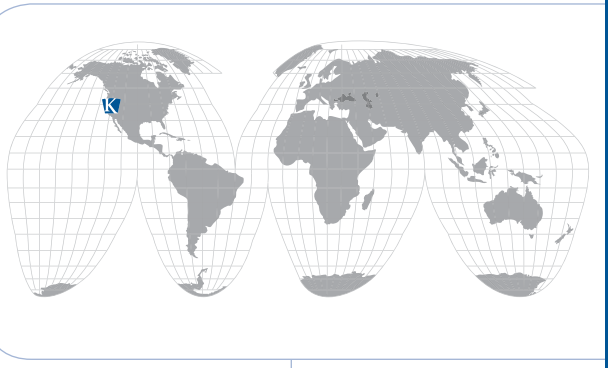
KEYSTONE® RETAINING WALL SYSTEMS

# Port of Seattle - Terminal #5

## Seattle, Washington



CASE STUDY

The Port of Seattle faced redevelopment and the undertaking of a massive new automated freight facility to strengthen efforts to compete globally. The waterfront area under consideration had previously been used for heavy industrial and toxic waste storage. The design concept was to mix a new heavy industry cargo facility and visitor areas including restaurants and observation overlooks, in a highly controversial, sentimental and valuable piece of Seattle shoreline.

To accomplish this project, architectured retaining walls were proposed to elevate the pedestrian walkways, in some cases up to 28' (8.54 m) high, to separate visitors, joggers and bicyclists from the heavy equipment operation areas. Meandering pathways, with lush vegetation along with safety fences and railings, would allow safe passage of visitors to ramps, bridges and observation points. With the raised elevation, visitors would have a great view of harbor shipping, cargo operations and the world famous Seattle skyline across the harbor.

A collaboration of project designers KPFF Engineers, Arai Jackson Architects and Hough, Beck and Baird Landscape Architects originally designed the project with cast-in-place concrete or pre-cast concrete panel options. M.A. Segale, the General Contractor encouraged by the Port of Seattle, solicited an alternative value engineered option from Keystone Retaining Wall Systems. Upon review, the Keystone KeySystem I (concrete units with steel soil reinforcement) was accepted. In addition to cost savings over the original options, the Owners benefited from a more attractive and flexible modular system with the ability to handle the tight geometric wall configurations.

### *Construction*

It was critical to the project that construction for the various walls progress in stages to avoid disruption of active terminal facility operations.

| | |
|---|---|
| **Project:** | *Port of Seattle Terminal #5 and SW Harbor Reclamation* |
| **Location:** | *Seattle, Washington* |
| **Owner:** | *Port of Seattle* |
| **Keystone Product:** | *KeySystem I, Compac Units & KeySteel soil reinforcement* |
| **Licensed Manufacturer:** | *Keystone Pacific Northwest Beaverton, Oregon* |
| **Total Wall Area:** | *22,500 sq.ft. (2,084 m²)* |
| **General Contractor:** | *M.A. Segale Construction Tukwila, Washington* |
| **Wall Contractor:** | *KRC Construction Issaquah, Washington* |
| **Civil Engineers:** | *KPFF Engineers Seattle, Washington* |
| **Architect:** | *Arai Jackson Seattle, Washington* |
| **Landscape Architect:** | *Hough, Beck & Baird Seattle, Washington* |

Pedestrian Ramp, Bridges and Overpass

After completing demolition of existing site elements and rough grading, the trenches for the concrete leveling pads were excavated and the 6" (150mm) non-reinforced concrete leveling pads were poured. As stated earlier, no deep foundation remedial work was performed.

Next the Keystone Compac Units were installed along the designed alignment on the leveling pad. Pins were installed, unit drainage fill (crushed stone) was placed in the unit cores and 8" (200mm) lifts of the new select fill were placed to the embedment depth of the steel reinforcement.

Pedestrian bridge supported by "near vertical" Keystone wall.

Smooth drum vibratory roller compaction was used at each lift to achieve required Proctor compaction. This heavy equipment was kept back a minimum of 3' (1m) from the back surface of the wall so as not to create an overstress condition. The face zone was compacted with a walk behind compactor.

Keystrip steel soil reinforcing was then placed over the steel pins in the units and lightly tensioned. Another lift of granular fill was placed over the keystrips and compacted. This same process was repeated until achieving the full height of the wall. For simplicity of design, the Keystrips are placed on every other unit horizontally and every third course, 2' (600mm), vertically in the wall.

The top of the walls was finished with cast-in-place concrete copings. The contractor formed the coping to follow the wall elevation (level or stepped) with a 1" (25mm) overhang. To assist in pouring the coping over the tri-plane rockface finish of the Keystone Compac Units, a thin sheet of galvanized steel was placed over the top course of units to close the gap between the forming face and the Keystone unit face.

