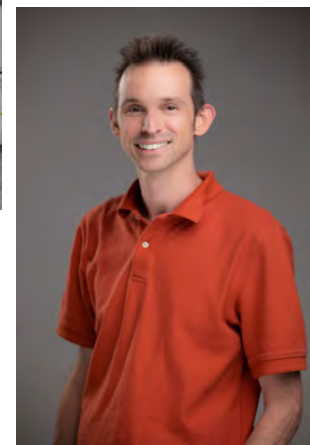


Dave Maynard

- Turner since 2012
- Concrete PM & Estimator
- Current role as a Consultant
- dfmaynard@tcco.com



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PRESENTATION GOALS:

1. Overview of Project
2. Sustainability on the project regarding Concrete
3. Other sustainable initiatives on the project

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Project Overview

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SELF-PERFORM OPERATIONS FORMWORK CREW

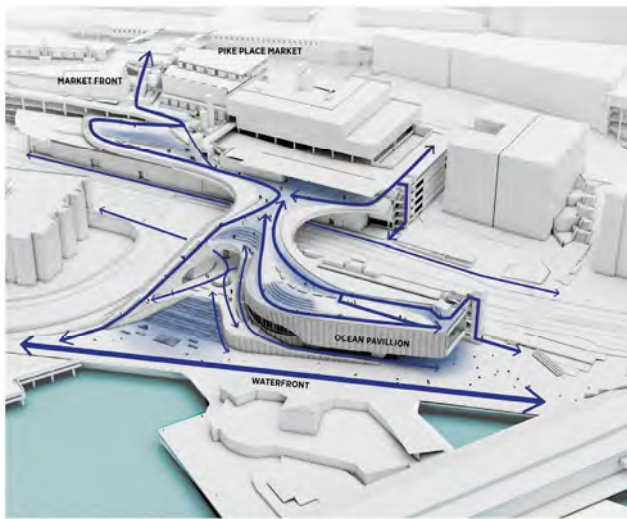


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PROJECT DESCRIPTION

- Approximately 45,000 SF
- About \$160 million budget ≈50% donations
- Total water capacity is 385,000 Gallons
- Will be home to around 3,500 tropical fish and invertebrates



OVERLOOK WALK
City Team



OCEAN PAVILLION
Aquarium Team

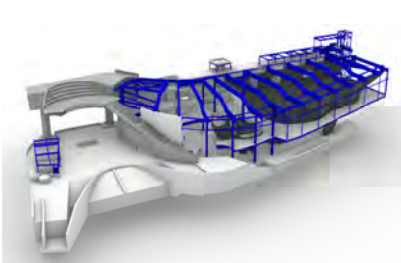


STREET IMPROVEMENT AND
WATERFRONT PROMENADE
SDOT and City Team

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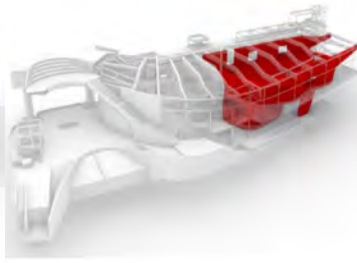
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STRUCTURAL DESIGN



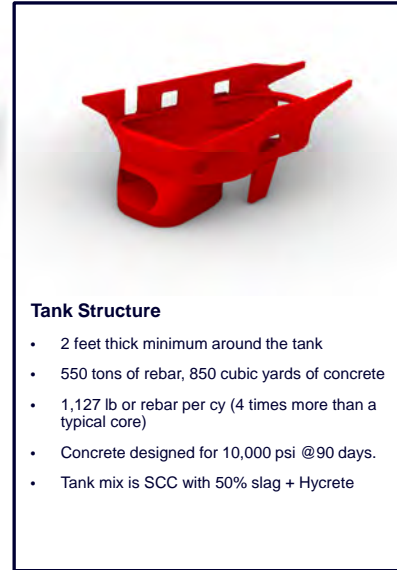
Concrete + Steel Structure

- Combination of concrete and steel structure



Coral Canyon Tank As Main Building Structure

- The tank is a heavily significant part of the structure of the building.
- Roof steel beams and precast concrete sit on Coral Canyon
- Steel structure is partially hanging from Coral Canyon



Tank Structure

- 2 feet thick minimum around the tank
- 550 tons of rebar, 850 cubic yards of concrete
- 1,127 lb of rebar per cy (4 times more than a typical core)
- Concrete designed for 10,000 psi @90 days.
- Tank mix is SCC with 50% slag + Hycrete

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Concrete Sustainability

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Seattle Waterfront History



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DSM Columns

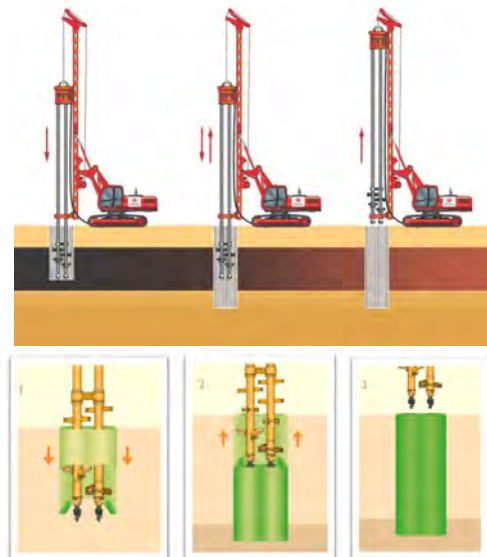
The entire Seattle Waterfront is built on fill with very little structural value.

