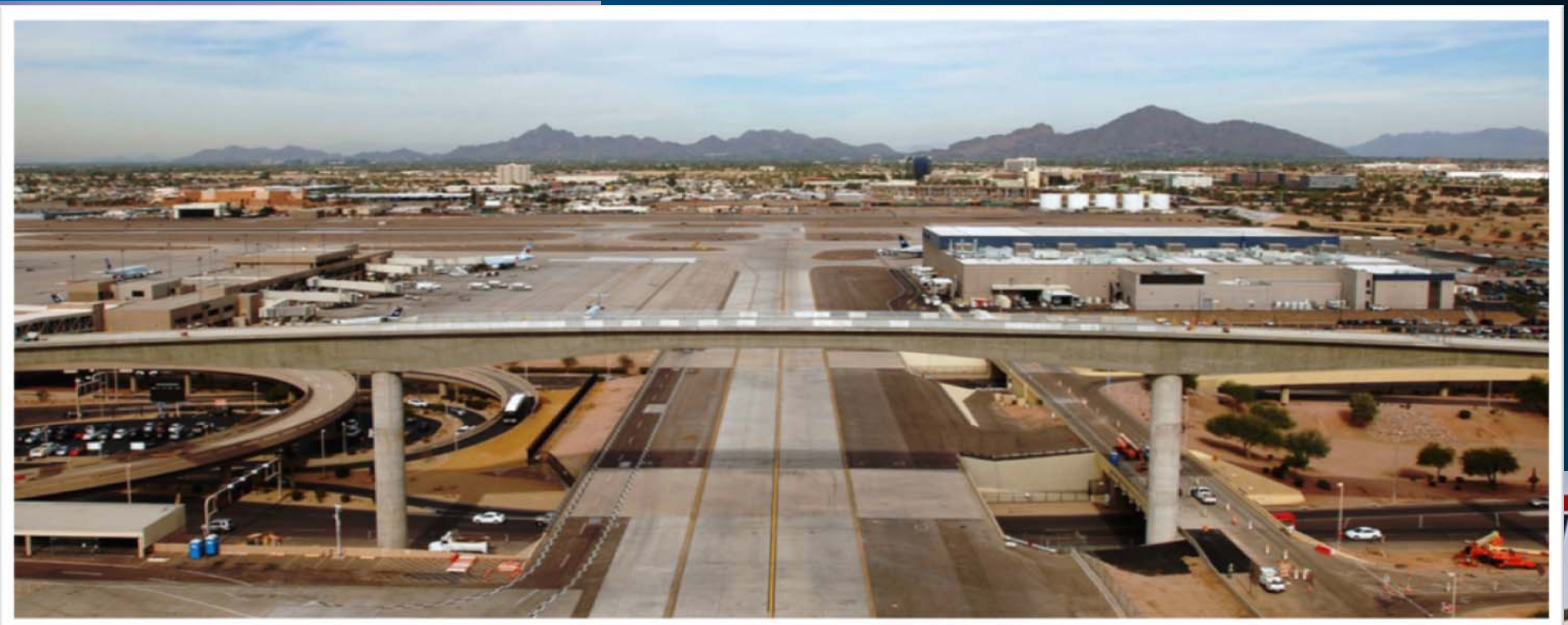
PHX Sky Train – Taxiway 'R' Bridge



World's First Transit Crossing o
Taxiway

David A. Burrows, P.E., Gannett Fleming, Inc.

Acknowledgements

City of Phoenix Aviation Department

GF Structural Design Team:

- Mark Pilwallis (PM)
- Steve Sherrill (Design Lead)
- John Lobo, Ehsan Abdullah, Demeke Ashebo, Mike Morrison, David Burrows

Assistance from various other Gannett offices and other design firms:

Kimley Horn, Nabar Stanley Brown, Premier & Hatch Mott McDonald

Hensel Phelps Construction Company (CMAR Contractor)

Austin Bridge & Road (Bridge Subcontractor)

PHX Sky Train – Taxiway 'R' Bridge

1. Project Location and Introduction
2. Design Considerations
3. Structure Selection and Final Design
4. Building the Bridge

