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# Design-Build of the First 10 Miles of Honolulu Rail Transit Project

2017 Western Bridge Engineers' Seminar
September 7, 2017
Kuan Go, PE, SE and Alan Marchman, PE

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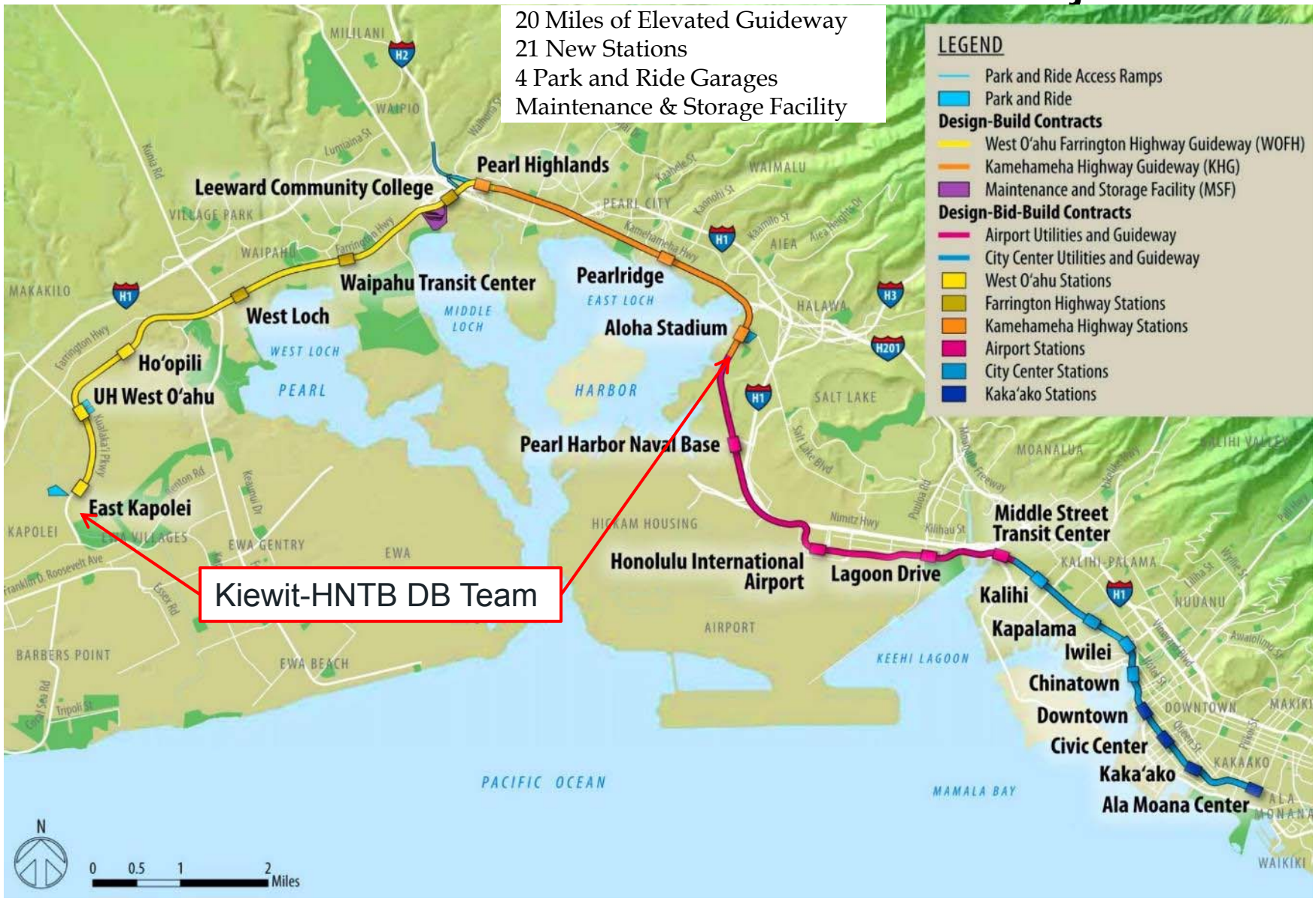
# Project Overview

