Bigelow Boulevard Reconfiguration Project

PRESENTED BY: OAKLAND DESIGN-BUILD, INC.

DECEMBER 11, 2015
ODB, Inc. - THE TEAM

- Project Manager: Nathan Schaeffer
- Water Resources Lead: Matthew Kambic
- Geotechnical Team: Robert Gehris, Garrett Swarm
- Structural Team: Nicholas Hoffmaster, Jiangmin Lin, Grant Stahl
This project is meant to address a well-known issue in Oakland, assess multiple project and design alternatives, and ultimately conduct a feasibility study for an ambitious, large-scale solution.
PROJECT LOCATION
THE PROBLEM
THE PROBLEM

- Unsafe pedestrian-to-vehicle interaction
- Current configuration encourages jaywalking
The problem:

- Heavy pedestrian volume generates constant roadway congestion
- Motorists miss multiple light cycles
- High potential for increased aggression leads to accidents
RECENT ACCIDENT DATA

- From 2009-2013
  - Bigelow Blvd & Forbes Ave Intersection
    - 6 pedestrian strikes, moderate to severe
  - Bigelow Blvd & Fifth Ave Intersection
    - 4 pedestrian strikes, moderate severity

- 5 casualties just in 2015...
  - 1 bicyclist
  - 4 pedestrians in bus lane
ORIGINIAL SOLUTION – Pedestrian Bridge

Concrete bridge deck with green spaces incorporated into design. Potential for sitting areas and other aesthetic appeal.

Eliminate traffic spots to widen road. Allows for concrete columns which shortens structural spans.

Deck structural system omitted due to numerous design possibilities.

Concrete or steel girders to maximize aesthetic appeal of area.

MSE Walls. Located at each ramp tying existing walkway system.

Concrete Foundations and bridge columns.

Alternative Option: Diverting traffic from Forbes to Fifth via a tunnel. Potential issues include spatial constraints, existing utilities, among others.
Elevated pedestrian bridge structure

Benefits
- Diverts pedestrians safely across corridor
- Adds pleasant plaza space

Option Abandoned
- Aesthetically unpleasing – even with limestone cladding
- ADA compliance difficulties – long routes deemed unacceptable
- Requires lowering Bigelow – not deep enough to make a true difference vertically
- Does not eliminate jaywalking without large barriers

ULTIMATE DECISION: Cost-Benefit ratio too low
### Pedestrian tunnel underneath Bigelow

**Benefits**
- Diverts pedestrians safely across corridor
- Maintains aesthetic appeal

**Option Abandoned**
- Minimal opportunity to create pleasant urban environment
- High potential to attract unwanted residents
- Safety concerns during late night hours
- Proposed by previous senior design team as an option

**ULTIMATE DECISION:** Unappealing to the public & dangerous
ALTERNATIVE SOLUTIONS

- **Vehicular underpass along Bigelow**

- **Benefits**
  - Diverts pedestrians safely across corridor
  - Adds ~45,000 SF of sustainable, campus-style area to an overly-urban campus
  - Maintains aesthetic appeal of Cathedral & Union
  - Allows vehicles to pass through corridor (limited)

- **Dis-benefits**
  - Minor vehicular restrictions and utility concerns
  - Large price tag

**ULTIMATE DECISION:** Best option with the following considerations
What design options will allow for the maximum access to the Soldiers & Sailors garage?

What sections of road or turning movements do we maintain or eliminate?

How do we construct this without crippling Oakland for half a decade?
PROJECT GOALS

- Provide innovative, multifaceted solution by,
  - Reducing pedestrian-vehicle conflicts
  - Creating a sustainable, campus-style landscape
  - Maintaining motorist access along corridor: O’Hara St. to Schenley Dr.
  - Maintain access into/out of Soldiers & Sailors garage
  - Preserving aesthetic appeal of the “Heart of Oakland”
    - William Pitt Union & Cathedral of Learning
PROJECT DELIVERABLES

- Proposed Roadway Vertical and Horizontal Alignment
- Re-routed Combined Sewer System
- Load-bearing & Non Load-bearing Wall Systems
  - LB – Secant Pile Walls
  - NLB – Cantilever (Gravity) Walls
- Steel Girder Structures: Comprehensive Design
  - Soldiers & Sailors Extension, Fifth Ave, Pedestrian Plaza, Forbes Ave
- Precast/Pre-stressed Concrete Slab Structures: Preliminary Design
  - Soldiers & Sailors Extension, Fifth Ave, Pedestrian Plaza, Forbes Ave
- Preliminary construction cost estimate and schedule
GLOBAL DESIGN CONSIDERATIONS

▶ Social Impact
  ▶ How daily life is disturbed during construction & community perception
▶ Construction Cost
▶ Construction Duration
▶ Historic Impact

▶ Deliverable activities weighted independently
View south from O’Hara Street
View north from Schenley Drive
View of proposed pedestrian plaza in between the Cathedral of Learning and the William Pitt Union.
STRAIGHT-LINE TRAFFIC MODEL

- Basic model for understanding of traffic movements and lane configurations
- Display project limits while excluding structures and drainage
Considerations

- 4'-0" superstructure depth allowed
- Must clear 14'-6" at entrance to Soldiers & Sailors Structure
- Must clear 15'-6" underneath Pedestrian Structure
- Maximum grade: 11%
- Maintain current elevations at outer intersections