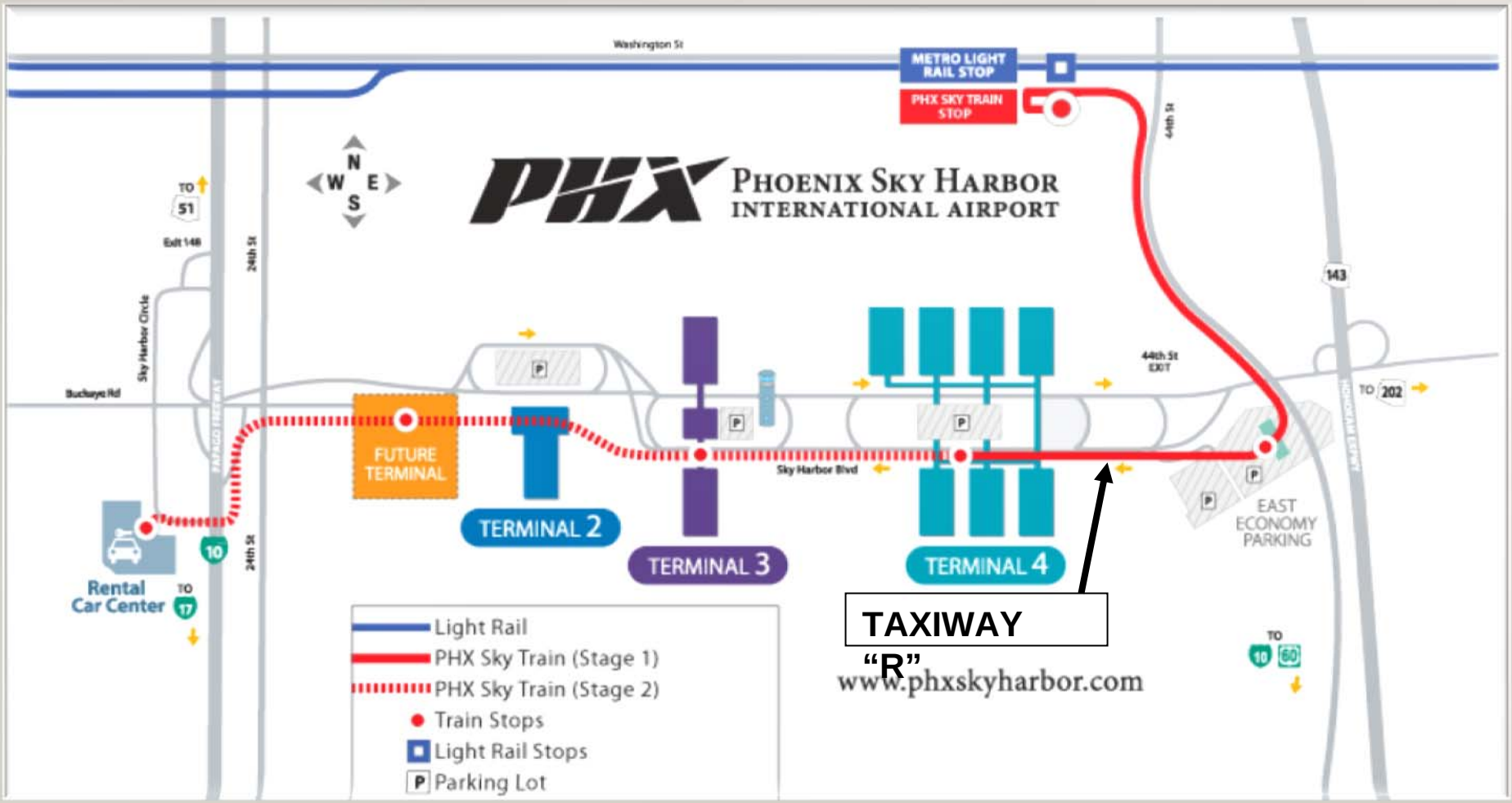
Project Location

PHOENIX SKY HARBOR INTERNATIONAL AIRPORT

Project Location

PHOENIX SKY HARBOR INTERNATIONAL AIRPORT

PHX Sky Train

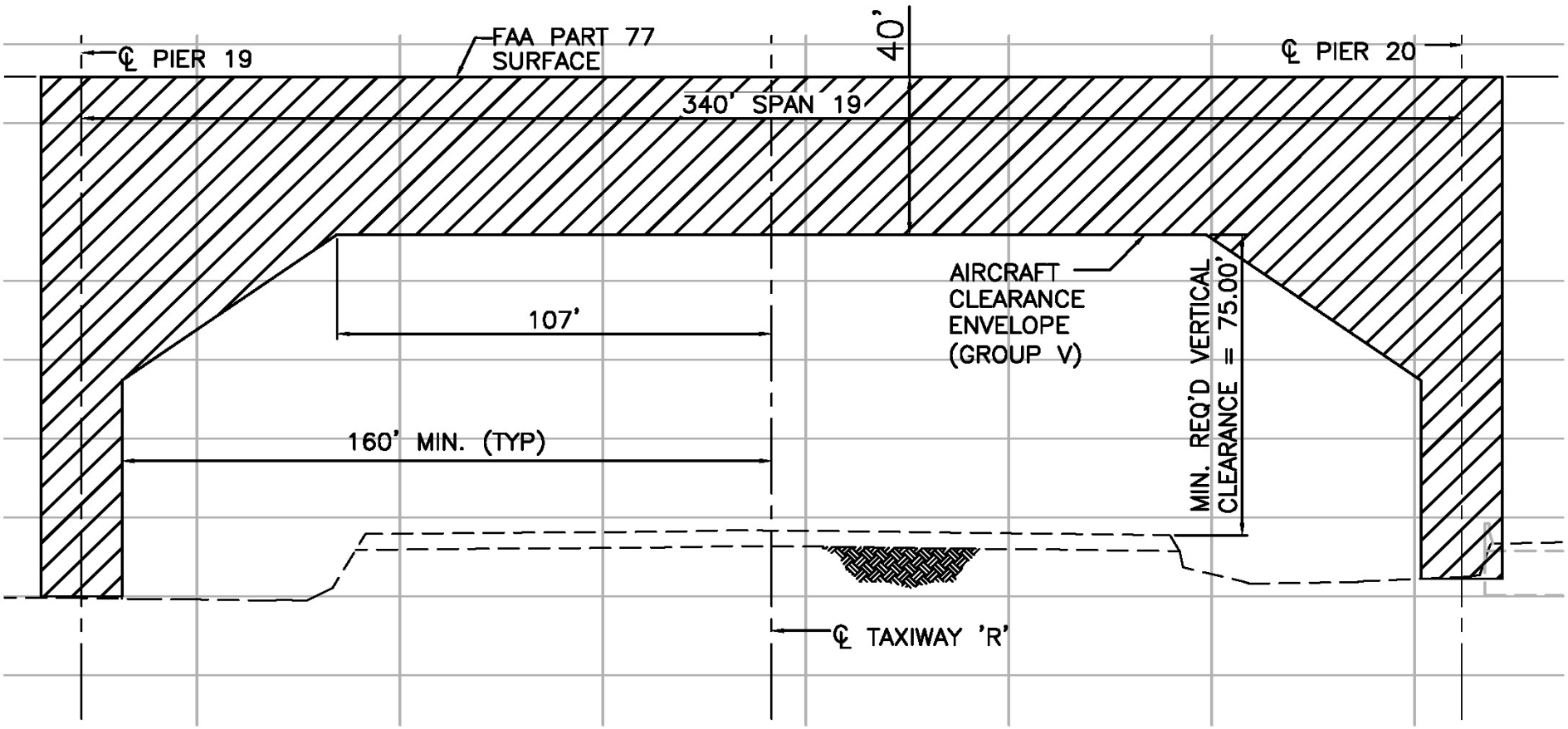


GUIDEWAY ALIGNMENT

Design Considerations

1. Airspace Restrictions & Aircraft Clearances
2. Grades & Deflections for Train Operations
3. Construction Impacts
4. Construction Cost
5. Longevity & Maintenance Requirements
6. Appearance/Aesthetics

Design Considerations



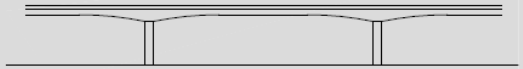
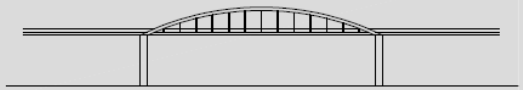
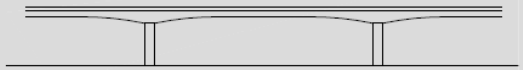
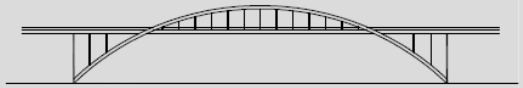
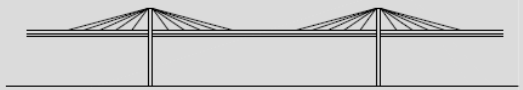
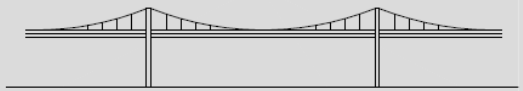
AIRSPACE RESTRICTIONS & AIRCRAFT CLEARANCES

Structure Selection

Key Selection Factors

- Constructability – 40%
- Cost - 25%
- Maintenance, Inspection and Train Serviceability – 25%
- Aesthetics – 10%