# HART – Honolulu Rail Transit Project

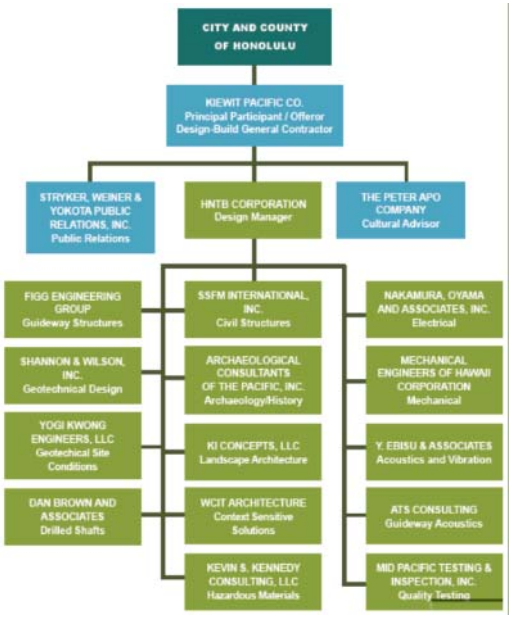



# First 10 miles of Design Build – Project Overview

- West O'ahu/Farrington Highway Guideway (WOFH)
  - Contract Start Date: December 2009
  - Contract Substantial Completion: March 2017
  - Current Contract Value - $669M
  - 6.8 Miles of Rail Alignment (0.6 Miles At-Grade)
  - Operational in Late 2020 (East Kapolei to Aloha Stadium Station)
- Kamehameha Hwy Guideway (KHG)
  - Contract Start Date: June 2011
  - Contract Substantial Completion: Sept 2017
  - Current Contract Value - $392M
  - 3.9 Miles of Rail Alignment
  - Operation in Late 2020 (East Kapolei to Aloha Stadium Station)

# Design-Build Team (WOFH & KHG)

- Design-Build Contractor & Precaster
  - Kiewit Infrastructure West Co.
- Bridge Design Engineers
  - HNTB (Prime & Substructure)
  - FIGG (Segmental Superstructure)
  - Shannon Wilson (Geotechnical)



# Constraints

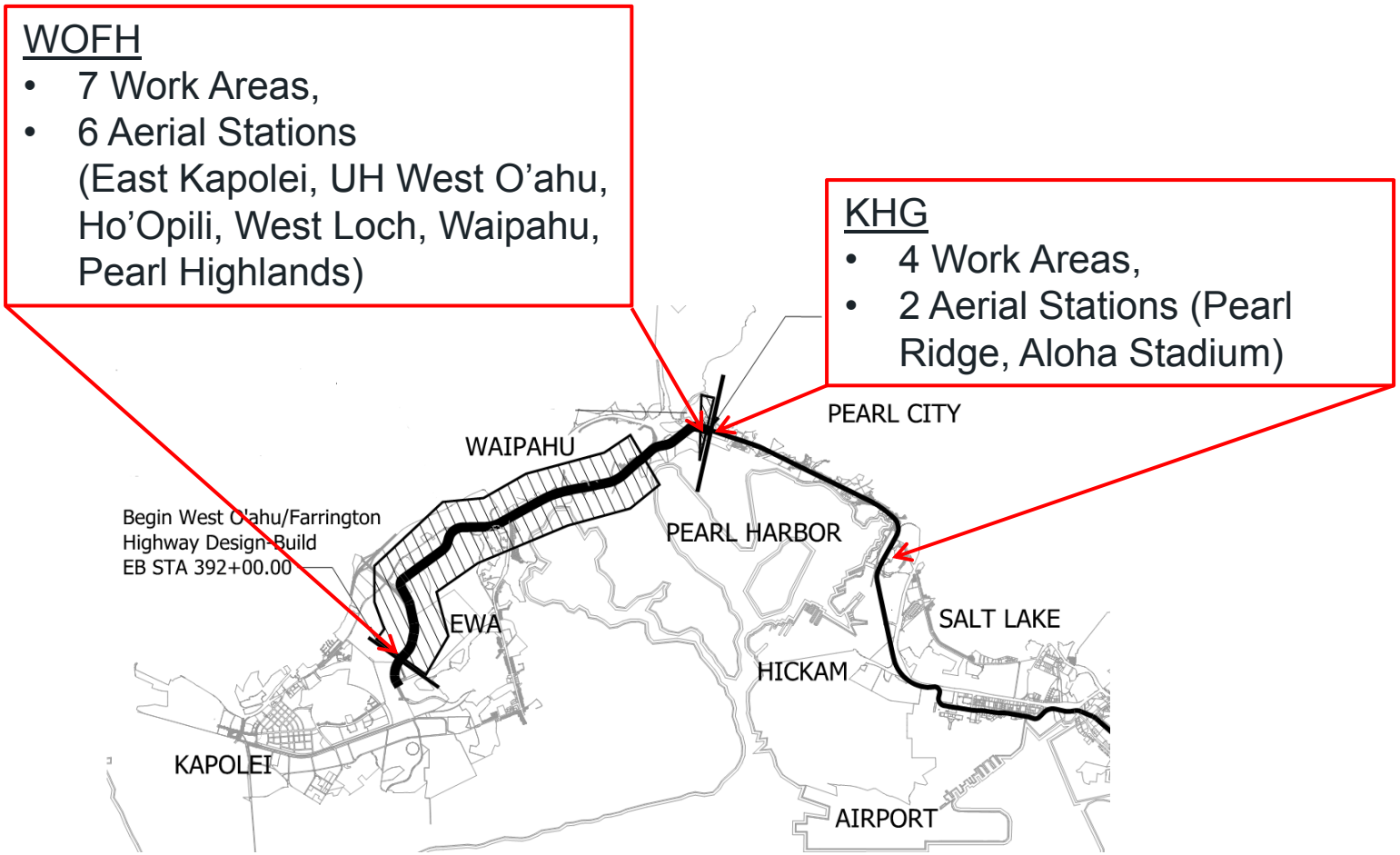
- Subsurface Conditions
- Guideway Profile
- Environmental Constraints
- Schedule