Maximum depth of cut ~30 ft

<table>
<thead>
<tr>
<th>Design Results</th>
<th>Value</th>
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<tbody>
<tr>
<td>Overall Length (ft)</td>
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<td>Design SSD (ft)</td>
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<td>Min. Horizontal Radius (ft)</td>
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<td>Superellevation (%)</td>
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<td>Crest Curve K-Value</td>
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<tr>
<td>Sag Curve K-Value</td>
<td>37</td>
</tr>
</tbody>
</table>
VERTICAL PROFILE DESIGN

Fifth Ave Structure

Pedestrian Structure

Sta 19+49.28

20' 11\(\frac{5}{8}\)"

21' 11\(\frac{9}{16}\)

21' 8\(\frac{9}{16}\)

17'-11\(\frac{5}{8}\)'

Sta 22+67.38

1.50%

Sta 24+00.33

PV
Water Resources Design Objectives

- Eliminate conflicts between proposed design and existing combined sewer system
  - Realign and resize pipes as needed

- Manage runoff in below-grade area
  - Add inlets, manholes, and new pipe
  - Use wet well with pump to tie stormwater back into combined sewer main
Water Resources Design

- Created model of existing pipe network using Autodesk Storm & Sanitary

- Model will give peak flows and allow analysis of existing and proposed systems
Combined Sewer Model

- Green area = Drainage Area
  - Not to scale.
- Black lines = Pipes/Channels
- Red circle with J = Junction/Manhole
- Grey box = Inlet
Combined Sewer Model

- Created layout in CAD
  - Overlay of pipe network imagery
    - Manhole locations, pipe sizes & locations
  - Drew in inlets from satellite imagery
- Imported CAD drawing into modelling software
- Modeled inlets
  - Type, rim elevation, bottom elevation
  - Connected 15" RCP pipe from inlet to sewer line
  - Added backflow prevention
  - Modeled small open channel between inlets in case of inlet flooding
Modeled pipe network
- Traced over CAD layout
- Input size, manning’s roughness, invert elevations, and length
  - Assumed RCP, unless otherwise known
  - Utilized survey data in area of project
- Connected to manholes and junctions

Modeled storm runoff to inlets
- Used modified rational method (PWSA suggestion)
  - \( Q = c \times i \times A \)
    - \( i = 5.8 \text{ in/hr (25 yr storm, from PWSA)} \)
- Used CAD to determine drainage areas, flow length, and runoff coefficient
Combined Sewer Model

- Estimated average sanitary flow in pipes using equation in PWSA Developer’s Guide
  - Average Flow = (Peak Flow) / 3.5
  - Peak Flow calculated using Manning’s Equation
  - Used default time series
- Completed existing conditions model can now be adjusted as necessary to check proposed conditions
Relocation and Resizing of Pipe

- Relocated pipes to prevent conflicts between proposed and existing conditions
- Designed to manage 25 year storm event
- Pipe sizes adjusted as required
- Used RCP per PWSA requirements
OLD VS. NEW
Inlets and Manholes

- Used standard details from PWSA
- Manholes located at major grade changes, where pipe size changes, and less than 450' apart (PennDOT Pub. 584)
- Proposed inlets spaced ~ 300 feet apart (PennDOT Pub. 584)
- Inlets placed before below-grade roadway & tie directly in to existing system
- Maintenance is key; inlets tend to clog unless regularly cleaned
Pump and Wet Well Calculations

- Below-grade pipes, including pump and wet well, designed to 50 year storm
  - Not required by PWSA but acts as safety factor since flooding of low point could be dangerous
  - \( I = 8.2 \text{ in/hr} \)
- Pump and storage must be designed to manage the inflow hydrograph
- Inflow hydrograph created from updated Autodesk Storm & Sanitary model

Inflow hydrograph into wet well (50 year storm)
System Curve Calculation

- Calculations performed using Microsoft Excel
- Hazen-Williams equation used to account for friction losses
  \[ h_f = 10.67 \times L \times \frac{Q^{1.85}}{C^{1.85} \times d^{4.87}} \]
  - C = pipe roughness coefficient
  - d = inside pipe diameter (ft)
  - Q = flow rate (cfs)
  - L = length of pipe (ft)
- Minor loss equation accounted for entrance, exit, bend, and check valve losses
  \[ h_m = \sum K \times \frac{V^2}{2g} \]
  - K = minor loss coefficient
  - V = velocity (fps)
  - g = acceleration due to gravity (ft/s^2)
- ~31' of static head
Submersible Pump Model: Tsurumi KRS2 B4
- 4” discharge
- Switches on at 3’ above minimum submergence
  - Minimum submergence is 1.50’
- Remains on until water level has returned to minimum submergence level
- Using average 50 year flow rate, will switch on about 5 times per hour
  - No manufacturer’s data available on actual minimum time between cycles
Wet Well

- 6’ diameter, circular cross section
- Precast concrete
- Hatch and ladder allow access to pump for maintenance
Sub Button1_Click()
Dim i As Integer
Dim j As Integer

i = 3
j = Cells(i - 1, 16) / (3.14 * 3 ^ 2)

Do Until i = 361
    If j >= 8 Then
        Do Until j = 0
            Cells(i, 13).Value = Cells(i, 9) - 0.534
            j = Cells(i - 1, 16) / (3.14 * 3 ^ 2)
            i = i + 1
        Loop
    Else
        Cells(i, 13).Value = Cells(i, 9)
    End If