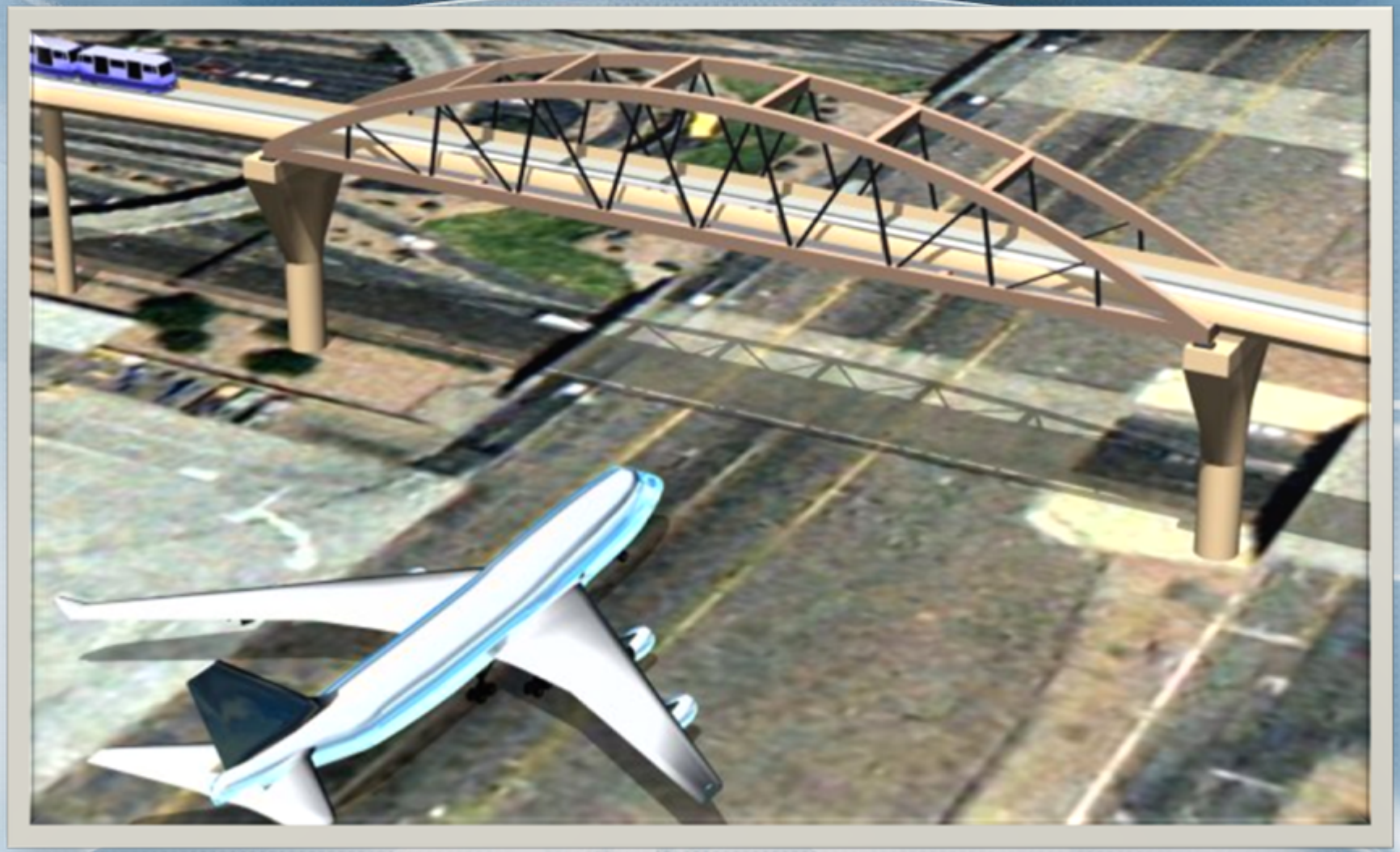
Structure Selection Matrix

RANK	SCORE	DESCRIPTION	DIAGRAM	COMMENTS COMMENTS RANKED 1,2,3 3 IS AN ADVANTAGE, 1 IS A DISADVANTAGE
1	7	THROUGH STEEL BOWSTRING TRUSS/ PARKER TRUSS		3 - RELATIVELY SHORT-DURATION SUPERSTRUCTURE ERECTION (LIMITS TAXIWAY CLOSURE) 3 - ROUTINE PIER AND FOUNDATION CONSTRUCTION 2 - LONG LEAD TIME FOR STEEL, STEEL MORE COSTLY 2 - MANY ELEMENTS TO MAINTAIN, PAINT AND INSPECT 3 - EFFICIENT ON-SITE CONSTRUCTION OF ENTIRE TRUSS OR LARGE PIECES
2	7	PRECAST CONCRETE SEGMENTAL BOX GIRDER		2 - MODERATE DURATION ON-SITE SPAN ERECTION SCHEDULE 3 - ROUTINE PIER AND FOUNDATION CONSTRUCTION 2 - TAXIWAY CLOSED UNTIL ALL SEGMENTS PLACED 3 - MINOR MAINTENANCE, OCCASIONAL BEARING REPLACEMENT 3 - CONCRETE LESS COSTLY THAN STEEL
3	6	THROUGH STEEL TIED ARCH		3 - RELATIVELY SHORT-DURATION SUPERSTRUCTURE ERECTION (LIMITS TAXIWAY CLOSURE) 2 - MORE COMPLEX PIER AND FOUNDATION CONSTRUCTION 2 - FRACTURE CRITICAL MEMBERS REQUIRE HAND-ON INSPECTION 2 - LONG LEAD TIME FOR STEEL, STEEL MORE COSTLY
4	5	CAST-IN-PLACE CONCRETE SEGMENTAL BOX GIRDER		1 - LONG DURATION ON-SITE SPAN ERECTION SCHEDULE 3 - ROUTINE PIER AND FOUNDATION CONSTRUCTION 2 - TAXIWAY CLOSED UNTIL FORMWORK REMOVED 3 - MINOR MAINTENANCE, OCCASIONAL BEARING REPLACEMENT 3 - CONCRETE LESS COSTLY THAN STEEL
5	5	MODIFIED THROUGH STEEL TRUSS WITH DELTA PIERS		2 - PIER CONSTRUCTION MAY LIMIT TAXIWAY FUNCTION 2 - MANY ELEMENTS TO MAINTAIN, PAINT AND INSPECT 2 - LONG LEAD TIME FOR STEEL, STEEL MORE COSTLY 2 - COMPLEX DATA PIER CONSTRUCTION
6	4	INTERMEDIATE STEEL DECK ARCH		1 - COMPLEX FOUNDATION CONSTRUCTION 1 - LONG DURATION ON-SITE ARCH ERECTION 2 - MANY ELEMENTS TO MAINTAIN, PAINT AND INSPECT 2 - LONG LEAD TIME FOR STEEL, STEEL MORE COSTLY
7	4	EXTRADOSED		1 - COMPLEX FOUNDATION CONSTRUCTION 2 - TAXIWAY CLOSED UNTIL SEGMENTS PLACED 2 - MODERATE MAINTENANCE, SPECIAL CABLE INSPECTION 1 - LITTLE CONSTRUCTION EXPERIENCE MAY TRANSLATE TO HIGHER COST
8	3	SELF-ANCHORED SUSPENSION		1 - COMPLEX FOUNDATION CONSTRUCTION 1 - TAXIWAY CLOSED DURING CABLING AND DECK PLACEMENT 1 - MANY ELEMENTS TO MAINTAIN AND INSPECT, SPECIAL CABLE INSPECTION 1 - LITTLE CONSTRUCTION EXPERIENCE MAY TRANSLATE TO HIGHER COST

