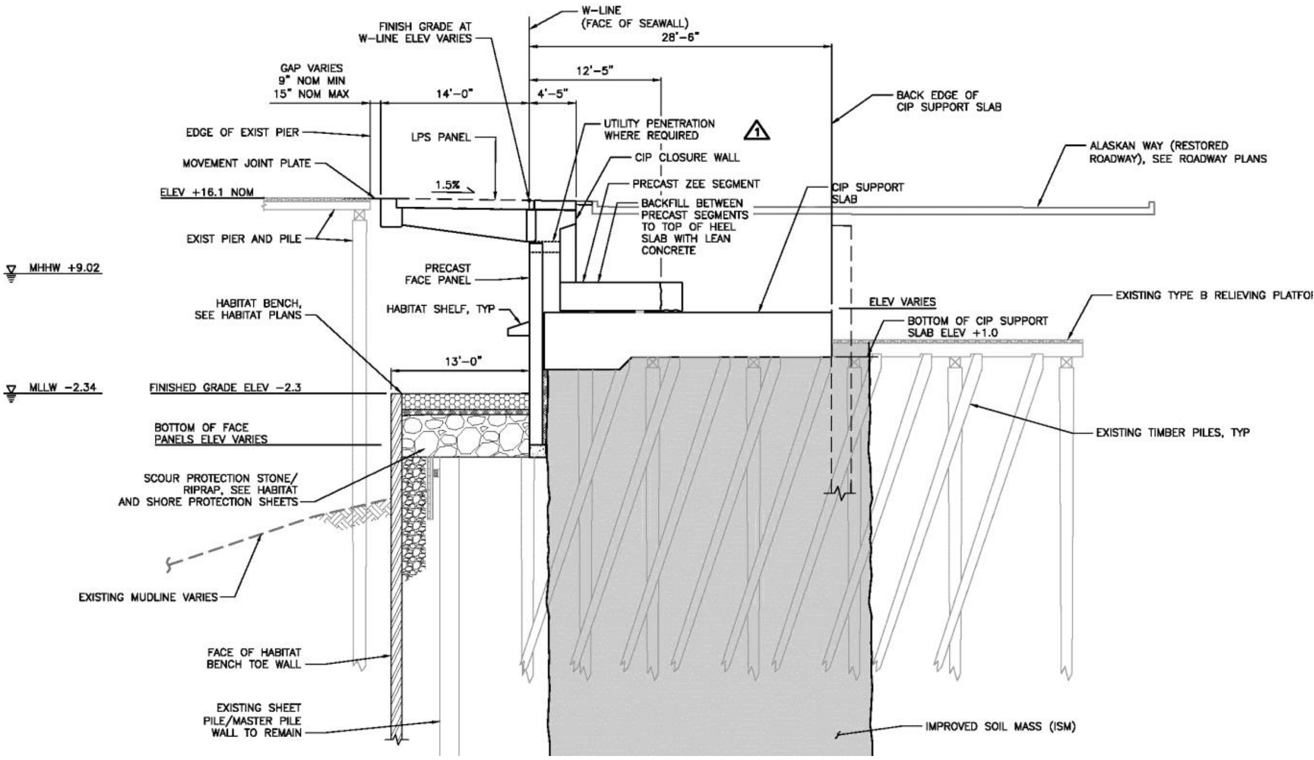
NEW SEAWALL STRUCTURAL SYSTEM

The proposed Seawall system consists of a combined system that uses soil strengthening techniques and secondary structural elements that together provide the static and dynamic load carrying capability of the system. A typical section of the seawall replacement structure is shown in Figure 4.

The improved soil supporting the seawall structure consists of a zone of jet-grouted soils extending from approximately 40 to 60 feet behind the new seawall. The jet grout columns are installed in a cellular arrangement at approximately a 50% replacement ratio. The cast-in-place support slab is then cast on top of the improved soil to provide a solid foundation for the gravity seawall structure.

The new seawall structure makes extensive use of modular precast concrete components in order to speed construction and reduce project costs. The project involves the fabrication of over 1,200 individual precast pieces encompassing over 12,000 cubic yards of precast concrete.