End Sub
Drop Manhole

- Connected pump discharge to drop manhole
  - Ties proposed storm system into combined sewer system
- Detail created from PWSA standard drop manhole detail
- Includes check valve to prevent sanitary flows from entering pump system
## Proposed Pipe Summary

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Pipe Size (inches)</th>
<th>Pipe Length (LF)</th>
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<tbody>
<tr>
<td>RCP</td>
<td>15</td>
<td>189</td>
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<tr>
<td>RCP</td>
<td>24</td>
<td>703</td>
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<tr>
<td>RCP</td>
<td>36</td>
<td>838</td>
</tr>
<tr>
<td>RCP</td>
<td>48</td>
<td>900</td>
</tr>
</tbody>
</table>
Geotechnical Design Constraints

- Boring data
  - Nordenberg Hall – PJ Dick
  - Soldiers and Sailors Parking Garage – Nicholson Construction
1. Silty Fill
   \( \gamma = 130 \text{ pcf} \)
   \( \phi = 28^\circ \)
   \( c = 0 \text{ psf} \)

2. Silty Clay
   \( \gamma = 130 \text{ pcf} \)
   \( \phi = 28^\circ \)
   \( c = 500 \text{ psf} \)

3. Fine to medium Sand
   \( \gamma = 120 \text{ pcf} \)
   \( \phi = 30^\circ \)
   \( c = 0 \text{ psf} \)

4. Rock fragments
   \( \gamma = 140 \text{ pcf} \)
   \( \phi = 30^\circ \)
   \( c = 0 \text{ psf} \)

5. Sandstone
   Massive & Hard
   \( Su = 4 \text{ TSF} \)

6. Claystone
   Moderately broken
   Soft to medium hard
   \( Su = 1.5 \text{ TSF} \)

Depth to water table = 22 ft
Seasonal perched water in clay layer
Geotechnical - Alternatives

- **Slurry walls**
  - Hold back water table
  - Support soil and structures
  - Cons
    - Slurry batch plant would be required
    - Create construction phasing issues
    - High cost
    - Disposal of bentonite post construction

- **Secant Piles and cantilevered gravity walls** provide a more effective solution
  - Vertical Auger allows for low-profile construction in tight spaces
  - Fully-cased drilling creates a near-impermeable seal against ground water.
  - Gravity walls where possible to minimize cost
Design Considerations - Secant Pile Walls

- Water level in front at same level as drainage structures
- Sandstone considered competent for keying
  - $Su = 4$ TSF
- Rankine’s Horizontal Earth Pressure Coefficients
- Horizontal load carried by reinforced piles
Secant Pile Design Components

- **Primary Piles**
  - Unreinforced concrete, $f'_c = 4000$ psi

- **Secondary Piles**
  - High strength concrete, reinforced with a steel beam

- **Mud Mat**
  - Located 2' below the roadway
  - Two 6” layers of unreinforced concrete
  - Compressive load beneath roadway

- **Soil nails**
  - Located 7' deep
  - Pre-tensioned skin friction nails
  - Located in cohesive soil layer
Secant Pile Constructability

1. Dig starter trench
   1a. Pour guide wall
2. Bore Primary Piles & fill with low strength concrete
   2a. Drill Primary Piles & fill with low strength concrete (10 ft offset)
3. Drill secondary piles overlapping secondary piles. Place Steel member and pour high strength concrete in secondary holes.
4. Bore, place, and pour secondary piles (10 ft offset)

Once piles are constructed, excavation and wall stabilization may begin in front of wall. Guide walls may be removed or left in place.

Primary pile
Secondary Pile
Secant Pile Design

- Moment distribution from active and passive soil pressures

Add moment distribution picture
Beam Reactions, H=22’

Shear, H=22’ (units of lb/ft)

Moment, H=22’ (units of lb-ft/ft)
Secant Pile Design

- 36 inch diameter with 6 inch overlap
- **Primary Piles**
  - Compressive Strength of concrete: $f'_c = 4$ ksi
- **Secondary Piles**
  - Reinforcement:
    - W18x71, $f_y = 50$ ksi
  - Concrete
    - Recommended $f'_c = 5$ ksi or greater
- Factor of Safety against flexure of 2
Design Considerations – Gravity Walls

- Surcharge loadings
  - 1000 psf above heel (Soldiers and Sailors)
  - 400 psf above heel (Hillman Library)
- Wall sections range in height from 4-18 ft
- Wall sections based on the worst case loading scenario
- Complete drainage behind wall
- Coulomb’s Horizontal Earth Pressure Coefficients
- Factor of Safety
  - Overturning, Sliding, & Bearing Capacity
- Temporary S.O.E. required
Cantilevered Gravity Wall Design

- Slope of 1:48 on front face of stem
  - Minimum stem thickness of 12" at top
- Compressive strength of concrete: $f'_{c} = 4$ ksi
- Rebar Yield Strength: $f_{y} = 60$ ksi
Cantilever Design Checks

- **Base Pressure**
  - Allowable bearing capacity of soil
  - Resultant force within middle-third

- **Overturning**
  - Factor of safety > 2.0
  - Resisting Moment/Overturning Moment

- **Sliding**
  - Factor of Safety
    - > 1.5 for granular backfill
    - > 2.0 for cohesive backfill
  - Coefficient of friction: $\mu = 0.5$
  - Cohesion between soil and base: $c_b = 0.6c$
  - Add Base key if necessary
Cantilever Reinforcement