• **Deep Soil Mix Columns:**

A multitude of soil mix columns were used to support the overall structure early in the project

Mix design utilized high replacement 75% slag 25% 1L cement, also used on the nearby seawall.

Technical benefits included better results in organic mixed soils.

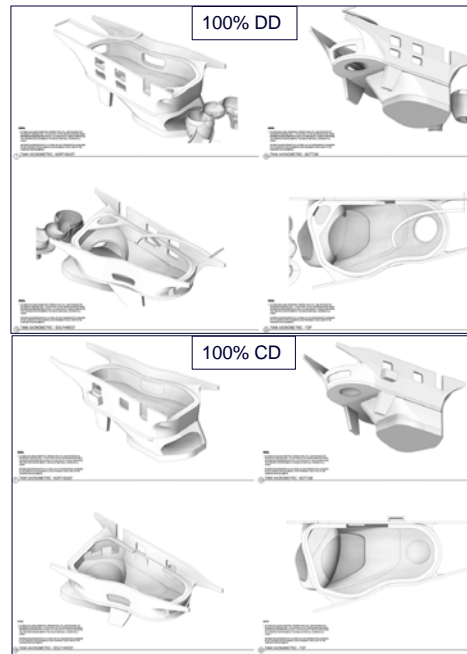
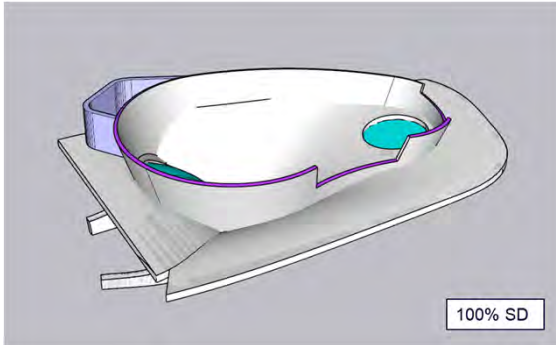


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CORAL CANYON DESIGN:

- Refining geometry (double curvature) over design phase in coordination:
 - Owner
 - Designer
 - GC
 - Marine Biologists
 - Subcontractors



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CORAL CANYON FORMWORK: 3D PRINTED REFERENCE MODEL

IN HOUSE 3D Print

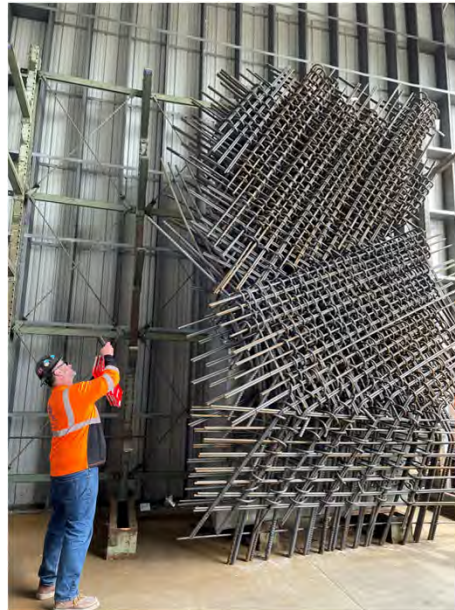


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REINFORCING MOCKUP

- Most complex zone in the Coral Canyon
 - 7 layers of bar: front back for (3) zones and center foundation dowels
 - CMC solutions:
 - #9 to #11 bar replaced by 2-3 #6 bars
 - Idea welded tie frames



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POUR PRESSURE MOCKUPS

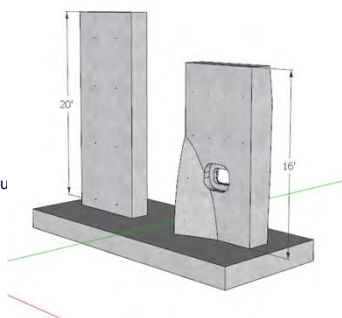
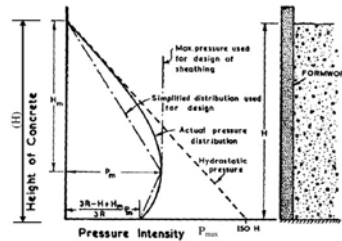
Walls need to pour 40' to put CJ above the water level.
 SCC pressure on formwork system was not studied before.