Structure Selection

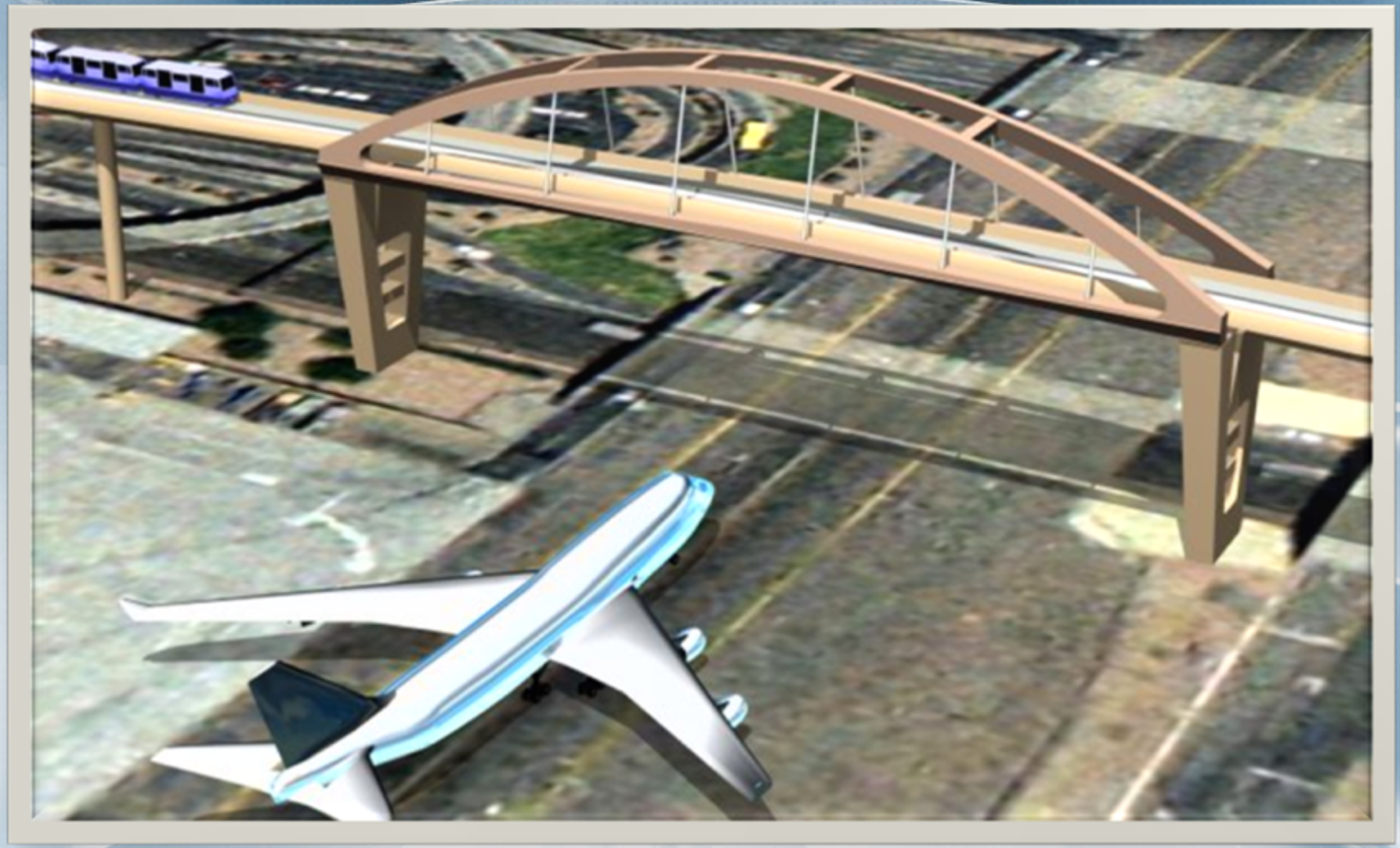
Post-Tensioned Concrete Box Girder

Structure Selection



Steel Bowstring Truss

Structure Selection



Steel Tied Arch

Structure Selection at 30% Design

Recommend Precast Concrete Segmental Box Girder

- 3 span: 200'-340'-200'
- 10 ft to 20 ft Variable Depth
- Projected taxiway closure of **2 months**

Owner

Bridge Designer

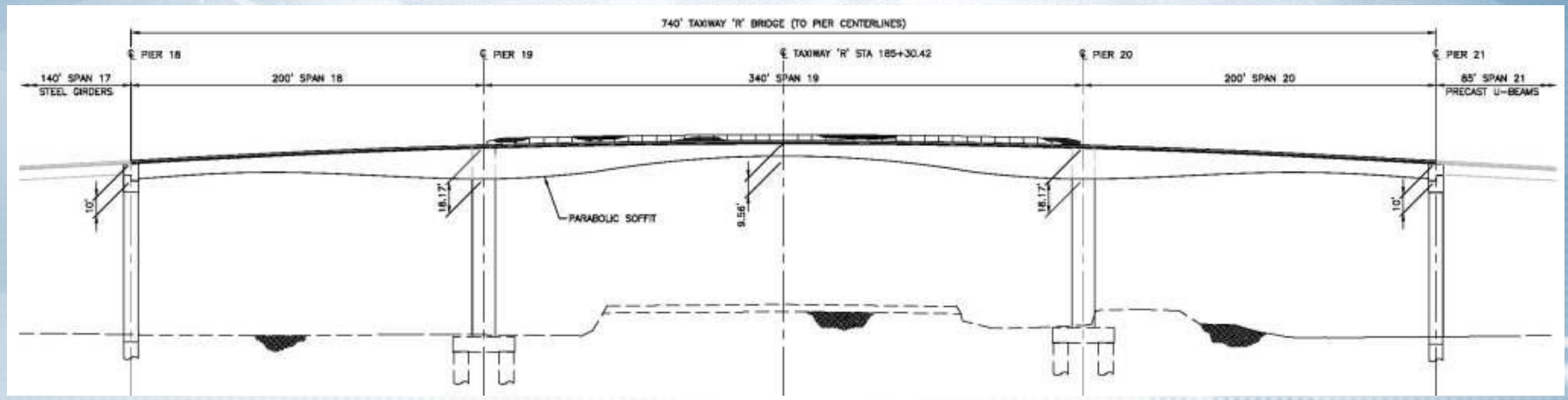
Reduce Estimated $10.5M Construction Cost