- Critical moment on various sections to calculate area of steel required
  - Stem – critical point at bottom
  - Heel – critical point at back face of stem
  - Toe – critical point at front face of stem
- #8 bars were suitable for all sections
  - Spacing varied for different sections
Gravity Wall Constructability

- Two layers
  - Base
  - Stem
- Stem key used to resist shear from horizontal forces
Cantilevered Gravity Wall Design

![Diagram of Cantilevered Gravity Wall Design](image)

- $H$: Height
- $D_f$: Foundation thickness
- $tb$: Base thickness
- $D_k$: Kerf thickness
- $B/3$: Wall thickness
- $B/6$: Height of the base
- $B/2$: Width of the wall
- $12''$ min: Minimum height
- $1.48$ slope: Slope angle
- $1.5''$ min: Minimum width
STRUCTURAL DESIGN PROCESS

- Steel Girder Option
- Precast, Pre-stressed Option
Overall Design Considerations:
Fifth/Forbes
Overall Design Considerations: Pedestrian

- 2012 AASHTO Bridge/Pedestrian Bridge Manuals
- 4’ Soil Load
- Drainage System
- Sidewalks, sod, flowers, bush loads
- Bigelow Bash – Temporary Stage/Pedestrian Loads
- Maintenance/Emergency Vehicle
Overall Design Considerations: Soldiers & Sailors
### Design Summary: Fifth Ave

#### Fifth Ave. with 10' girder spacing

<table>
<thead>
<tr>
<th>Available members</th>
<th>W18 x 143</th>
<th>W21 x 111</th>
<th>W24 x 103</th>
<th>W27 x 94</th>
<th>W30 x 90</th>
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<tbody>
<tr>
<td>Deflection [in]</td>
<td>0.383</td>
<td>0.395</td>
<td>0.351</td>
<td>0.322</td>
<td>0.292</td>
</tr>
</tbody>
</table>

| Mu [kip*ft]       |   |   |   |   |   |
| Vu [kips]        |   |   |   |   |   |

#### Interior Girders
- 1240
- 166

#### Exterior Girders
- 1300
- 165

<table>
<thead>
<tr>
<th>W24 x 103</th>
<th>W27 x 94</th>
<th>W30 x 90</th>
<th>Limit</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Mn [kip*ft]</td>
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<td>2300</td>
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<tr>
<td>Vn [kips]</td>
<td>360</td>
<td>361</td>
<td>385</td>
<td>-</td>
</tr>
<tr>
<td>f_{top} [ksi]</td>
<td>0.34</td>
<td>0.33</td>
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<td>&lt; 45</td>
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<tr>
<td>f_{bot} [ksi]</td>
<td>28.0</td>
<td>28.7</td>
<td>28.5</td>
<td>&lt; 45</td>
</tr>
<tr>
<td>Fatigue [ksi]</td>
<td>4.92</td>
<td>5.04</td>
<td>5.00</td>
<td>&lt; 7.31</td>
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</tbody>
</table>

#### Fifth Ave. with 7'-6" girder spacing

<table>
<thead>
<tr>
<th>Available members</th>
<th>W18 x 106</th>
<th>W21 x 101</th>
<th>W24 x 94</th>
<th>W27 x 84</th>
<th>W30 x 90</th>
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<tr>
<td>Deflection [in]</td>
<td>0.436</td>
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<td>0.231</td>
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</table>

| Mu [kip*ft]       |   |   |   |   |   |
| Vu [kips]        |   |   |   |   |   |

#### Interior Girders
- 1020
- 135

#### Exterior Girders
- 1120
- 141

<table>
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<th>W24 x 94</th>
<th>W27 x 84</th>
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<td>339</td>
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<tr>
<td>f_{top} [ksi]</td>
<td>0.13</td>
<td>0.20</td>
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<td>f_{bot} [ksi]</td>
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<td>4.89</td>
<td>4.34</td>
<td>&lt; 7.31</td>
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**Fifth Avenue Overpass @ 10 ft spacing**

![Diagram of Fifth Avenue Overpass](image-url)
## Design Summary: Forbes Ave

### Forbes Ave. with 9'-2" girder spacing

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<tr>
<td>Vu [kips]</td>
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<td>Exterior Girders</td>
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<th>Specification</th>
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<tbody>
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<td>Mn [kip*ft]</td>
<td>2080</td>
<td>2230</td>
<td>2280</td>
<td>-</td>
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<tr>
<td>f_{top} [ksi]</td>
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### Forbes Ave. with 6'-10.5" girder spacing

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<th>W24 x 84</th>
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<td>0.231</td>
</tr>
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<td>Mu [kip*ft]</td>
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<td>Vu [kips]</td>
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<td>Interior Girders</td>
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<td>Exterior Girders</td>
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</table>

<table>
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<td>-</td>
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<td>Vn [kips]</td>
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<td>385</td>
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<tr>
<td>f_{top} [ksi]</td>
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<tr>
<td>Fatigue [ksi]</td>
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<td>4.61</td>
<td>4.09</td>
<td>&lt; 7.31</td>
</tr>
</tbody>
</table>

---

**Forbes Avenue Overpass @ 9'-2" ft spacing**

![Diagram of Forbes Avenue Overpass at 9'-2" spacing]
# Design Summary: Pedestrian Plaza