• **20' Tall Wall:**

A very rapid fill rate (60 ft/hr) was used.
 Concrete remained highly liquid throughout the pour.
 Vibration resulted in increasing the pressure.

• **16' Tall Wall:**

The 16 ft tall wall form was filled with a batch style approach (4 ft/hr).
 Maximum pressure reached 5.6 psi (806 psf) instead of hydrostatic pressure of 14.7 psi (2,116 psf).
 The results show how pressures can be controlled by filling rate.



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Testing:

- Formwork Systems: Peri (Left) and Masons (Right)
- Formwork Coating
- Form Release Agents


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CONCRETE SERVICE LIFE

Coral Canyon designed for 75 years of service life

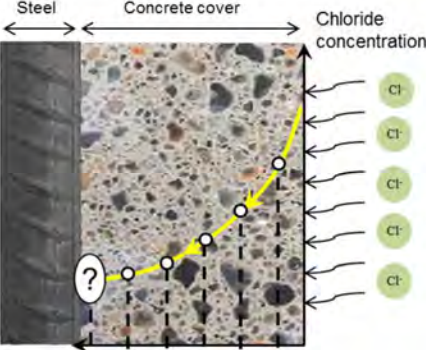
- Stainless Steel, Fiberglass, Chromex did not affect difference between MKA Life Service Models
- Originally Spec'ed 5-10% Silica Fume, removed in final design

- **Foundation:** top cover increased to 4" and no epoxy bar
- **Coral Canyon:** Tank SCC mix has apparent chloride diffusion (D_a) of 2.3×10^{-10} IN²/SEC
 - 33 times more dense than typical concrete
 - Required D_a : 9.6×10^{-10} IN²/SEC
- **Archipelago Tank:** Epoxy bar at surface close to water



$$C(x,t) = C_s - (C_s - C_i) \cdot \text{erf}\left(\frac{x}{\sqrt{4 \cdot D_a \cdot t}}\right)$$

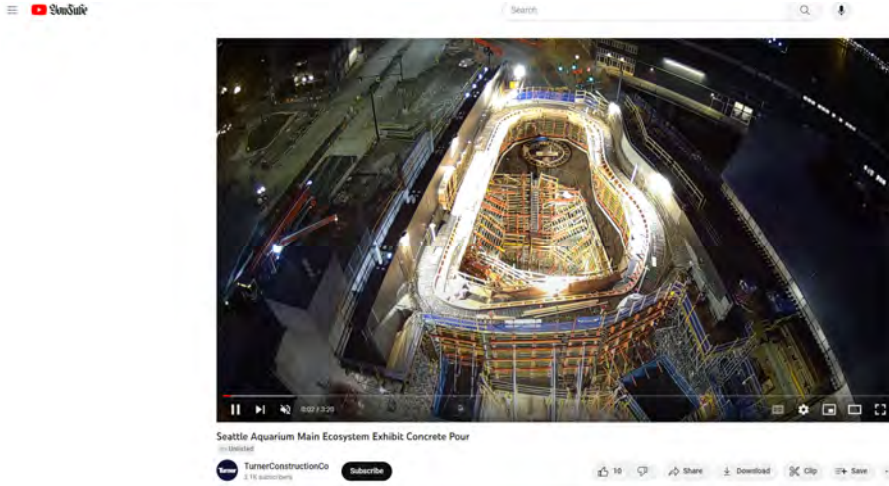
C_s = projected chloride concentration at the interface between the exposure liquid and test specimen that is determined by the regression analysis, mass %
 C_i = initial chloride-ion concentration of the cementitious mixture prior to submersion in the exposure solution, mass %
 x = depth below the exposed surface (to the middle of a layer), m,
 D_a = apparent chloride diffusion coefficient, m²/s,
 t = the exposure time, s, and



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CONCRETE PLACEMENT:

<https://www.youtube.com/watch?v=DIA6FcygeuQ>



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Overall Carbon Reduction

Project GWP reduced between 35-45% against NRMCA regional baseline

Very little cost impact

Mix #	Description	Total Cubic Yards	psi @ 28 days	Baseline GWP (m ³)	Actual GWP (m ³)	Baseline GWP	Total GWP
575371	Shotcrete	127	5,000	455.53	463	44,231	44,957
532174	Foundation	4,216	5,000	455.53	237	1,468,339	763,937
535174	Slabs	911	5,000	455.53	255	317,281	177,610
429174CR	Walls	456	4,000	366.73	211	127,856	73,562
535374	Columns/Shear Walls	405	5,000	455.53	254	141,052	78,650
458374C	SOMD	116	5,000	455.53	356	40,400	31,573
450174	Misc. Concrete (Curb/Pads)	537	4,000	366.73	325	150,567	133,434
860078A	Main Tank	732	8,000	588	422	329,077	236,174
810078A	Archipelego Tank	53	5,000	455.53	632	18,459	25,610
Totals		6,768				2,289,726	1,303,723

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Other Project Initiatives & Opportunities