East Kapolei Aerial


Aloha Stadium Aerial

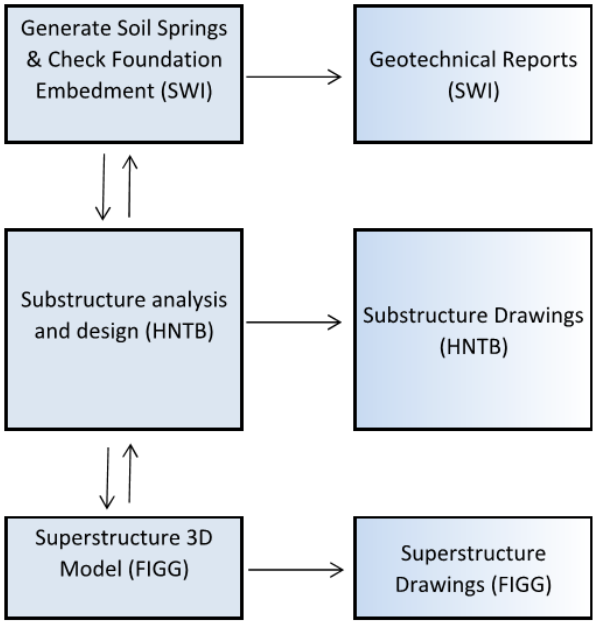
Photo Source: HART Flickr account.
https://www.flickr.com/photos/honolulurail/albums/with/72157663300219845

# Guideway Structures Design Packages



# Guideway Team Work Flow

- Interactions Between
  - Superstructure (FIGG)
  - Substructure (HNTB)
  - Geotech (SWI)
- 3D FEM
- Soil Springs Sensitivity Analyses
- Design Presented in Tables