Structure Selection at 60% Design

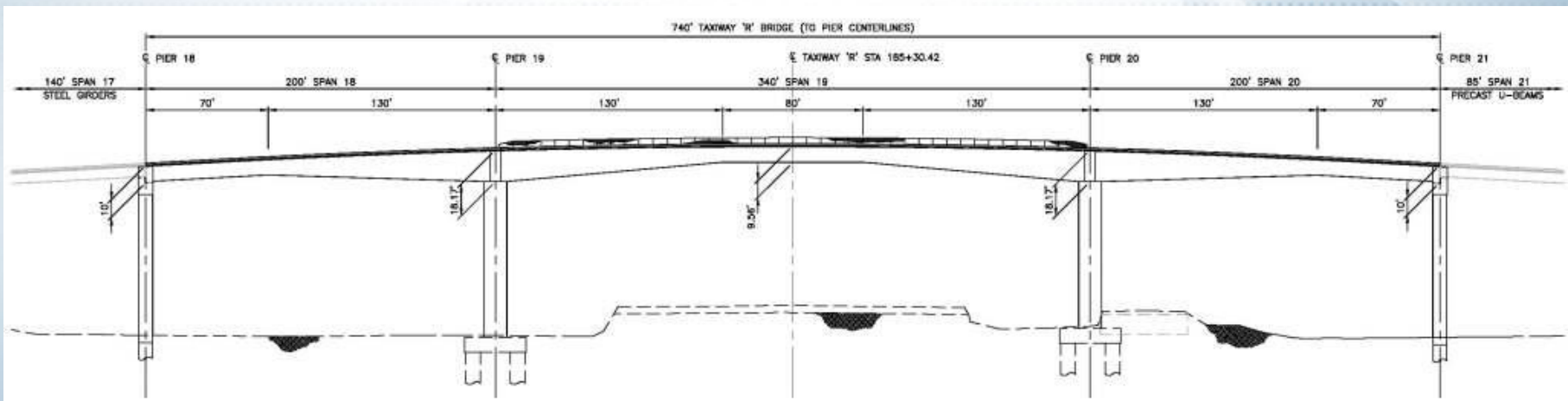
- Projected taxiway closure of **6 months**
- City Aviation Dept. to divert more traffic to parallel taxiways
- **Recommend Cast-in-Place Concrete Box Girder**
- Generate more bids
- Projected $1M savings (actual savings higher)

Final Design Development

Parabolic or Linear Haunch Soffit?



Parabolic Soffit

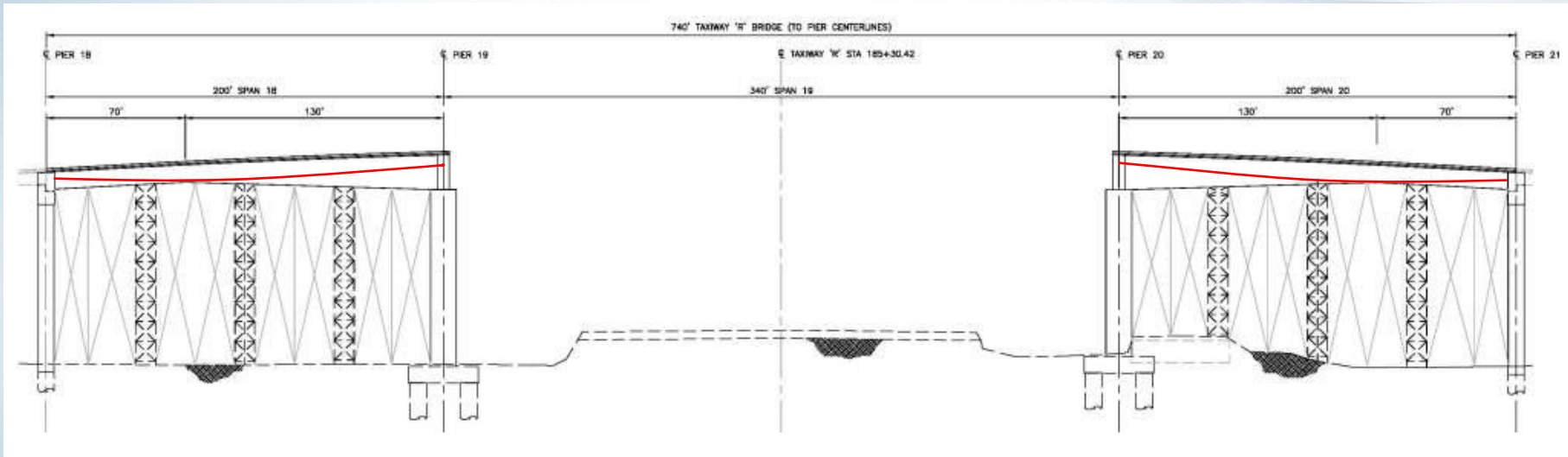


Linear Haunch Soffit

Final Design Development v1.0

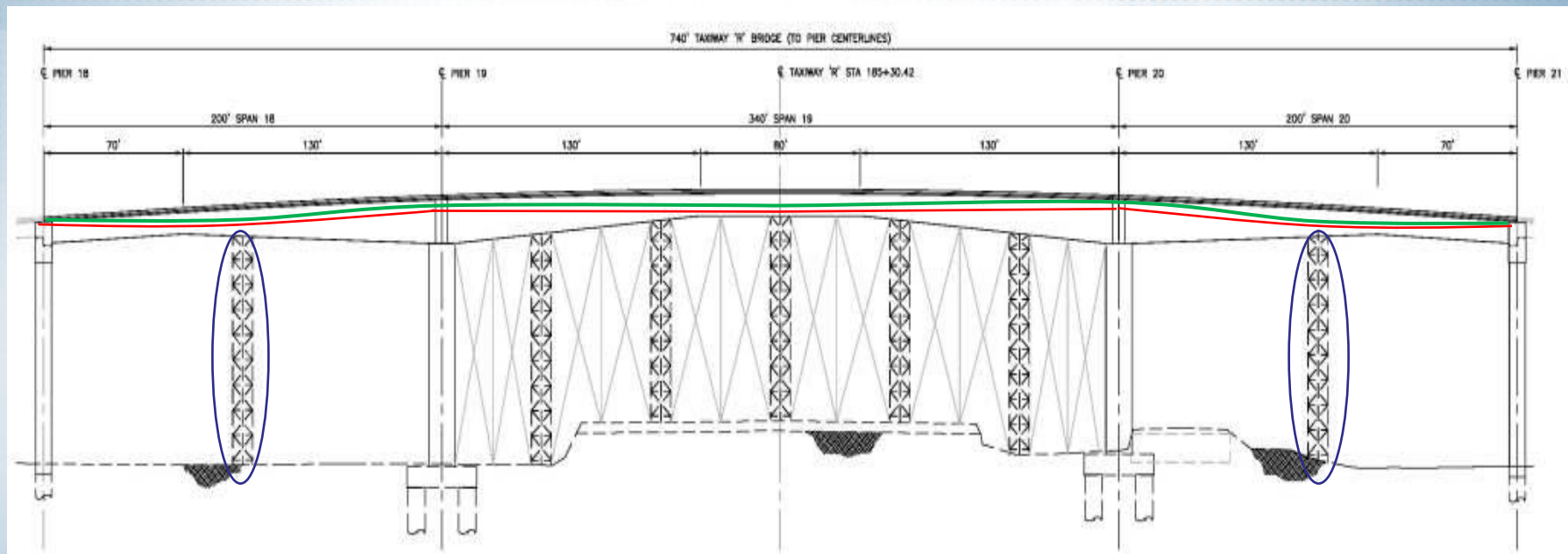
Cast-in-Place Concrete Box Girder

- Design based on two-stage construction
  - End spans constructed first on falsework, supplemental PT needed for self-weight