Figure 4 - Typical Cross Section of New Seawall



The primary precast components include custom precast concrete face panels fitted with precast habitat shelves, precast zee-shaped superstructure segments, and precast light penetrating sidewalk panels fitted with architectural glass blocks as shown in Figures 5 through 7 below.

Figure 5 - Typical Precast Concrete Zee-Shaped Superstructure Segments

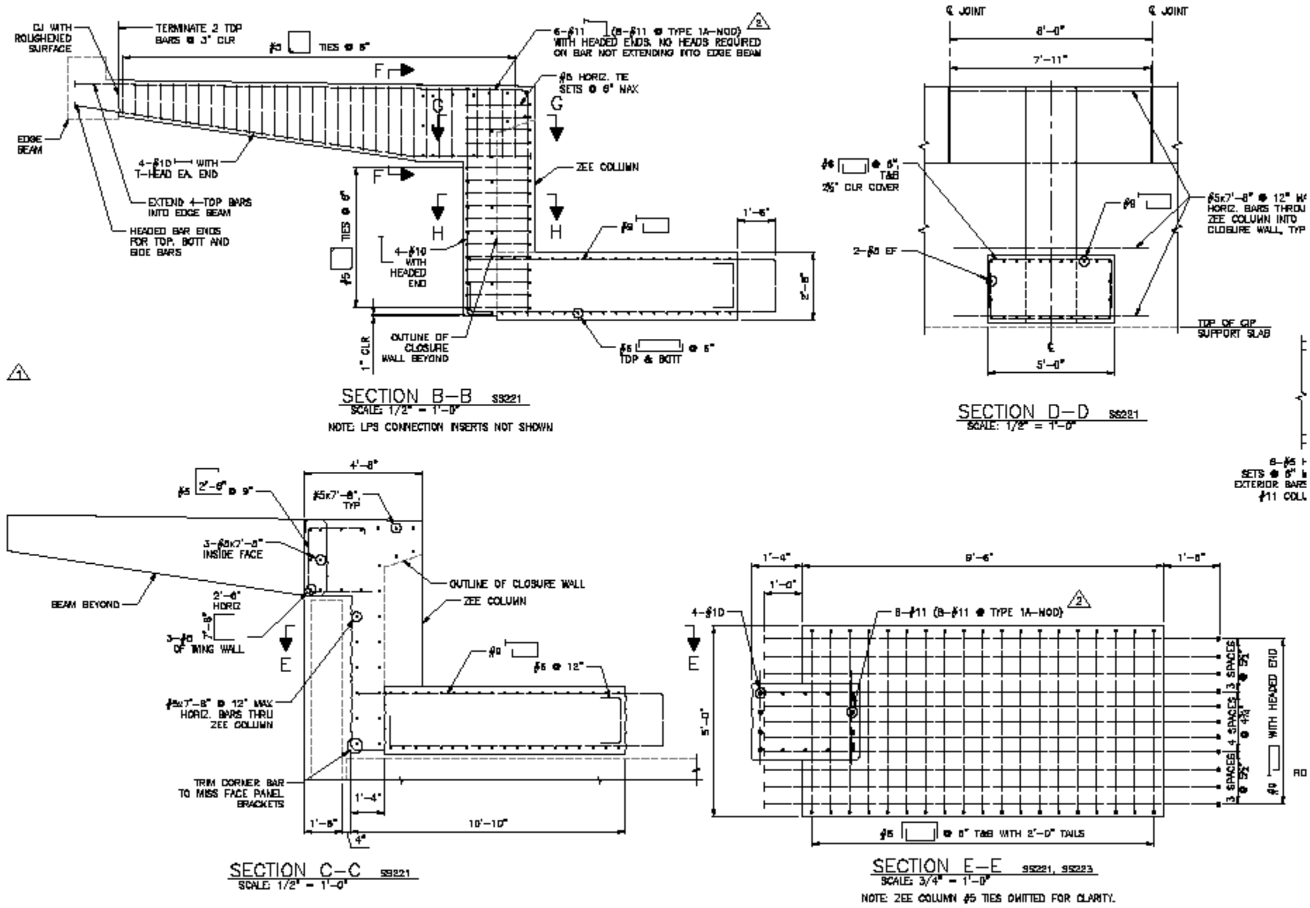


Figure 6 - Typical Precast Face Panels