| PIER NO | STA | OFFSET | SHAFT TYPE | DIAMETER | CONCRETE Note 6 | TOP OF SHAFT ELEV "E" | MIN TIP ELEV "Q" | MIN. ROCK SOCKET LENGTH | MAX. ROCK SOCKET LENGTH | MIN. TOP OF ROCK SOCKET ELEV | MAX. TOP OF ROCK SOCKET ELEV | "E" | BASE GROUTING | CASING "W" | CASING "H" | CASING WALL THICK | REINFORCEMENT TYPE A BAR | NO | TYPE B BAR | NO | TYPE C BAR | NO | TYPE D BAR | NO | "C" | "D" | "J" | "K" | "L" | "R" | SEISMIC DESIGN CATEGORY | COORDINATES EASTING | NORTHING |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (FT) | | (FT) | (PSI) | (FT) | (FT) | (FT) | (FT) | (FT) | (FT) | (FT) | | (FT) | (FT) | (IN) | | | | | | | | | (FT) | (IN) | (FT) | (FT) | (FT) | (FT) | | (FT) | (FT) |
| 309 | 831+30.35 | 4.00L | BA | 8.00 | 4000 | 35.4 | -4.6 | 16.9 | 25.0 | 12.3 | 20.4 | 40.0 | No | -- | -- | -- | 11DS01 | 36 | 11DS02 | 36 | 11DS03 | 36 | 11DS04 | 36 | 10'-9" | 6.0 | 3.1 | 0.0 | -- | 24.9 | B | 1,653,558.64 | 81,254.26 |
| 310 | 832+70.35 | 0.00 | 7Q | 7.33 | 4000 | 33.7 | 19.7 | 8.2 | 11.0 | 27.9 | 30.7 | 14.0 | No | -- | -- | -- | 11DS01 | 24 | 11DS02 | 24 | -- | -- | -- | -- | 8'-10" | 6.0 | -- | 4.4 | -- | -- | B | 1,653,683.69 | 81,191.20 |
| 311 | 834+15.35 | 0.00 | 7Q | 7.33 | 4000 | 31.5 | 20.5 | 8.0 | 8.0 | 28.5 | 28.5 | 11.0 | No | -- | -- | -- | 11DS01 | 24 | 11DS02 | 24 | -- | -- | -- | -- | 8'-10" | 6.0 | -- | 1.4 | -- | -- | B | 1,651,814.94 | 81,179.56 |
| 312 | 835+20.35 | 0.00 | 7Q | 7.33 | 4000 | 29.9 | -9.1 | 21.0 | 34.0 | 11.9 | 24.9 | 39.0 | No | -- | -- | -- | 11DS01 | 24 | 11DS02 | 24 | -- | -- | -- | -- | 8'-10" | 6.0 | -- | 29.4 | -- | -- | B | 1,653,809.62 | 81,084.16 |
| 313 | 836+65.35 | 0.00 | 7Q | 7.33 | 4000 | 27.6 | -11.4 | 19.0 | 29.5 | 7.6 | 16.1 | 39.0 | No | -- | -- | -- | 11DS01 | 24 | 11DS02 | 24 | -- | -- | -- | -- | 8'-10" | 6.0 | -- | 29.4 | -- | -- | B | 1,654,059.70 | 81,020.11 |
| 314 | 838+10.35 | 0.00 | 7Q | 7.33 | 4000 | 25.5 | 4.5 | 7.7 | 12.0 | 12.2 | 16.5 | 21.0 | No | -- | -- | -- | 11DS01 | 24 | 11DS02 | 24 | -- | -- | -- | -- | 8'-10" | 6.0 | -- | 11.4 | -- | -- | B | 1,654,169.11 | 80,954.70 |
| 315 | 839+35.35 | 0.01R | 7Q | 7.33 | 4000 | 24.0 | -22.0 | 3.0 | 41.0 | -19.0 | 19.0 | 46.0 | No | -- | -- | -- | 11DS01 | 24 | 11DS02 | 24 | -- | -- | -- | -- | 8'-10" | 6.0 | -- | 36.4 | -- | -- | B | 1,654,280.59 | 80,898.15 |
| 316 | 840+60.35 | 0.00 | 7R | 7.00 | 4000 | 21.8 | -17.2 | 13.4 | 16.6 | -3.8 | -0.6 | 39.0 | No | 20.9 | -- | 0.75 | 11DS01 | 24 | 11DS02 | 24 | 11DS03 | 24 | 11DS04 | 24 | 8'-10" | 6.0 | 12.4 | 0.0 | -- | 16.5 | B | 1,654,392.36 | 80,842.19 |
| 317 | 841+85.35 | 0.00 | 7R | 7.00 | 4000 | 20.1 | -48.9 | 34.0 | 34.0 | -14.9 | -14.9 | 59.0 | No | 30.0 | -- | 0.75 | 11DS01 | 20 | 11DS02 | 20 | 11DS03 | 20 | 11DS04 | 20 | 8'-10" | 6.0 | 19.2 | 5.9 | -- | 33.9 | B | 1,654,504.66 | 80,787.30 |
| 318 | 842+99.35 | 0.00 | 7R | 7.00 | 4000 | 19.4 | -23.6 | 5.0 | 12.5 | -18.6 | -11.1 | 43.0 | No | 25.0 | -- | 0.75 | 11DS01 | 20 | 11DS02 | 20 | 11DS03 | 20 | 11DS04 | 20 | 8'-10" | 6.0 | 19.2 | 1.4 | -- | 12.4 | B | 1,654,607.18 | 80,737.43 |
| 319 | 844+35.35 | 0.00 | 7R | 7.00 | 4000 | 18.7 | -31.3 | 4.5 | 4.5 | -26.8 | -26.8 | 50.0 | No | 23.0 | -- | 0.75 | 11DS01 | 20 | 11DS02 | 20 | 11DS03 | 20 | 11DS04 | 20 | 8'-10" | 6.0 | 19.2 | 16.4 | -- | 44 | B | 1,654,729.47 | 80,677.93 |
| 320 | 845+60.35 | 0.00 | 7R | 7.00 | 4000 | 17.9 | -34.1 | 3.7 | 14.0 | -30.4 | -20.1 | 52.0 | No | 18.0 | -- | 0.75 | 11DS01 | 28 | -- | -- | 11DS03 | 28 | -- | -- | 8'-10" | 6.0 | 13.5 | 14.6 | -- | 13.9 | B | 1,654,841.66 | 80,623.25 |
| 321 | 846+85.35 | 0.00 | 7R | 7.00 | 4000 | 17.4 | -42.6 | 1.7 | 37.0 | -40.9 | -5.6 | 60.0 | No | -- | -- | -- | 11DS01 | 28 | -- | -- | 11DS03 | 28 | -- | -- | 8'-10" | 6.0 | 13.0 | 0.0 | -- | 36.9 | B | 1,654,954.28 | 80,568.57 |
| 322 | 848+10.35 | 0.00 | 7R | 7.00 | 4000 | 16.5 | -43.5 | 26.7 | 34.0 | -16.8 | -9.5 | 60.0 | No | -- | -- | -- | 11DS01 | 28 | -- | -- | 11DS03 | 28 | -- | -- | 8'-10" | 6.0 | 13.5 | 2.6 | -- | 33.9 | B | 1,655,066.69 | 80,513.89 |
| 323 | 849+35.35 | 0.04R | 7R | 7.00 | 4000 | 16.3 | -31.7 | 21.0 | 21.0 | -10.7 | -10.7 | 48.0 | No | -- | -- | -- | 11DS01 | 28 | -- | -- | 11DS03 | 28 | -- | -- | 8'-10" | 6.0 | 13.5 | 3.6 | -- | 20.9 | B | 1,655,179.08 | 80,459.18 |
| 324 | 850+60.35 | 0.13R | 7R | 7.00 | 4000 | 15.8 | -51.2 | 2.0 | 41.0 | -49.2 | -10.2 | 67.0 | No | -- | -- | -- | 11DS01 | 28 | -- | -- | 11DS03 | 28 | -- | -- | 8'-10" | 6.0 | 13.5 | 2.6 | -- | 40.9 | B | 1,655,291.89 | 80,405.33 |
| 325 | 851+96.35 | 0.05R | 7R | 7.00 | 4000 | 15.6 | -52.2 | 7.7 | 7.7 | -44.5 | -44.5 | 67.8 | No | -- | -- | -- | 11DS01 | 28 | -- | -- | 11DS03 | 28 | -- | -- | 8'-10" | 6.0 | 13.5 | 36.7 | -- | 7.6 | B | 1,655,415.80 | 80,349.28 |