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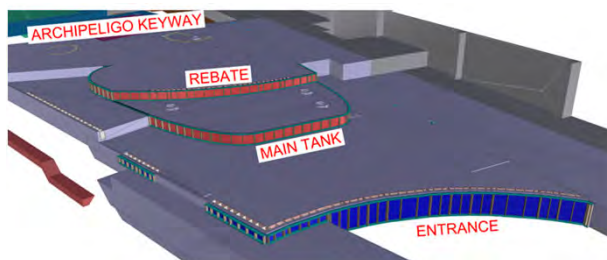
FOOTINGS

- Minimizing CJ locations due to Coral Canyon
- 1,530 CY South Mat Footing with Hycrete
- 550 lb of rebar per cy – (2 times more than a typical Highrise foundation)
- Custom wood formwork was designed by the VDC department and manufactured in Turner's shop



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12' Deep Foundation
#11 Bar

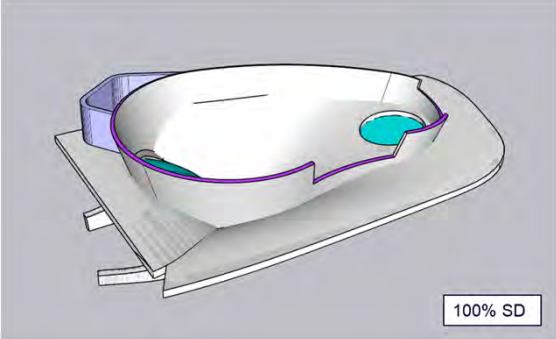
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Coral Canyon

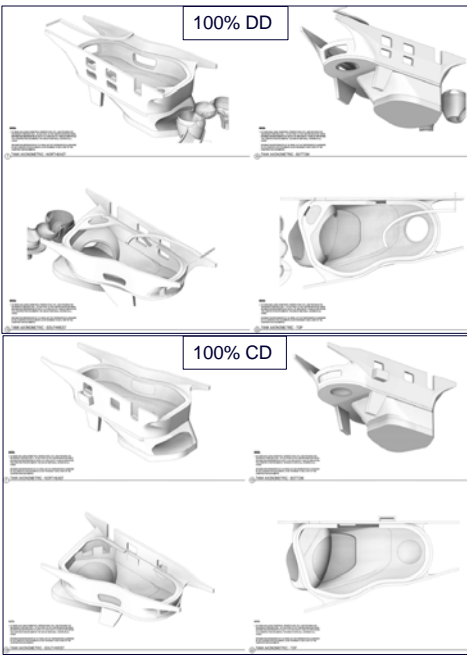
DESIGN:

- Refining geometry (double curvature) over design phase in coordination:
 - Owner
 - Designer
 - GC
 - Marine Biologists
 - Subcontractors



100% DD

100% CD



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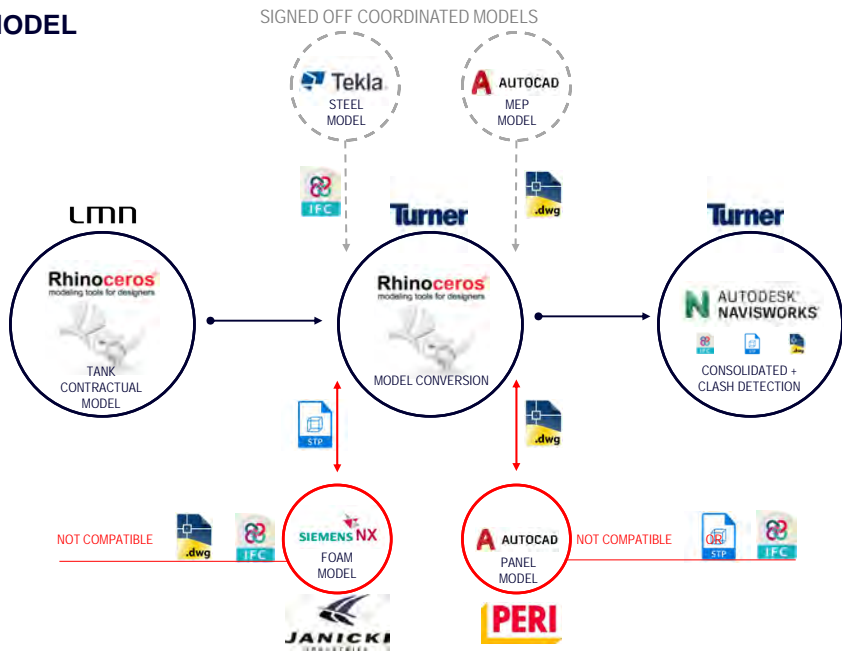
Coral Canyon FORMWORK: MODEL

SIGNED OFF COORDINATED MODELS

- Models provided as Contract Documents (Rhino)
- Subs utilize different programs
- Turner consulted with Navisworks, SketchUp, Tekla on exporting from Rhino
- Turner was the conduit for import/exporting information to and from respective programs to Rhino
 - QAQC'ed each iteration of exports
- Turner clash coordinated in Navisworks