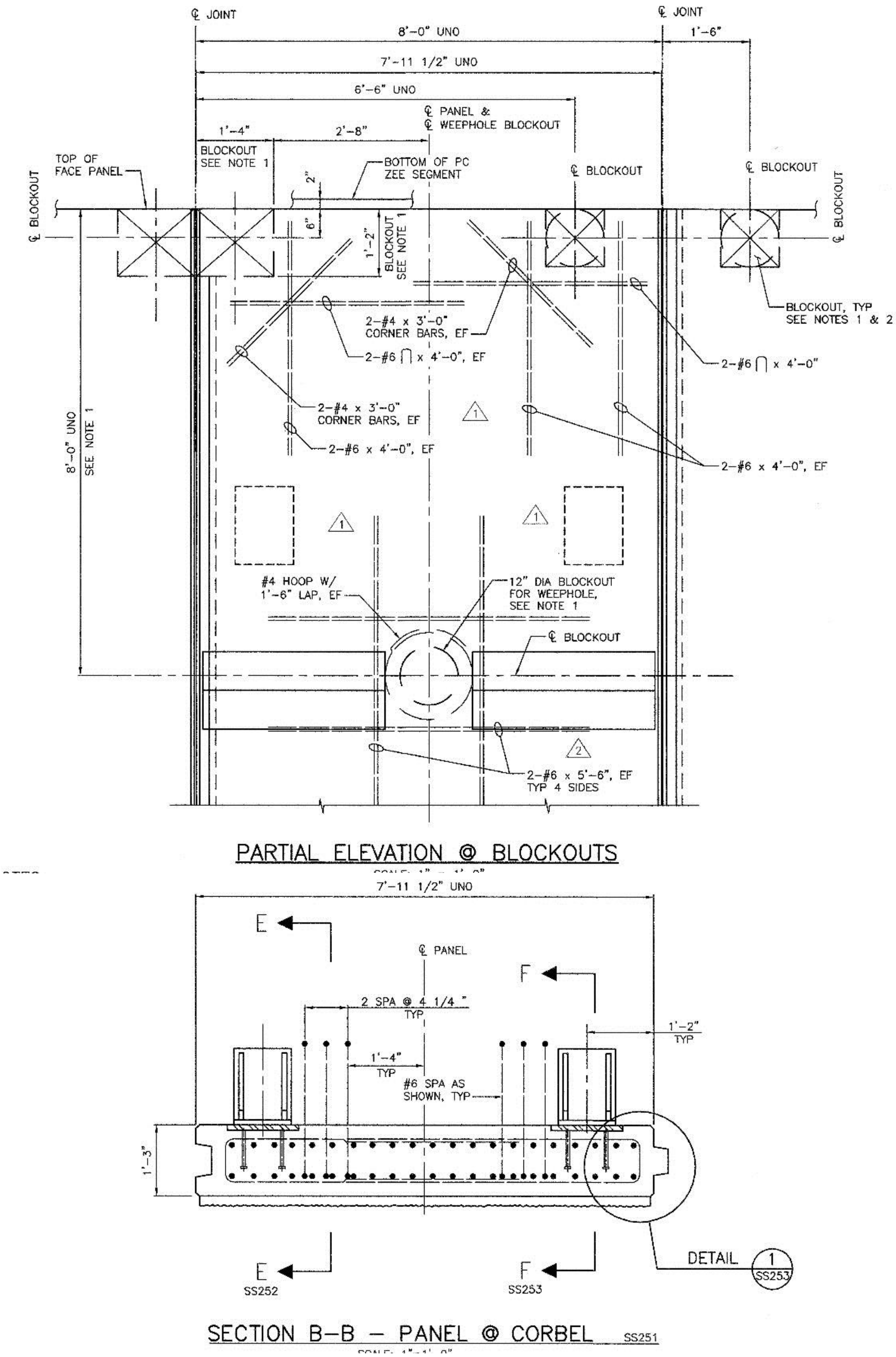
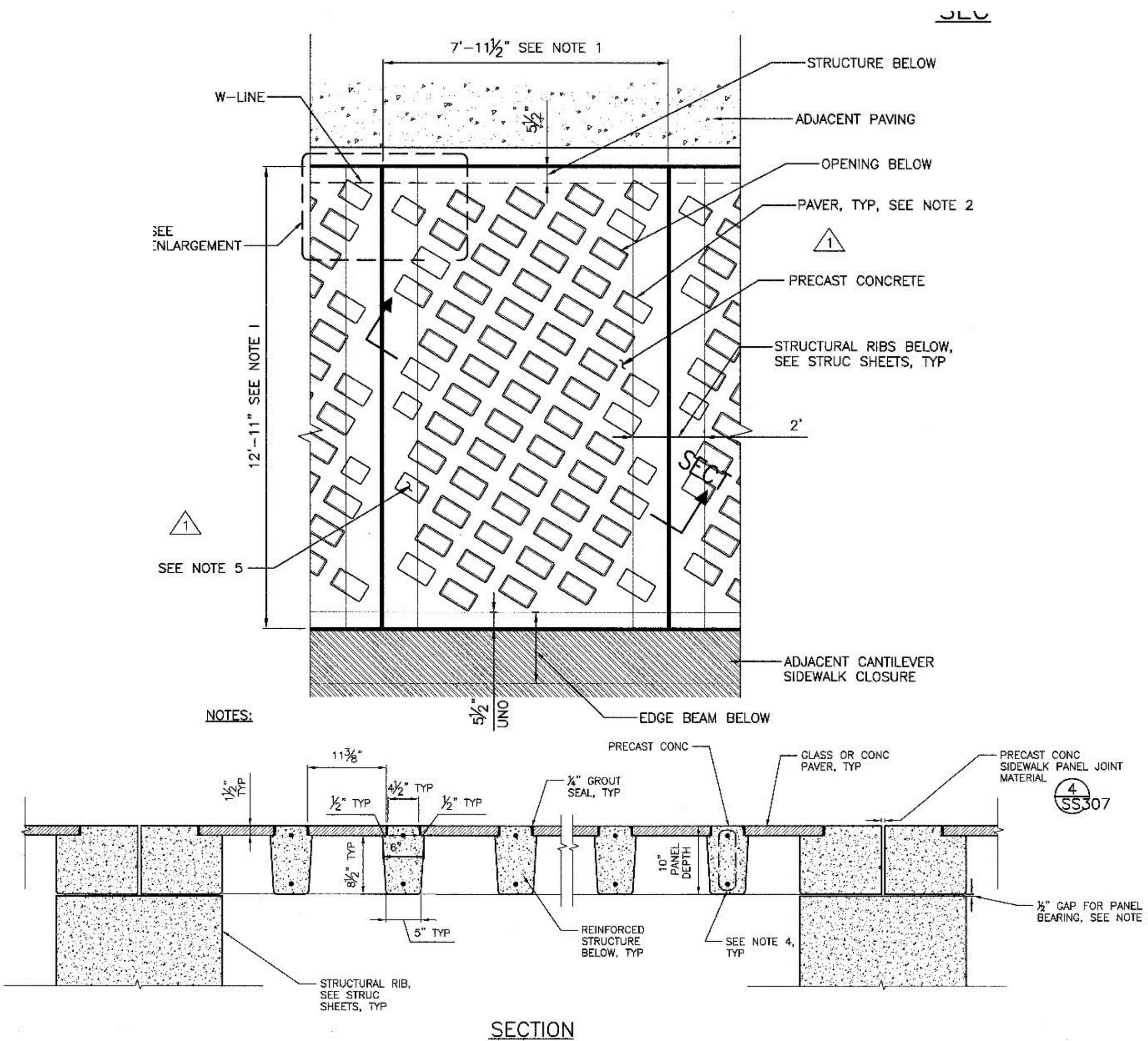


Figure 7 - Typical Precast Light-Penetrating Sidewalk Panels



DESIGN AND CONSTRUCTABILITY CONSIDERATIONS

Mock-up Fabrication of Precast Zee Segment Rebar Cage (photo by author).