# Design & Construction “Standard” Features

- Precast Segmental Construction
  - Erected By Span-by-Span Method
- Round Columns
- Single Drilled Shafts

# Precast Segmental Construction

- 7 ft 2 in. Deep Box Girders
  - 30 ft Wide for Double Track
  - 17 ft 3 in Wide for Single Track
- Longitudinally Post-Tensioned
- Top Slab Transversely Post-Tensioned

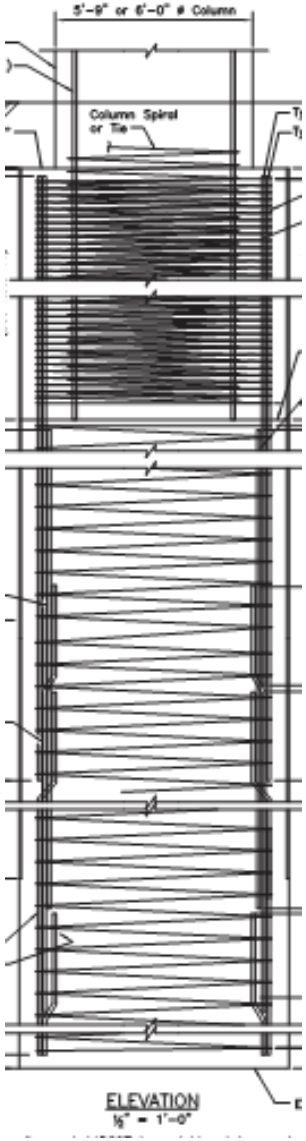
# Precast Segmental Construction

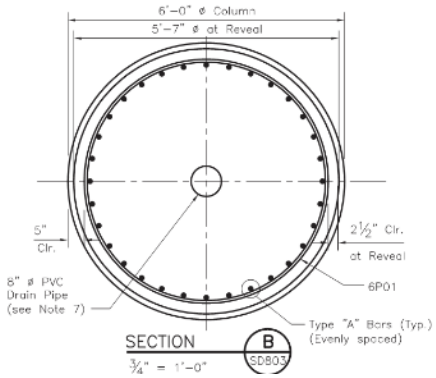
- Erected By Span-by-Span
- Typical 11’ Segments
- 125’ Spans

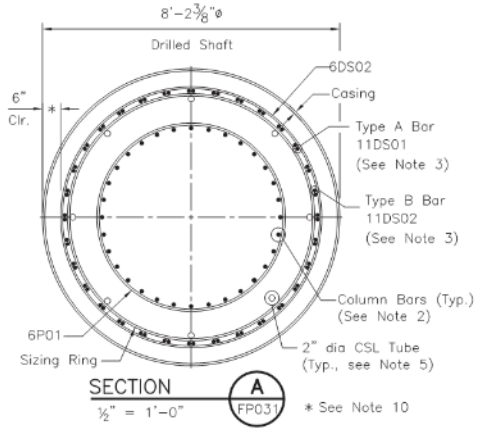
# Round Columns & Single Drilled Shafts

- Minimize Excavation Footprint
- Mitigates Risk of Encountering Hazardous Materials or Culturally Sensitive Burial Sites
- Minimized Noise / Vibration
- Standardized Column and Shaft Sizes