## Bigelow Blvd with 10' Girder Spacing

<table>
<thead>
<tr>
<th>Available Members</th>
<th>W24 X 131</th>
<th>W27 X 114</th>
<th>W30 X 108</th>
<th>W30 X 116</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection [in]</td>
<td>0.415</td>
<td>0.409</td>
<td>0.373</td>
<td>0.338</td>
</tr>
<tr>
<td>Interior Girders</td>
<td>1640</td>
<td>195</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior Girders</td>
<td>1640</td>
<td>197</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W24 X 131</td>
<td>2670</td>
<td>2720</td>
<td>2810</td>
<td>2970</td>
</tr>
<tr>
<td>W27 X 114</td>
<td>475</td>
<td>505</td>
<td>536</td>
<td>556</td>
</tr>
<tr>
<td>W30 X 108</td>
<td>0.26</td>
<td>0.19</td>
<td>0.23</td>
<td>0.34</td>
</tr>
<tr>
<td>W30 X 116</td>
<td>13.8</td>
<td>14.8</td>
<td>14.8</td>
<td>13.7</td>
</tr>
</tbody>
</table>

## Bigelow Blvd with 8' Girder Spacing

<table>
<thead>
<tr>
<th>Available Members</th>
<th>W 24 X 104</th>
<th>W27 X 102</th>
<th>W30 X 90</th>
<th>W30 X 99</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection [in]</td>
<td>0.538</td>
<td>0.461</td>
<td>0.462</td>
<td>0.418</td>
</tr>
<tr>
<td>Interior Girders</td>
<td>1410</td>
<td>164</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior Girders</td>
<td>1400</td>
<td>166</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W24 X 104</td>
<td>2197</td>
<td>2393</td>
<td>2340</td>
<td>2534</td>
</tr>
<tr>
<td>W27 X 102</td>
<td>393</td>
<td>456</td>
<td>463</td>
<td>513</td>
</tr>
<tr>
<td>W30 X 90</td>
<td>0.05</td>
<td>0.21</td>
<td>0.12</td>
<td>0.30</td>
</tr>
<tr>
<td>W30 X 99</td>
<td>16.4</td>
<td>15.8</td>
<td>17.1</td>
<td>15.4</td>
</tr>
</tbody>
</table>

*Typical Pedestrian Plaza at 10' Spacing*

60' section, 5 full bays with 2 half bays

![Diagram of Pedestrian Plaza](image-url)
## Design Summary: Soldiers & Sailors Structure

<table>
<thead>
<tr>
<th>Available members</th>
<th>W33X169</th>
<th>W33X201</th>
<th>W30X235</th>
<th>W30X211</th>
<th>W30X191</th>
<th>W27X235</th>
<th>W27X217</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection [in]</td>
<td>0.4439</td>
<td>0.3555</td>
<td>0.3524</td>
<td>0.4003</td>
<td>0.4482</td>
<td>0.4251</td>
<td>0.4628</td>
</tr>
<tr>
<td>Mu (kip-ft)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vu (kips)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior Girder</td>
<td>2120.68</td>
<td>279.94</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior Girder</td>
<td>2208.68</td>
<td>290.94</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W33X201</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W30X211</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W27X217</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mn (kip-ft)</td>
<td>3579.47</td>
<td>3450.68</td>
<td>3269.26</td>
<td>-</td>
<td>6.10.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vn (kips)</td>
<td>651.08</td>
<td>635.14</td>
<td>611.38</td>
<td>-</td>
<td>6.10.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ff_top [ksi]</td>
<td>5.82</td>
<td>5.63</td>
<td>5.35</td>
<td>&lt; 45</td>
<td>6.10.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ff_bot [ksi]</td>
<td>18.13</td>
<td>18.93</td>
<td>20.29</td>
<td>&lt; 45</td>
<td>6.10.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatigue</td>
<td>1.16</td>
<td>1.12</td>
<td>1.06</td>
<td>&lt; 7.31</td>
<td>6.6.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Girder Selection Summary

- Fifth Ave: W30 x 90 @ 10' spacing
- Forbes Ave: W30 x 90 @ 9'-2" spacing
- Pedestrian: W30 x 108 @ 10' spacing with 1-1/6 inch camber
- Soldiers & Sailors: W30 x 211 @ 10' spacing

Selections made to streamline construction and for enhanced motorist comfort.
Concrete Deck Design

- LRFD Section 5
- \( f'c = 4 \text{ ksi} \)
- Rebar Grade = 60 ksi

**Soldiers & Sailors Deck Design Summary**

<table>
<thead>
<tr>
<th>Typical Bridge Deck</th>
<th>Typical Bridge Overhand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Thickness = 8.5 inch</td>
<td>Overhand Thickness = 11.7 inch</td>
</tr>
<tr>
<td>Top Clear Cover = 2.5 inch</td>
<td>Top Clear Cover = 2.5 inch</td>
</tr>
<tr>
<td>Bottom Clear Cover = 1.0 inch</td>
<td>Bottom Clear Cover = 1.0 inch</td>
</tr>
<tr>
<td>Side Clear Cover = 3.0 inch</td>
<td>Side Clear Cover = 3.0 inch</td>
</tr>
<tr>
<td>Top Transverse Bar = #5 @ 9&quot;</td>
<td>Top Transverse Bar = #6 @ 9&quot;</td>
</tr>
<tr>
<td>Development Length = 28 inch</td>
<td>Development Length = 34 inch</td>
</tr>
<tr>
<td>Cutoff Length = 85.50 inch</td>
<td></td>
</tr>
<tr>
<td>Bot Transverse Bar = #5 @ 8&quot;</td>
<td>Bot Transverse Bar = #5 @ 8&quot;</td>
</tr>
<tr>
<td>Development Length = 28 inch</td>
<td>Development Length = 28 inch</td>
</tr>
<tr>
<td>Top Longitudinal Bar = #4 @ 18&quot;</td>
<td>Top Longitudinal Bar = #4 @ 18&quot;</td>
</tr>
<tr>
<td>Development Length = 23 inch</td>
<td>Development Length = 23 inch</td>
</tr>
<tr>
<td>Bot Longitudinal Bar = #4 @ 9&quot;</td>
<td>Bot Longitudinal Bar = #4 @ 9&quot;</td>
</tr>
<tr>
<td>Development Length = 23 inch</td>
<td>Development Length = 23 inch</td>
</tr>
</tbody>
</table>