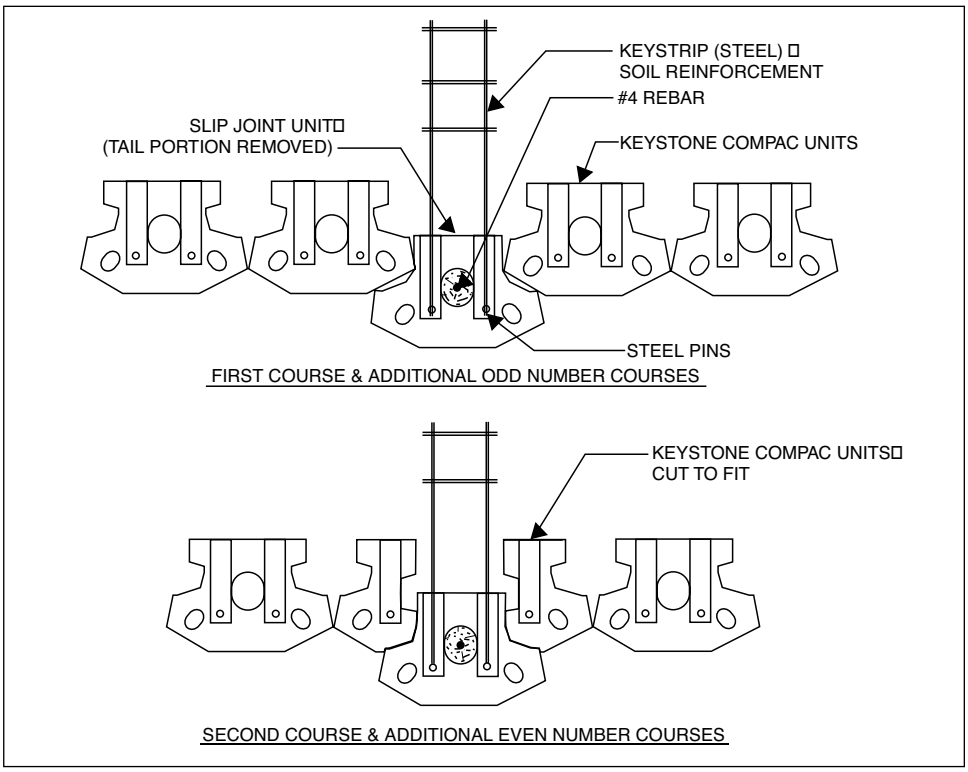
At intervals of approximately 50' (15m) along the wall, a vertical slip joint was installed to allow for differential settlement along the plane of the wall face. These joints were constructed using a Keystone Compac unit with the rear tail legs removed (see detail and photo on page 3). The Keystrip steel reinforcement elements were connected to the slip joints at intervals of 2' (600mm) vertical. The slip joint was thus a continuous stack bond of units.

Select granular fill with vibratory compaction.

Adjacent wall units, built in running bond, were installed behind this face flange of the slip joint units. Adjacent units were cut in half at alternating courses as shown in the detail.

In the southwest corner of the project, an oblique corner was needed to provide support for the ramp and pedestrian bridge to the observation tower. The unique geometry of the corner prevented the Keystrip steel reinforcing from extending the full embedment depth into the fill zone and caused overlapping of these layers of reinforcing in the corners. After discussions with the Contractor, Keystone Retaining Wall System engineers recommended the oblique corner area be constructed using a lean concrete mix instead of trying to compact the select granular fill. This method provided for structurally bonding the steel reinforcing to a solid mass in the corner. It provided a sound solution as well as simplifying the installation process.

Forming of site poured copings.



Typical slip joint detail.


Compac units are cut to fit at vertical slip joints.


Steel reinforcing layout at bridge support point.

### *Foundation Soils*

Because the site is along the waterfront of Seattle Harbor, the majority of the foundation soils consisted of silty sands with shear strength values of 30°. On one corner of the site, soft alluvial soils were discovered which entered into the design problem and analysis. Due to the variation in base soils, differential settlement was expected to be a concern on this project. The decision to use segmental retaining wall (SRW) units with their inherent flexibility yet interlocked design, allowed the project to be built without requiring deep foundation or deep compaction to the existing foundation soils. All walls were founded on a typical 6" (150 mm) unreinforced concrete leveling pad.

Even with the flexibility of the SRW system, construction slip joints were provided at all corners along the wall alignment to allow differential settlements and movements beyond what would normally be expected for SRW and reinforced soil structures.