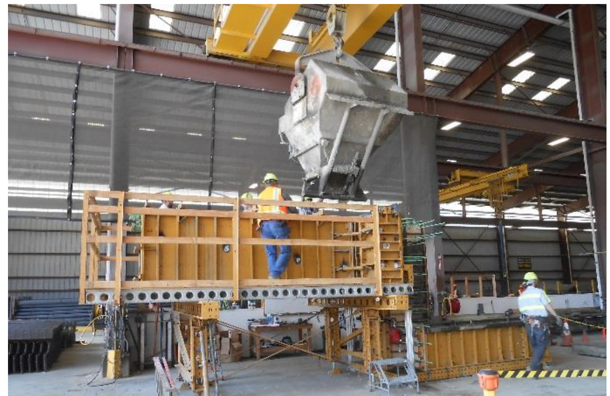
There were a number of design and constructability considerations that were balanced in order to select the appropriate superstructure configuration for this project, including the following:

- Field fit-up and construction tolerances.
- Precast element fabrication, handling, shipping, setting, and fit-up.

- Field fit-up with adjacent existing piers (horizontal and vertical fit-up, seismic gap).
- Flexibility for required utility penetrations.
- Durability, corrosion resistance, and future maintenance requirements.

Other key project considerations that influenced the final solution included:

- Requirements for habitat restoration / enhancement and development of the habitat "bench" in front of the new seawall.
- Accommodation of proposed urban design features (promenade surface materials, light penetrating surfaces, railings, etc.).
- Compatibility with adjacent future projects.
- The goal to minimize business and user impacts during construction to the extent possible.
- A focus on speed of construction that is constrained by tidal influence and restricted by allowable work windows (both in-water and season periods of high tourism).
- Coordination with utilities for service connections and affected primary systems, including identification of protect-in-place, relocated, and planned utilities.



Formwork and SCC Placement for Precast Mock-Up Segment (photo by author).

The precast elements were laid out using a basic 8-foot module that was repeated to the maximum extent in order to minimize the number of unique pieces, facilitating an economical precast fabrication process. The precast face panels were designed to allow small utility penetrations to be installed at virtually any panel location to accommodate the dozens of utility penetrations required to provide services to the piers. The face panels were designed with aesthetic form liner surface treatments unique to the project. In some locations, where existing major utilities are needed to be protected in place, special panels were designed to accommodate the existing conditions.

Though not required by the project specifications. The precast concrete supplier proposed use of Self-Consolidating Concrete (SCC) for construction of the precast elements. To validate the suitability of SCC for this application, a mock-up program was performed to confirm that SCC would perform well for the various precast elements given the complexity of the geometry, reinforcing levels, etc. A full scale precast zee segment and precast face panel were constructed, then saw cut at several locations to confirm that the