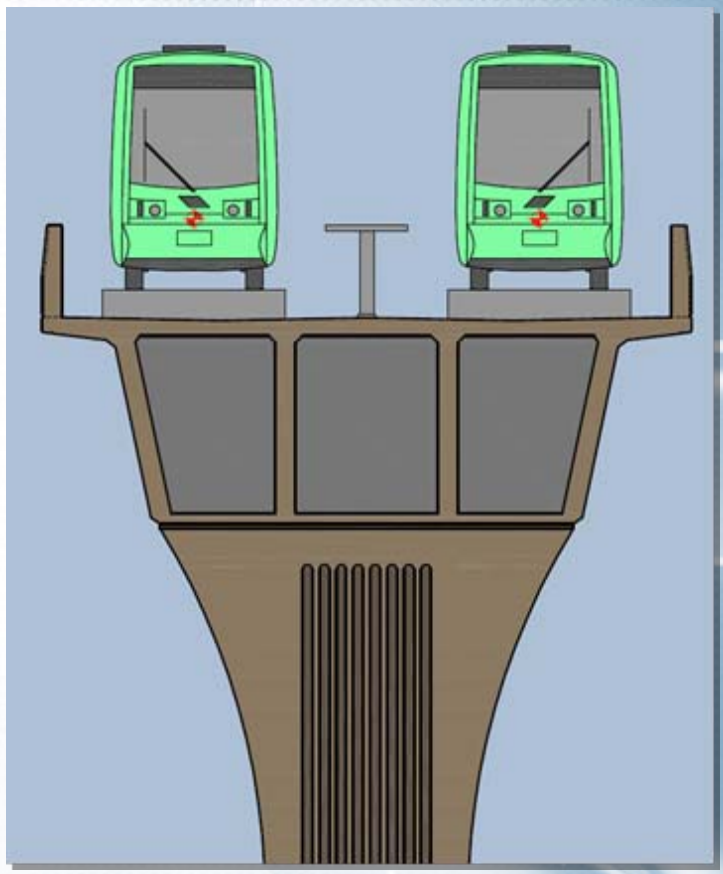
Final Design Development v1.0

- Tower kept at midspan of end spans, central span constructed on falsework, supplemental PT
- PT of continuous tendons, remove all falsework



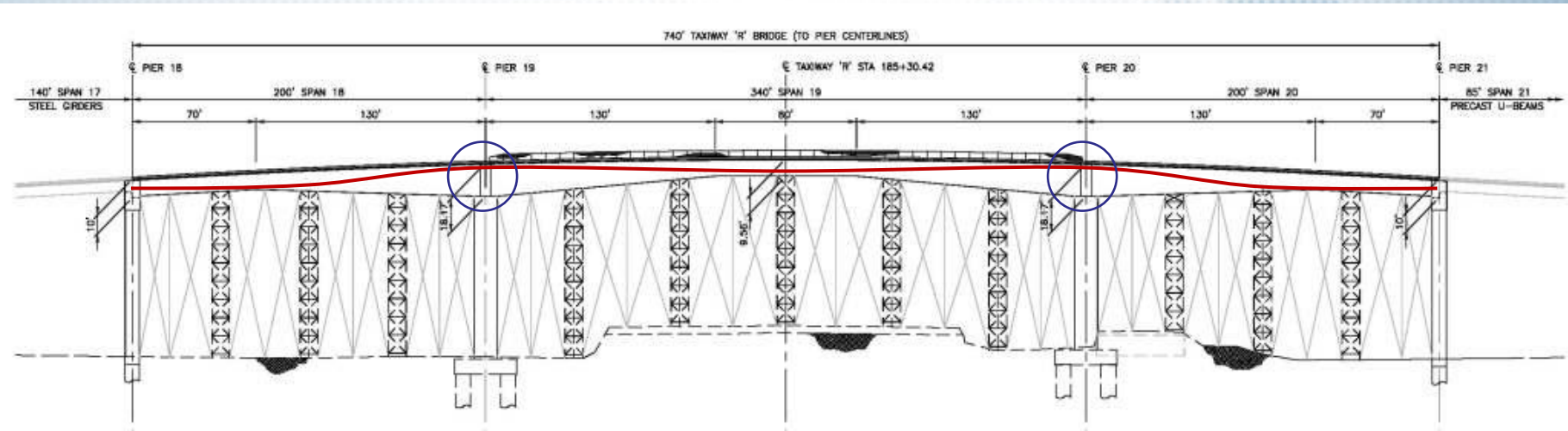
Final Design Development v1.0

- 3 span: 200'-340'-200'
- 8'-9" ft to 17'-6" Variable Depth
- Main Piers: 13 ft Diameter on Drilled Shaft Group
- Post Tensioning - Continuous Tendons 20.2M lbs jacking force Supplemental Tendons 4.5M lbs



Final Design Development v2.0

- Design revisited based on contractor's final construction plan
- Post-tensioning arrangement revised - leaner and cleaner
- One stage construction, PT in one step, eliminate closure pours
- PT jacking force optimized at 19M lbs
- Lower cost and faster construction



Building The Bridge

- Construction Management At-Risk (CMAR) – CMAR / Subcontractor relationship
- Scheduling Challenges & Timeline
- Construction Issues
  - Sky Harbor Boulevard Traffic
  - 41st Street Traffic
  - Taxiway R & SWA Traffic