# Round Columns & Single Drilled Shafts




- Standardized Column and Shaft Sizes
  - 5'-9", 6', 7' Columns,
  - 7' & 8' Shafts (w & w/o Casings)
  - Transition Zones

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# Construction Photos

# Casting Yard

# Casting Yard – 13 Casting Beds

# Casting Yard – 3000 Segments Stored

# Erection Truss

# Erection Truss

# Erection Truss

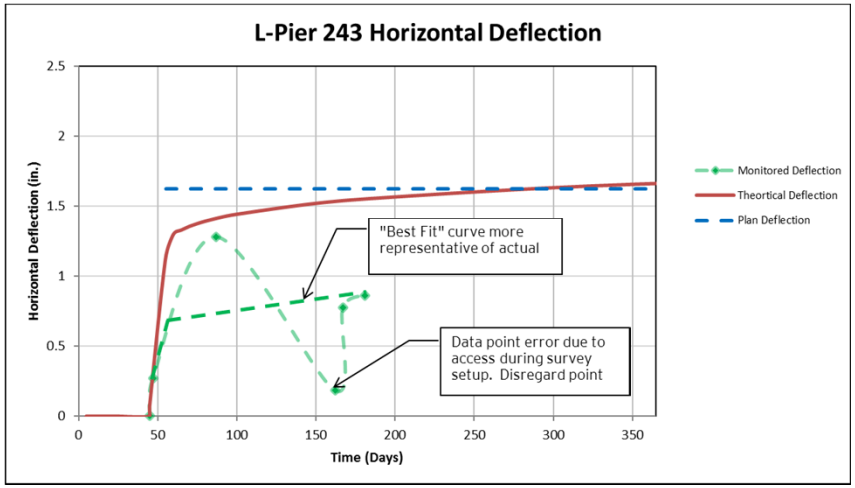
# “Non-Standard” Construction

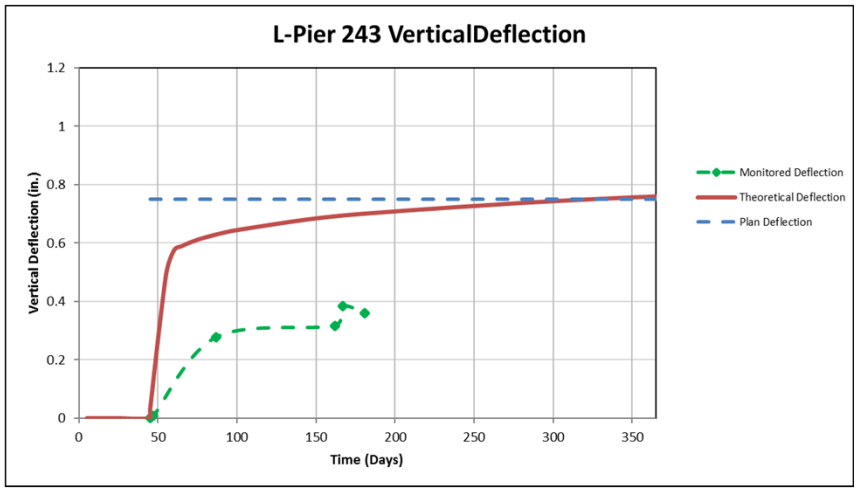
- C & L Piers
- Station Piers
- Cast-in-Place Balanced Cantilever Construction Over H-1