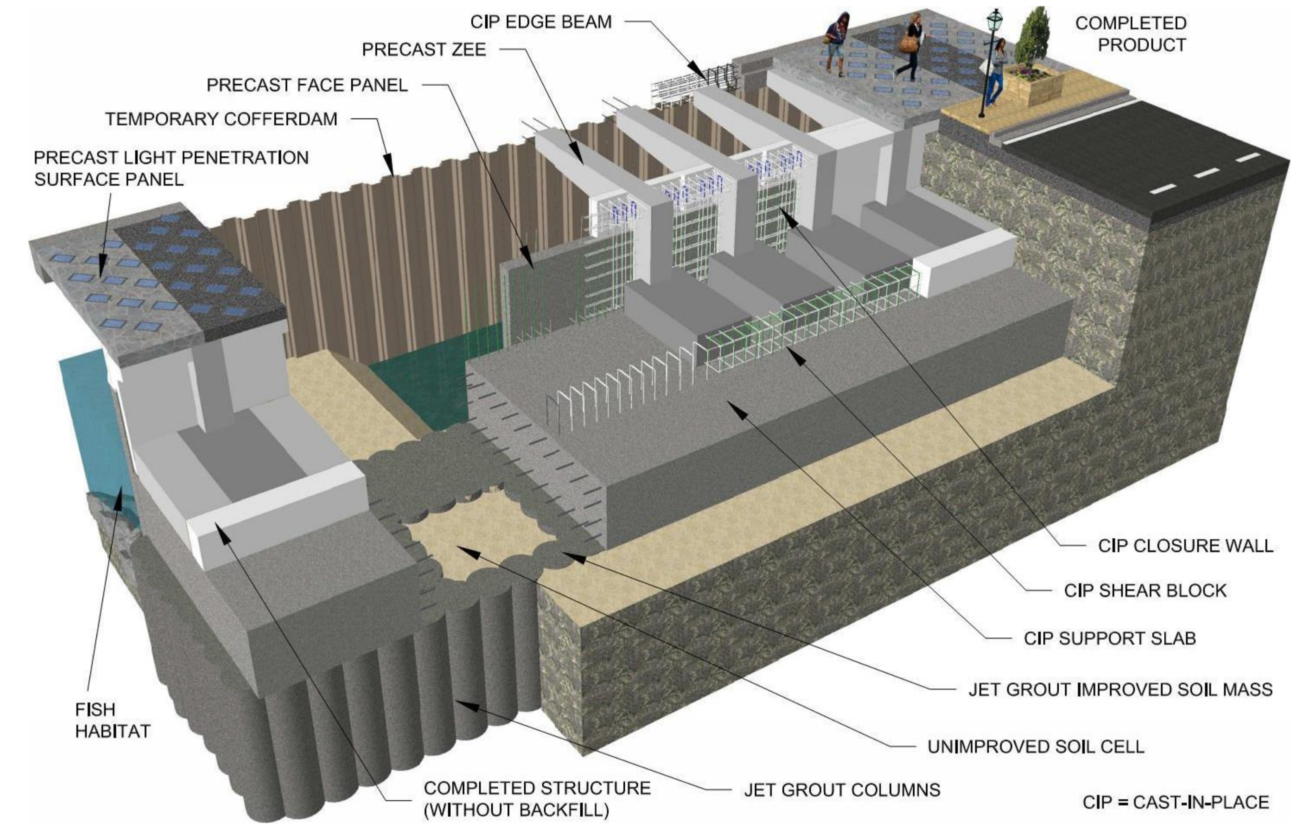
Precast Mock-Up Segment after Saw cutting (photo by author).

mix performed well with good flow characteristics, attaining adequate consolidation and aggregate distribution without segregation.

OVERVIEW OF PRECAST CONSTRUCTION SEQUENCE

A graphic illustrating the various components of the new seawall structure is shown in Figure 8 below.

Figure 8 - Elliott Bay Seawall Structure Construction Schematic (graphic by authors)



After initial excavation is complete, a cast-in-place concrete support slab is constructed over the improved soil mass. The Contractor elected to construct the cast-in-place slab within a dewatered excavation. The dewatered areas were isolated from the bay using a continuous cofferdam wall that also doubled as a containment wall during the jet grouting process.