Schedule:

- Coordination
 - Start – July 21
 - Finish – June 22
- Delivery
 - Start – July 22
 - Finish – Dec 22



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Coral Canyon FORMWORK: MODEL

FORMWORK/FOAM + CONTEXT

FORMWORK/FOAM + CONTEXT

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Coral Canyon FORMWORK: FABRICATION PROCESS

- No straight edges in the pour
- 229 panels and 40 foam inserts
- Each Panel goes through three companies before reaching site
- Panels are CNC'd foam glued to Peri backing and sprayed with a truck bed liner
- Minimal laydown space at the jobsite

PERI FAB'ED PANEL

JANICKI INDUSTRIES CNC'D FOAM GLUED TO PANEL

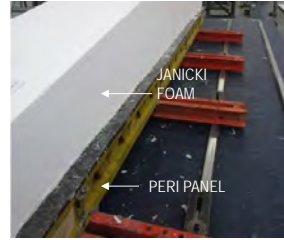
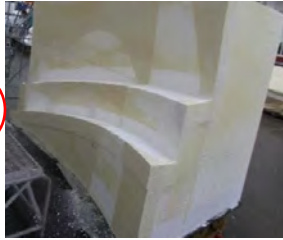
PSC PUGET SOUND COATINGS SPRAY COATED

Turner ASSEMBLED ON SITE

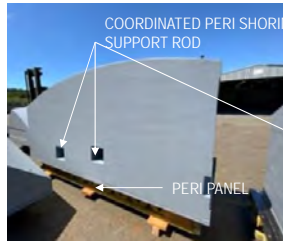
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Coral Canyon FORMWORK: FABRICATION PROCESS

JANICKI CNC'ED + GLUED TO PERI PANEL



SPRAY COATED BY PSC

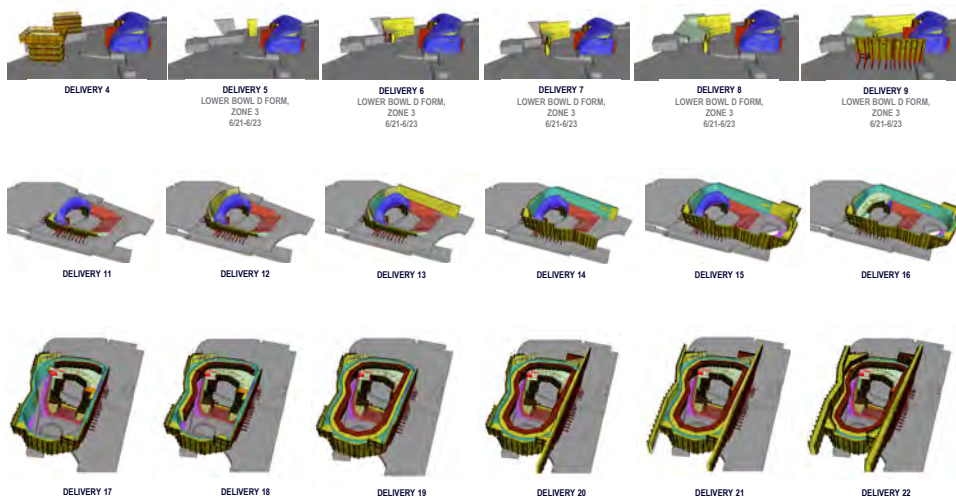


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Coral Canyon FORMWORK: INSTALL SEQUENCE

4D SEQUENCE MODEL / DELIVERY TRACKING (SKETCHUP)

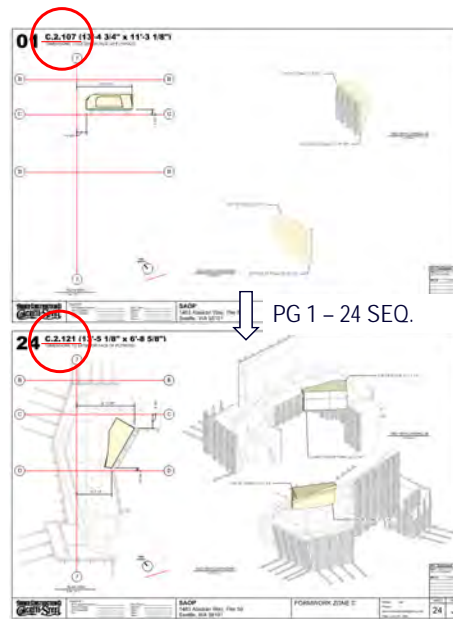
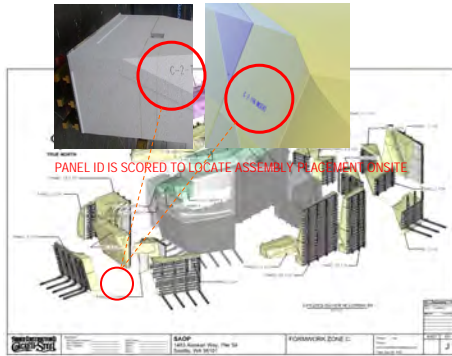