**Pedestrian Plaza Deck Design Summary**

<table>
<thead>
<tr>
<th>Typical Bridge Deck</th>
<th>Typical Bridge Overhand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Thickness = 8.5 inch</td>
<td>Overhand Thickness = 11.7 inch</td>
</tr>
<tr>
<td>Top Clear Cover = 2.5 inch</td>
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<td>Bottom Clear Cover = 1.0 inch</td>
</tr>
<tr>
<td>Side Clear Cover = 3.0 inch</td>
<td>Side Clear Cover = 3.0 inch</td>
</tr>
<tr>
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</tr>
<tr>
<td>Development Length = 28 inch</td>
<td>Development Length = 34 inch</td>
</tr>
<tr>
<td>Cutoff Length = 85.50 inch</td>
<td></td>
</tr>
<tr>
<td>Bot Transverse Bar = #5 @ 8&quot;</td>
<td>Bot Transverse Bar = #5 @ 8&quot;</td>
</tr>
<tr>
<td>Development Length = 28 inch</td>
<td>Development Length = 28 inch</td>
</tr>
<tr>
<td>Top Longitudinal Bar = #4 @ 18&quot;</td>
<td>Top Longitudinal Bar = #4 @ 18&quot;</td>
</tr>
<tr>
<td>Development Length = 23 inch</td>
<td>Development Length = 23 inch</td>
</tr>
<tr>
<td>Bot Longitudinal Bar = #4 @ 9&quot;</td>
<td>Bot Longitudinal Bar = #4 @ 9&quot;</td>
</tr>
<tr>
<td>Development Length = 23 inch</td>
<td>Development Length = 23 inch</td>
</tr>
</tbody>
</table>
Typical Deck Details
Shear Stud Design

- LRFD 6.10.10

### Shear Stud Design Summary:

<table>
<thead>
<tr>
<th></th>
<th>Exterior Girders</th>
<th>Interior Girders</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_y, sc$ [ksi]</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>$F_u, sc$ [ksi]</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

### Fifth Ave 10' Girder Spacing

<table>
<thead>
<tr>
<th></th>
<th>Exterior Girders</th>
<th>Interior Girders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear Stud Diameter [in]</td>
<td>0.875</td>
<td>0.875</td>
</tr>
<tr>
<td>Shear Stud Height [in]</td>
<td>5.000</td>
<td>5.000</td>
</tr>
<tr>
<td>Number of Studs</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>Number of Studs in Cross Section</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Pitch [in]</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Transverse Stud Spacing [in]</td>
<td>6.00</td>
<td>6.00</td>
</tr>
</tbody>
</table>

### Pedestrian Plaza 10' Spacing Shear Stud Design

<table>
<thead>
<tr>
<th></th>
<th>Interior Girders</th>
<th>Exterior Girders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter [in]</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Stud Height [in]</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>$Q_s$ [kips]</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Shear Studs Needed</td>
<td>315</td>
<td>305</td>
</tr>
<tr>
<td>Number of Studs in Cross-section</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Pitch [in]</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Transverse Stud Spacing [in]</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

---

**Fifth & Forbes Ave – Varying Girder Spacing**

<table>
<thead>
<tr>
<th></th>
<th>Exterior Girders</th>
<th>Interior Girders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear Stud Diameter [in]</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Shear Stud Height [in]</td>
<td>2.125</td>
<td>2.125</td>
</tr>
<tr>
<td>$Q_s$ [kips]</td>
<td>11.8</td>
<td>11.8</td>
</tr>
<tr>
<td>Number of Studs</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>Number of Studs in Cross Section</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Pitch [in]</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Transverse Stud Spacing [in]</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Typical Shear Stud Details

4 \frac{1}{2}'' \times 2 \frac{5}{8}'' (BW),
mild steel @ 2.5''
BEARING PAD DESIGN CRITERIA

<table>
<thead>
<tr>
<th>L [IN]</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>W [IN]</td>
<td>20</td>
</tr>
<tr>
<td>H (TOTAL HEIGHT OF PAD) [IN]</td>
<td>4</td>
</tr>
<tr>
<td>h (LAYER DEPTH) [IN]</td>
<td>1</td>
</tr>
</tbody>
</table>

FORCE EFFECTS IN PAD

| AXIAL FORCE [KIPS] | 290.937 |

COMPRRESSIVE STRESS

| STRESS LIMIT 1 | 4.75 |
| STRESS LIMIT 2 | 0.8 |
| SIGMA_S [KSI] | 0.72734 |

Total Movement

| Maximum Opening (in.) | 2" + Contraction on Skew | 2.763 |
| Minimum Opening (in.) | 2" - Expansion on Skew | 1.730 |
| Total Movement (in.) | Max. Opening - Min. Opening | 1.033 |
| REQUIRED MOVEMENT | 3.000 |