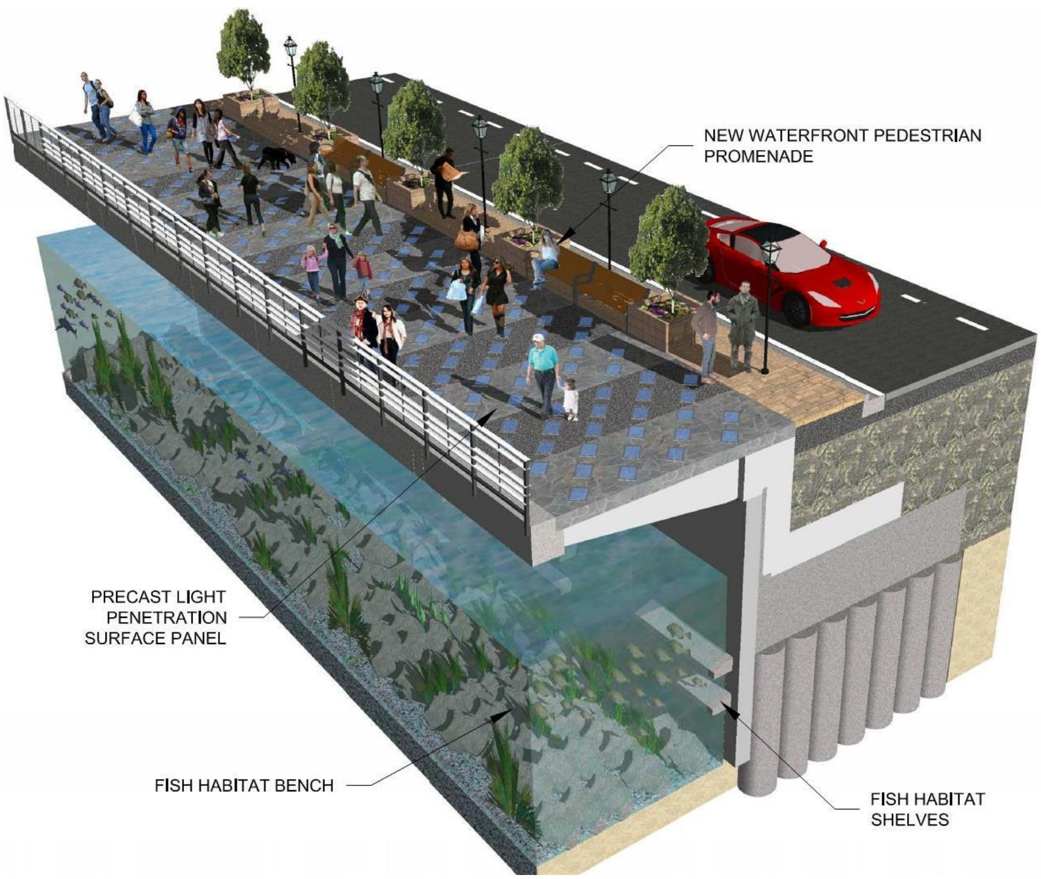
Precast concrete face panels are then set and temporarily supported from the support slab by corbel brackets attached to the back of the face panels. The precast concrete habitat shelves and in-water fish habitat corridor is then installed in front of the face panels. The precast zee segments are then set on the support slab over the top of the face panels. Both elements are set on adjustable shims to enable fine tuning of their final position for field fit-up.

Once the precast face panels and zee segments are set and aligned, a field-cast closure wall and shear block are installed to tie the system together into an integral composite unit. The zee segment base is then pressure grouted. The zee segments were designed to be independently stable under their own weight until the field cast closures are completed.

Next, a cast-in-place edge beam is constructed at the cantilevered end of the precast segments, which serves as a diaphragm to tie the segments together and allow distribution and sharing of concentrated loads applied to the cantilever. Finally, the precast sidewalk panels are set on bearing pads, seated into recesses formed into the precast and edge beam to create the finished sidewalk surface. A steel cover plate is used to span the gap between the new seawall and adjacent pier structures.

Following completion of the new seawall structure, a new waterfront promenade will be constructed to complete the adjacent surface treatments and pedestrian amenities. A graphical depiction of the completed seawall and waterfront promenade is shown below in Figure 9.

Figure 9 - Completed Seawall with Fish Habitat and Pedestrian Promenade *(graphic by authors)*



CONCLUSIONS

When completed, the new seawall and waterfront promenade will create an exciting new "front porch" to the City of Seattle's waterfront while also improving marine habitat within Elliott Bay. Collectively, the Waterfront Program presents a once-in-a-lifetime opportunity for the City of Seattle to enhance the waterfront experience for its citizens and tourists.

The Elliott Bay Seawall serves as the structural backbone of the Waterfront redevelopment, and the innovative use of precast concrete was critical to successful design and execution of the project. The new seawall structure makes extensive use of modular precast concrete components designed to speed construction, reduce project costs, and minimize impacts to adjacent properties. This project exemplifies the unique advantages that precast concrete construction can offer, and will serve to protect the City's waterfront for many years to come.

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