# C & L Piers

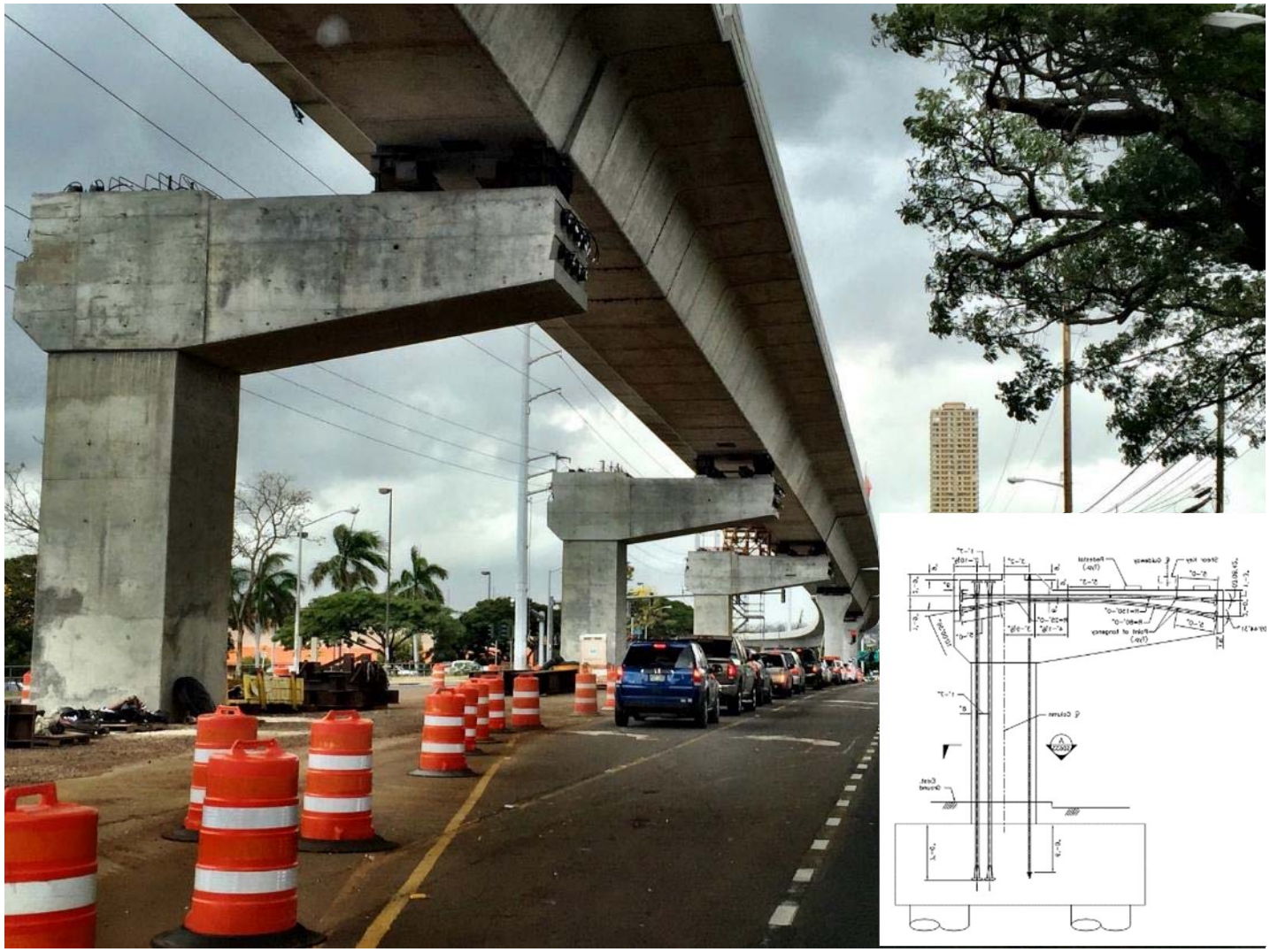
# C & L Piers Design Considerations

- Pier / Superstructure Deflections
- Shear Key Offset
- Creep
- Deflection Variables
  - Soil Springs
  - Concrete Strength
  - Construction Tolerance
- Adjust Deflection Values on Future Piers



# C & L Piers (PT Cap & Column)



# Station Pier (Ho'Opili Station)

**Wind, Sun, Showers**

**Wildlife**
'Ōhia forest, Lei of Ma'o

**Kalo'i/Kīpuka**
Kalo'i Spring, Hapu'u

# Station Pier (Ho'Opili Station)


Source: HART Flickr account:
https://www.flickr.com/photos/honolulurail/35737898252/in/album-72157631052041034/