Steel

<table>
<thead>
<tr>
<th>TEMP. F</th>
<th>A(INCHES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10</td>
<td>2.763</td>
</tr>
<tr>
<td>0</td>
<td>2.665</td>
</tr>
<tr>
<td>10</td>
<td>2.567</td>
</tr>
<tr>
<td>20</td>
<td>2.470</td>
</tr>
<tr>
<td>30</td>
<td>2.372</td>
</tr>
<tr>
<td>40</td>
<td>2.274</td>
</tr>
<tr>
<td>50</td>
<td>2.176</td>
</tr>
<tr>
<td>60</td>
<td>2.078</td>
</tr>
<tr>
<td>68</td>
<td>2.000</td>
</tr>
<tr>
<td>70</td>
<td>1.987</td>
</tr>
<tr>
<td>80</td>
<td>1.923</td>
</tr>
<tr>
<td>90</td>
<td>1.859</td>
</tr>
<tr>
<td>100</td>
<td>1.794</td>
</tr>
<tr>
<td>110</td>
<td>1.730</td>
</tr>
</tbody>
</table>

Specification of Joint:

Use Strip Seals, AS 300 on fixed end slab
Provide 3" dam spacing on slab at free end
Provide 3" clear spacing at both beam end
Vibration Analysis

- Pedestrian traffic induced vibrations
  - Normal Walking: 1.3-2.4 Hz
  - Running: 2-3.5 Hz

- Vehicular traffic induced vibrations: 6.31 Hz

- Bridge Natural Frequencies
  - Forbes: 6.41 Hz
Alternative Design
P/S CONCRETE GIRDER PRELIMINARY SECTION

PCI
P/S CONCRETE GIRDER: LOAD INPUT

DEAD LOADS ON COMPOSITE
UNITS: (Point: kips, Location: ft, Line: klf, Trapez: klf, Area: ksf, Width: ft)

<table>
<thead>
<tr>
<th>Span</th>
<th>DC/DS</th>
<th>Type</th>
<th>Mag.1</th>
<th>Loc.1/Width</th>
<th>Mag.2</th>
<th>Loc.2</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 DN</td>
<td>Area</td>
<td>0.210</td>
<td>60,000</td>
<td></td>
<td>-</td>
<td>-</td>
<td>Future Wearing Surface</td>
</tr>
</tbody>
</table>

TEMPERATURE LOADS - NONE

LIVE LOADS
Live load deflection: not included.

<table>
<thead>
<tr>
<th>ID</th>
<th>Design Lane</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design Lane</td>
<td>Design Tandem - not incl.</td>
</tr>
<tr>
<td></td>
<td>Design Truck</td>
<td>Design Truck</td>
</tr>
</tbody>
</table>
## P/S Concrete Girder Bentley Load Result

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Bending Torque (kN.m)</th>
<th>Shear Force (kN)</th>
<th>Moment (kN.m)</th>
<th>Diagonal Force (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS (Max)</td>
<td>245.6</td>
<td>154.2</td>
<td>321.7</td>
<td>56.9</td>
</tr>
<tr>
<td>LS (Min)</td>
<td>202.4</td>
<td>130.5</td>
<td>266.9</td>
<td>48.1</td>
</tr>
</tbody>
</table>

### LS Flexural Analysis

- **Deck +**
  - Bending Torque: 245.6 kN.m
  - Shear Force: 154.2 kN
  - Moment: 321.7 kN.m
  - Diagonal Force: 56.9 kN

- **Deck**
  - Bending Torque: 202.4 kN.m
  - Shear Force: 130.5 kN
  - Moment: 266.9 kN.m
  - Diagonal Force: 48.1 kN

**Location:**
- **Beam 1:**
  - Bending Torque: 321.7 kN.m
  - Shear Force: 154.2 kN
  - Moment: 321.7 kN.m
  - Diagonal Force: 56.9 kN

**Beam 1:**
- Location: 12.5 m
- Bending Torque: 245.6 kN.m
- Shear Force: 154.2 kN
- Moment: 321.7 kN.m
- Diagonal Force: 56.9 kN
NUMBER OF STRANDS RECOMMENDED BY BENTLEY FOR EXTERIOR GIRDER
P/S CONCRETE EXTERIOR GIRDER RECOMMENDATION
Design Recommendation

- Fifth/Fifth Ave: SB-II with 9 pre-stressing strands
- Pedestrian: SB-II with 11 pre-stressing strands
- Soldiers & Sailors: SB-II with 21 pre-stressing strands and 3 group deboned
**CONSTRUCTION COST ESTIMATE**

- **Overall Project Cost:** **$35 Million**
- Some large ticket items listed below