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Coral Canyon FORMWORK: FORMWORK LIFT DRAWINGS

- (SKETCHUP) can also be generated from Tekla and Revit
- Use of Sketchup was modeler's choice of preference

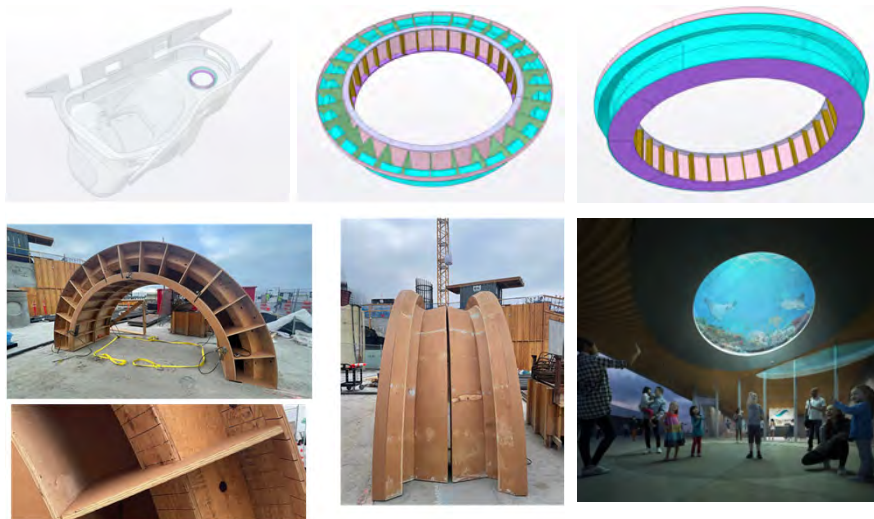


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Coral Canyon FORMWORK: ADDITIONAL PRODUCTION

IN HOUSE SHARKULUS FORMWORK (RHINO CAM + CNC)

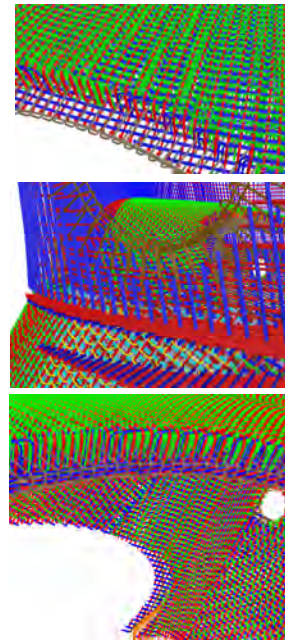
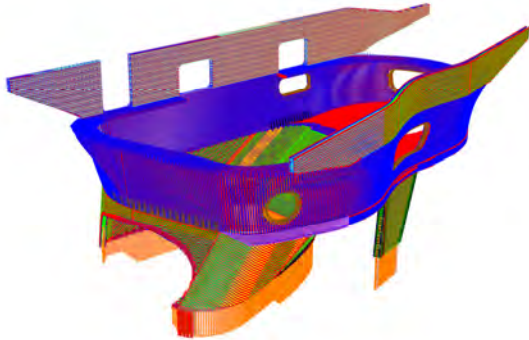


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Coral Canyon REBAR: MODEL & COORDINATION FABRICATION MODEL (RHINO + GRASSHOPPER)

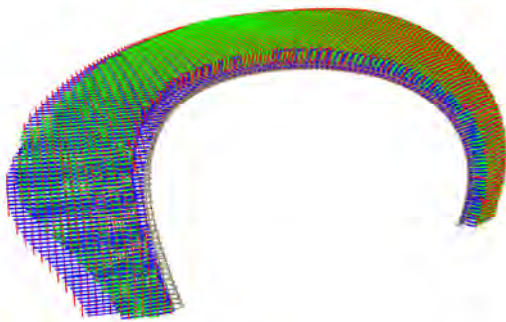
- LEAN Process:
 - 3D Contract Model used in tandem with 2D Structural Drawings
 - Provided 3D to design team with 2D shop drawings
- Rhino software used for concrete geometry due to double curvatures.
- Rhino does not export into Tekla (rebar detailing software) accurately.
- Grasshopper plug in used to make the export



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Coral Canyon REBAR: INSTALL FABRICATION + ON SITE ASSEMBLY



RHINO + GRASSHOPPER MODEL
(INSIDE ZONE C)