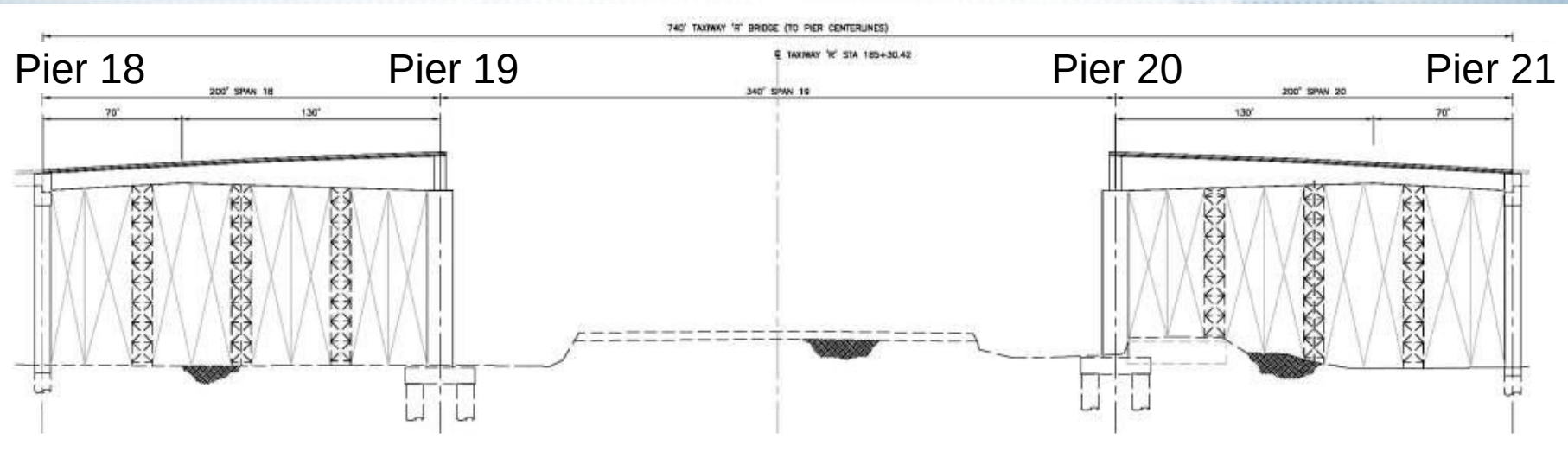
Scheduling Issues

- Contract Award – September 2009
- Six Month Taxiway Closure – April to October 2010
- One Year Completion
  - Out of 307 shifts available (excludes Sunday), AB&R worked 272
- Holiday Moratoriums
  - Veteran's Day, Thanksgiving, Christmas, New Year's, Memorial Day, 4th of July, Labor Day

Sequence of Construction

Construct End Spans First:

- Start with drilled shaft foundations
- Construct end piers first (Piers 18 & 21)
- Taxiway restriction for main piers (Piers 19 & 20)



Challenges Working at SHIA

- Extremely restrictive clearances due to WB Sky Harbor Blvd, 41st St, Terminal 4 ramp, SWA Gates, & Taxiway R
- Site restrictions required night operations both landside and airside
- Extremely high temperatures inside bridge with floor and webs in place

Pier 18 Column Pour #1

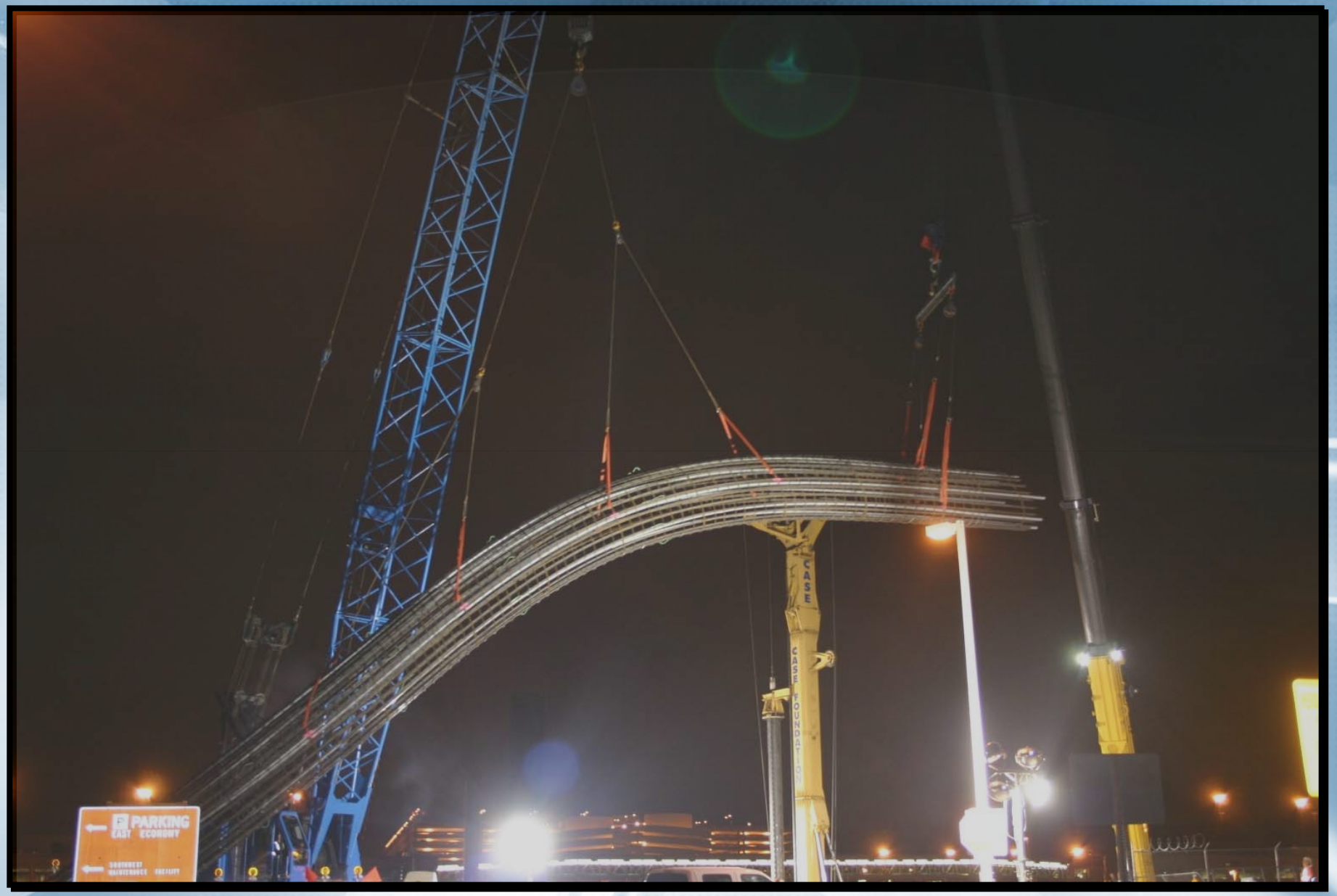
Terminal 4 Ramp

SWA "Pizza Oven"