<table>
<thead>
<tr>
<th>Bid Item Cost</th>
<th>Item Description</th>
<th>Self/Sub</th>
<th>Unit of Measure</th>
<th>Quantity</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ 1,920,000.00</td>
<td>Install Secant Piles - Forbes/Fifth Ave Structures</td>
<td>Sub</td>
<td>SF</td>
<td>12,000.00</td>
<td>$ 160.00</td>
</tr>
<tr>
<td>$ 5,452,000.00</td>
<td>Install Secant Piles - Pedestrian Structure</td>
<td>Sub</td>
<td>SF</td>
<td>37,600.00</td>
<td>$ 145.00</td>
</tr>
<tr>
<td>$ 3,996,000.00</td>
<td>Install Secant Piles - Soldiers &amp; Sailors Structure</td>
<td>Sub</td>
<td>SF</td>
<td>21,600.00</td>
<td>$ 185.00</td>
</tr>
<tr>
<td>$ 457,500.00</td>
<td>Install Pipe Runs - Average Diameter</td>
<td>Self</td>
<td>LF</td>
<td>2,500.00</td>
<td>$ 183.00</td>
</tr>
<tr>
<td>$ 1,894,662.00</td>
<td>Underpass Excavation - Includes Bracing</td>
<td>Self</td>
<td>EA</td>
<td>45,111.00</td>
<td>$ 42.00</td>
</tr>
<tr>
<td>$ 493,360.00</td>
<td>Purchase Structural Steel</td>
<td>Self</td>
<td>LB</td>
<td>394,688.00</td>
<td>$ 1.25</td>
</tr>
<tr>
<td>$ 72,000.00</td>
<td>Purchase Concrete - Forbes/Fifth &amp; Soldiers and Sailors Bridge Deck (5% waste)</td>
<td>Self</td>
<td>CY</td>
<td>450.00</td>
<td>$ 160.00</td>
</tr>
<tr>
<td>$ 58,800.00</td>
<td>Purchase Concrete - Pedestrian Bridge Deck (5% waste)</td>
<td>Self</td>
<td>CY</td>
<td>490.00</td>
<td>$ 120.00</td>
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<tr>
<td>$ 14,344,322.00</td>
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</tbody>
</table>
CONSTRUCTION SCHEDULE

Overall Project Duration = 3.45 years
1261 days (902 working) = 42 months
Assumes no weekends, days lost to weather not considered
CONSTRUCTION CONSIDERATIONS

- 7 Proposed Phases
- Typical procedure
  - Install drainage, install walls, install superstructure
- Utilities locations are critical
- Traffic phasing will be complex

- Ultimately: recommend design-build delivery method
ALTERNATIVE ROUTE ANALYSIS

- Primary paths to Soldiers & Sailors Garage
- Parking considerations
Typical vehicle routes from all directions to turn into Soldiers & Sailors garage
Proposed routes to turn into Soldiers & Sailors garage after reconfiguration
Problem
- Losing approximately 50 public parking spots

Proposed Solution
- Add approximately 25 parking spots back adjacent to Union
- Utilize existing entrance/exit which is already at a lighted intersection
- Left turn in from Fifth Ave, Left turn out onto Fifth Ave
- One-way direction
- Utilize unnecessarily wide sidewalk
- Build around existing trees, planters or replace in-kind where possible

Proposed parking options available.
- Owned by UPMC
- Possible deal to construct UPMC/City of Pittsburgh joint parking structures
CASE STUDY: 1997 TRIAL CLOSURE

Study Limits
- Forbes from McKee Pl to Craig St
- Fifth from McKee Pl to Bellefield Ave
- Bouquet St, Roberto Clemente Dr, and Schenley Dr.

Conclusion
- Traffic on Forbes & Fifth virtually unaffected
- Southbound traffic not significantly inconvenienced (despite longer distance)
- Northbound traffic doubled
- Adds partial validity to our selection

<table>
<thead>
<tr>
<th></th>
<th>AM Peak</th>
<th>Afternoon Peak</th>
<th>PM Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open</td>
<td>Closed</td>
<td>Open</td>
</tr>
<tr>
<td>Northbound</td>
<td>2 min 21 sec</td>
<td>5 min 40 sec</td>
<td>1 min 11 sec</td>
</tr>
<tr>
<td>Southbound</td>
<td>1 min 28 sec</td>
<td>2 min 14 sec</td>
<td>1 min 56 sec</td>
</tr>
<tr>
<td>Eastbound</td>
<td>1 min 21 sec</td>
<td>1 min 21 sec</td>
<td>2 min in 40 sec</td>
</tr>
<tr>
<td>Westbound</td>
<td>1 min 23 sec</td>
<td>1 min 41 sec</td>
<td>1 min 52 sec</td>
</tr>
</tbody>
</table>
FUTURE CONSIDERATIONS

- Complete PC/PS concrete slab design
- Verify existing utilities
- Run extensive traffic & transportation analysis
  - Final lane configurations, intersection design, light cycles, parking options
- Design HMA and PCC road structures
- Devise new route for Pitt and Port Authority Buses
- Develop extensive construction phasing
  - Traffic shifts, lane closures, optimize S&S garage access
- Develop accurate cost estimate and schedule
SPECIAL THANKS TO

Academic
- Dr. Oyler
- Dr. Magalotti
- Dr. Harries
- Dr. Sanchez
- Dr. Bunger
- Dr. Liang
- Dr. Budny
- Dr. Yu
- Dr. Vandenbossche
- Dr. Lin
- Professor Sebastian
- Professor Beck

Professional
- Brian Long – SAI Consulting Engineers, Inc.
- Todd Wilson – GAI Consultants, Inc.
- Brian Budny - PJ Dick
- Don Cunningham – HDR, Inc.
- Robert Griffin – Lane Construction
- Gino DiNardo – City of Pittsburgh Department of Public Works
- Derrick Lubomski
- The engineers at Nicholson Construction
  - Mark Rothbauer
  - Thomas Joussellin
  - Abby Stein
  - Andrew Moran
  - Tom Richards
  - Youssef Hamami
  - Eric Brichler
  - Dan Uranowski
QUESTIONS?

▶ Please feel free to check out our model up front!