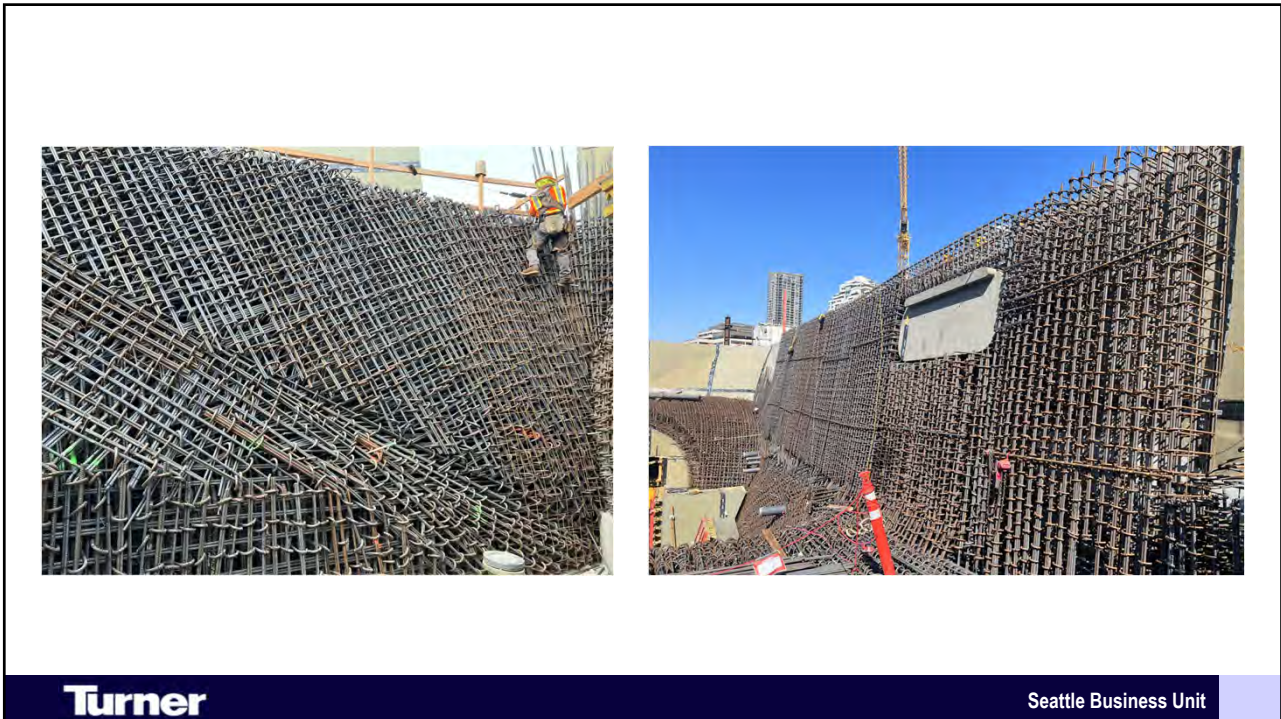
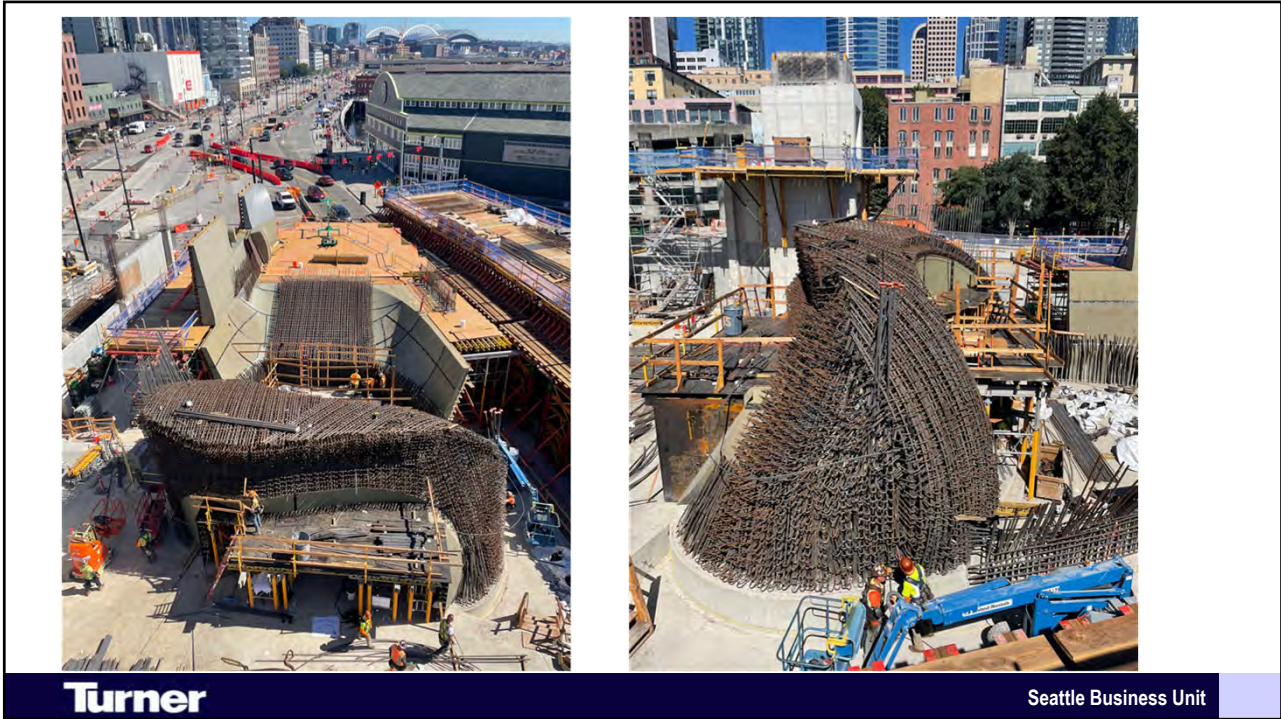