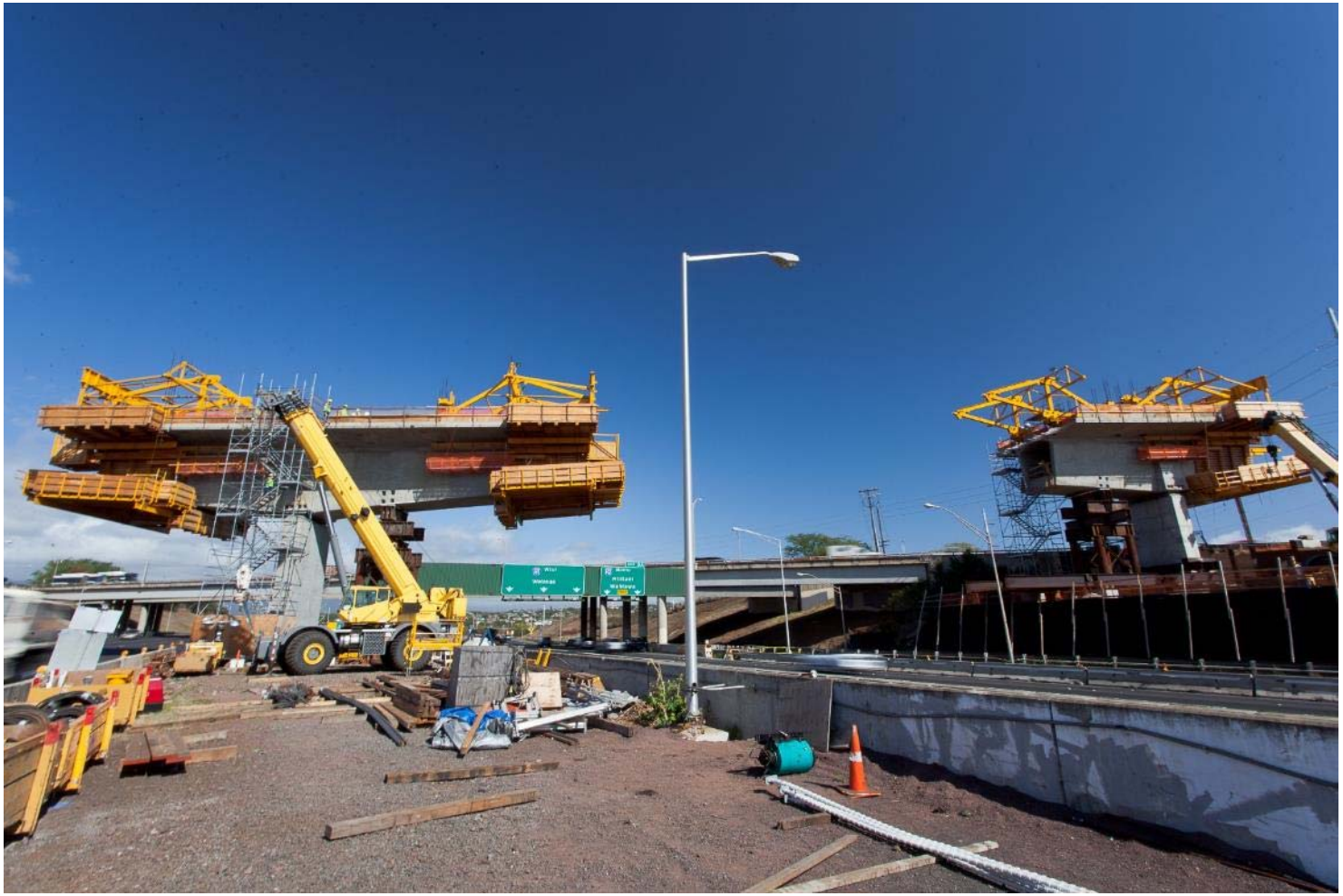
# Station Piers (Aloha Stadium)

# Balanced Cantilever Structures Over H-1



- Photo Source: HART Flickr account.
  https://www.flickr.com/photos/honolulurail/albums/with/72157663300219845

# CIP BCS - March 2015



# CIP BCS - May 2015

# CIP BCS - August 2015

# CIP BCS – Oct 2016

# CIP Balanced Cantilever Structures at KHG

# CIP Balanced Cantilever Structures at KHG


# First 10 miles of Design Build

| | WOFH | KHG | TOTAL |
|---|---|---|---|
| Shafts | 309 | 186 | 495 |
| Columns | 283 | 169 | 452 |
| Segment Casting | 3209 | 2029 | 5238 |
| Spans Stressed | 274 | 163 | 437 |
| Avg Segments per Span | 11.7 | 12.4 | 12.0 |
| Avg Span Length | 120 feet | 126 feet | 122 feet |
| Avg Segment Length | 10.3 feet | 10.2 feet | 10.2 feet |

# Honolulu Rail Transit Project - By the Numbers
# First 10 Miles

- 10 Miles of Elevated Guideway
- 9 Stations (8 Aerial + 1 At Grade)
- 80 ksi Max Rebar Used on Project
- 72,000 lb – Weight of Each Car
- 64 ft Long Car Trains (2-Car Trains)
- **5**,238 Segments on First 10 Miles, 55 mph Train Speed
- No. 4 on *Roads & Bridges* 2016 Top 10 Bridges list
- 3 Superstructure Erection Trusses
- 2020 – Planned Opening of East Kapolei to Aloha Stadium
- 1st Phase, 1st Driverless Rail Transit System in the US

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# Lessons Learned

- Value of IPO (Integrated Project Office)
- Interface Challenges With DB & DBB Contracts
- Complexities of Large Cantilever C Piers

# Acknowledgements

## Design-Build of the First 10 Miles of Honolulu Rail Transit Project

And… Many Other Subcontractors / Subconsultants

For More Info:

http://www.honolulutransit.org/

https://www.flickr.com/photos/honolulurail/albums/with/72157646789537243

# Thank You 2017 WBES