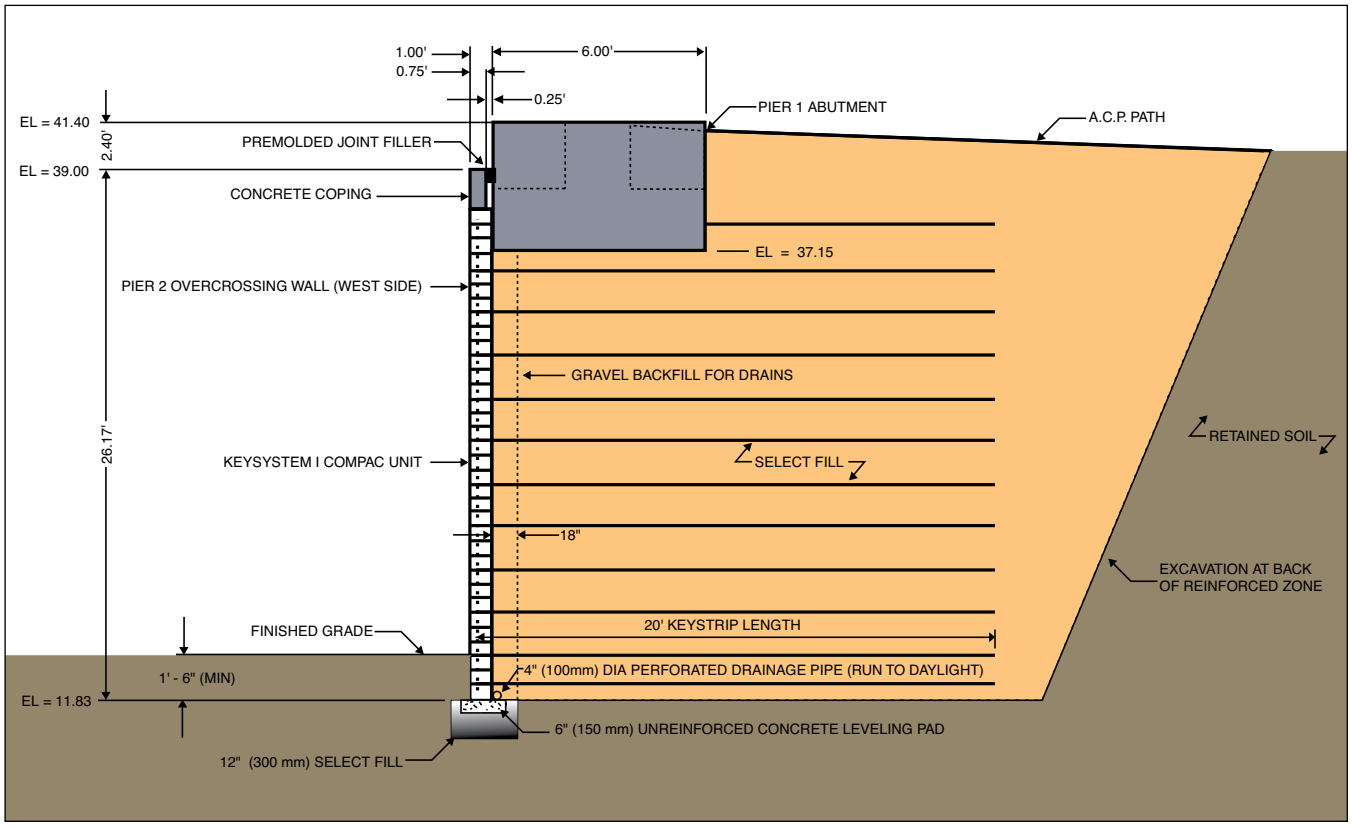
### *Backfill Soils*

The project required the construction of built up areas using imported fills to create ramps and bridges on the existing site. This method of construction utilized clean, granular fill materials that met AASHTO requirements when using steel in the soil reinforcement zone.

### *Design Parameters*

The design methodology used was AASHTO 1994, using the Gravity Earth Method of Design. Seismic forces were included in the design using the Mononobi Okabi method of pseudo-static analysis. Seattle is in a seismic zone THREE area. Seismic requirements for the walls accounted for a maximum horizontal acceleration of 0.2 g.

| Soil Zone | Friction Angle | Cohesion | Moist Unit Weight |
|---|---|---|---|
| Reinforced Fill | $\phi$ = 34° | C = 0 | $\gamma$ = 125 pcf |
| Retained Fill | $\phi$ = 30° | C = 0 | $\gamma$ = 120 pcf |
| Foundation Soils | $\phi$ = 30° | C = 0 | $\gamma$ = 120 pcf |




Wall section at bridge pier - ramp to observation tower wall.

Wall heights varied from 3' (1m) to over 20' (7m), with the maximum section being 28' (8.5m) tall. The selection of the Keystone structural wall facing system was dictated by the requirement that all walls be constructed in a near vertical position to minimize the length at the bridge span while maximizing the usable space in the roadway and heavy equipment operations area. (See photo on page 2)

### *Construction Costs & Schedule*

The cost of the completed wall construction was approximately $18/S.F. ($195/$m^2$). The total project took 20 weeks to complete. Heavy rains in the Seattle area hampered general construction at the beginning of the project, but the free draining nature of the Keystone System and the use of select granular fill made the job easier to work with than if more silty backfill material had been used. Due to the unique geometry of these walls, the corners, slipjoints and steeply stepping fill areas, the construction timing for this project was slowed as compared to a more simplified wall project.

For more information on the Keystone Compac unit, KeySystem I - KeySteel reinforcement or other innovative Keystone products, please visit www.keystonewalls.com or call 800-747-8971.



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