REBAR PLACEMENT ONSITE
(INSIDE ZONE C)

- Collaborative site walks throughout install of rebar

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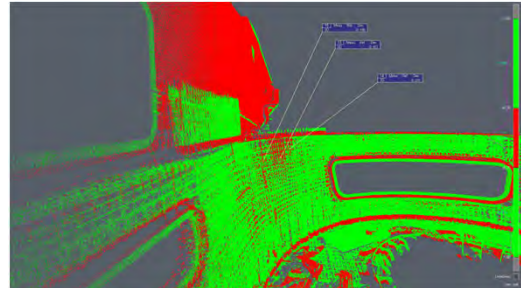
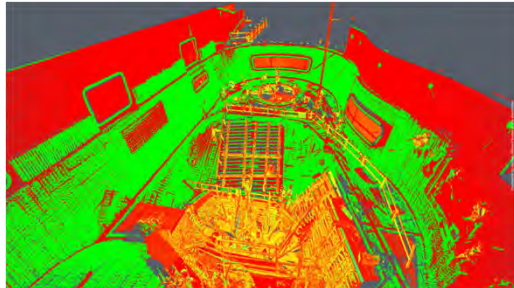
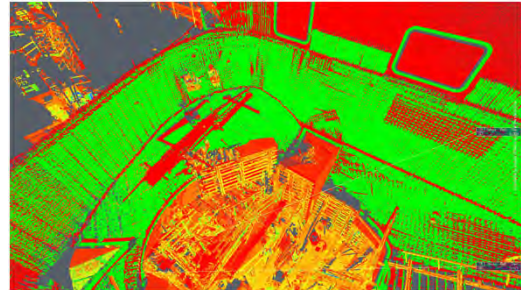
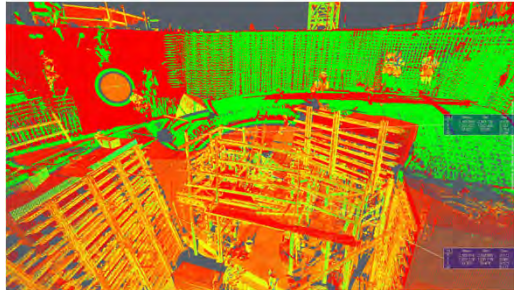


PRE-POUR QC: 3D SCANNING OF CORAL CANYON REINFORCING

Tolerances

Wet Side:
3" +/- ¼"

Dry Side:
1 ½" +/- ¼"



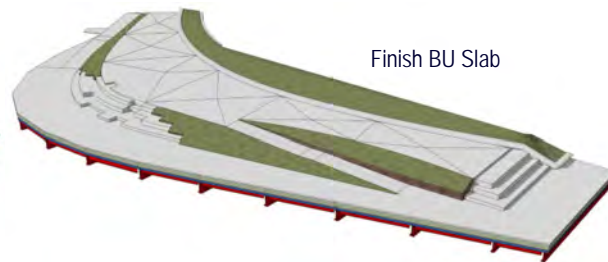
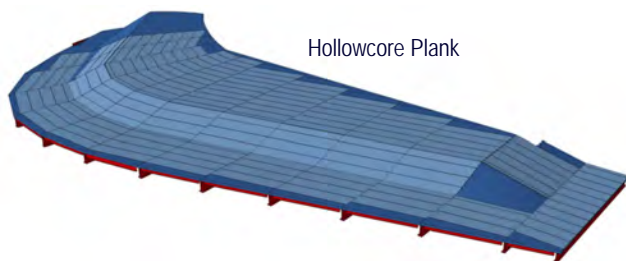
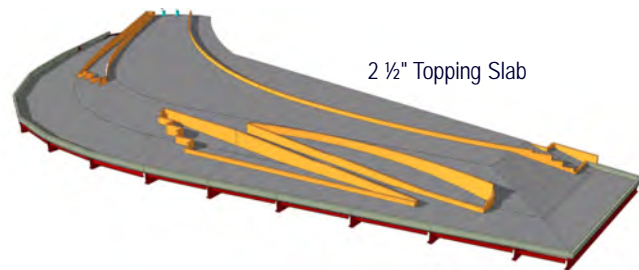
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ROOF: HOLLOWCORE PRECAST DESIGN

Design Evolution:

- Waffle Slab
- Bubble Deck
- PT
- Mild Steel
- Precast & Foam



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Want to learn more or donate?
www.seattleaquarium.org

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QUESTIONS?

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