Pier 20 Challenges

41st St. →

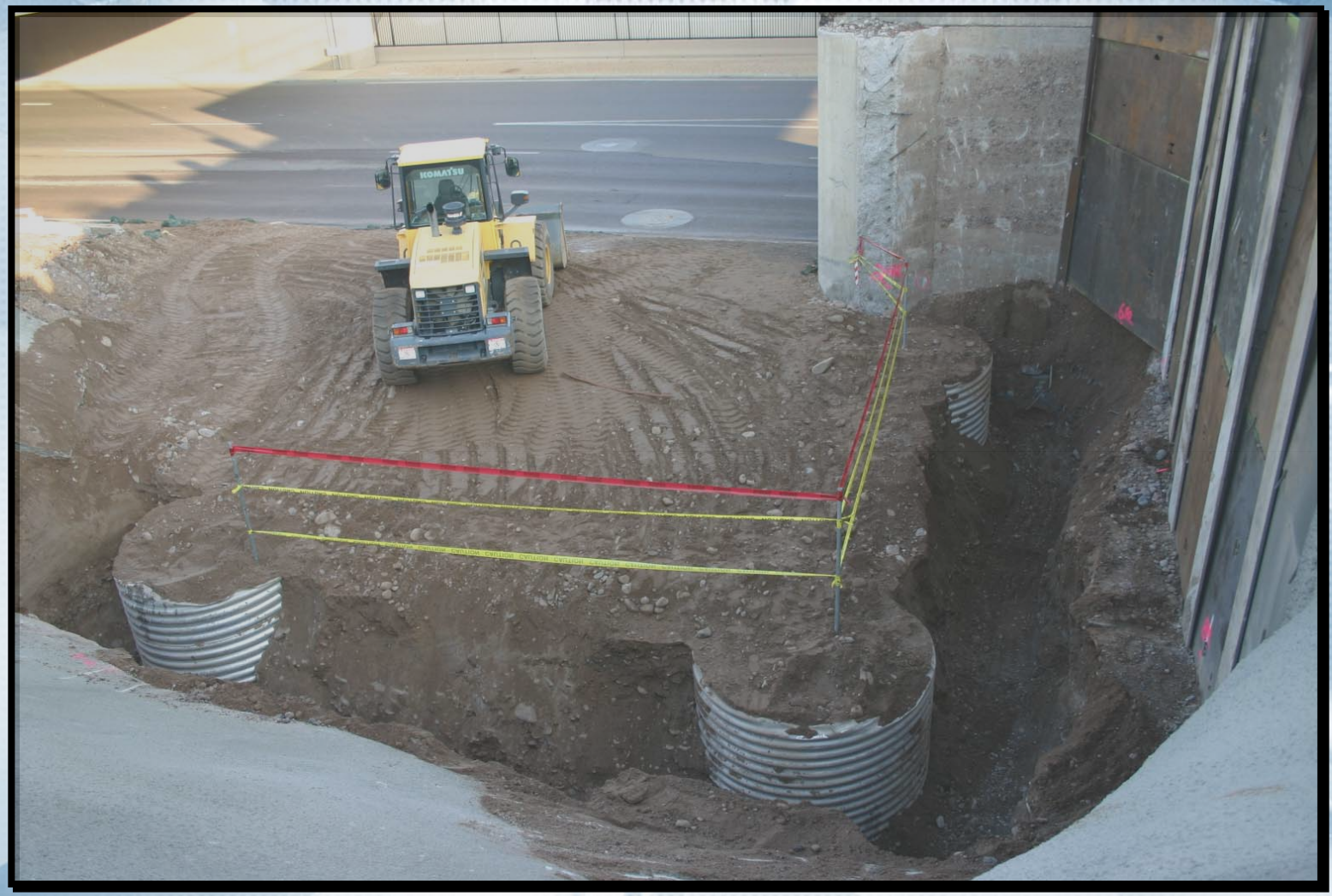
Pier 2 – Drilled Shaft Rebar


P PARKING
CASE
CASE FOUNDATION


P PARKING
EAST ECONOMY


480-893-0081 800-579-0081
GROVE 6350

Pier 20 Shafts Completed

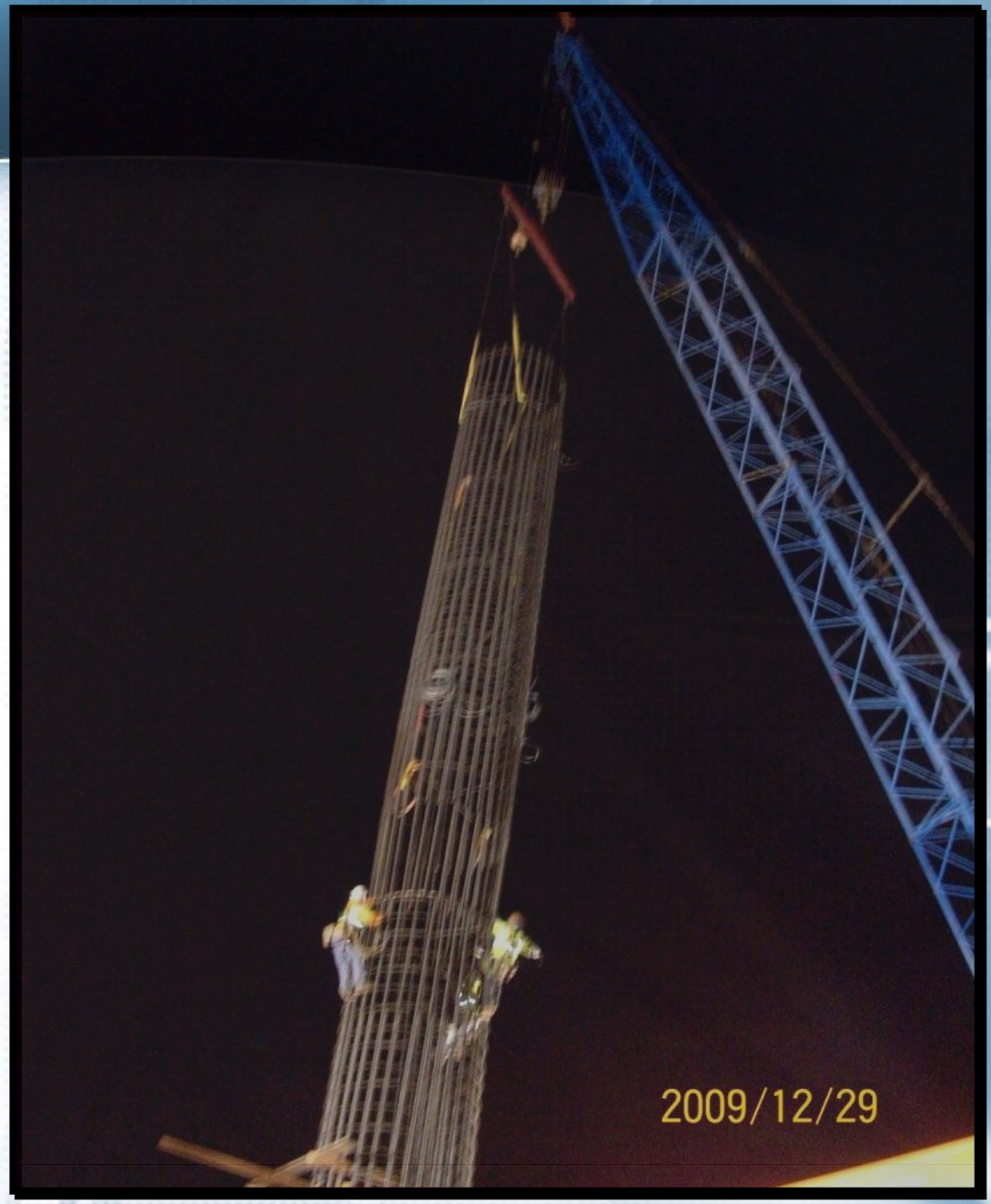


Pier Cap & Column Rebar

Pier 20 Pile Cap Completed

Pier 20 Column Rebar Pour #1

Pier 20 Column Rebar Pour #2



Pier 20 Column Pour #2

Falsework Bent #1

Falsework Assembled Onsite

Falsework Assembled Offsite

Lifting Bent from Sky Harbor Blvd.

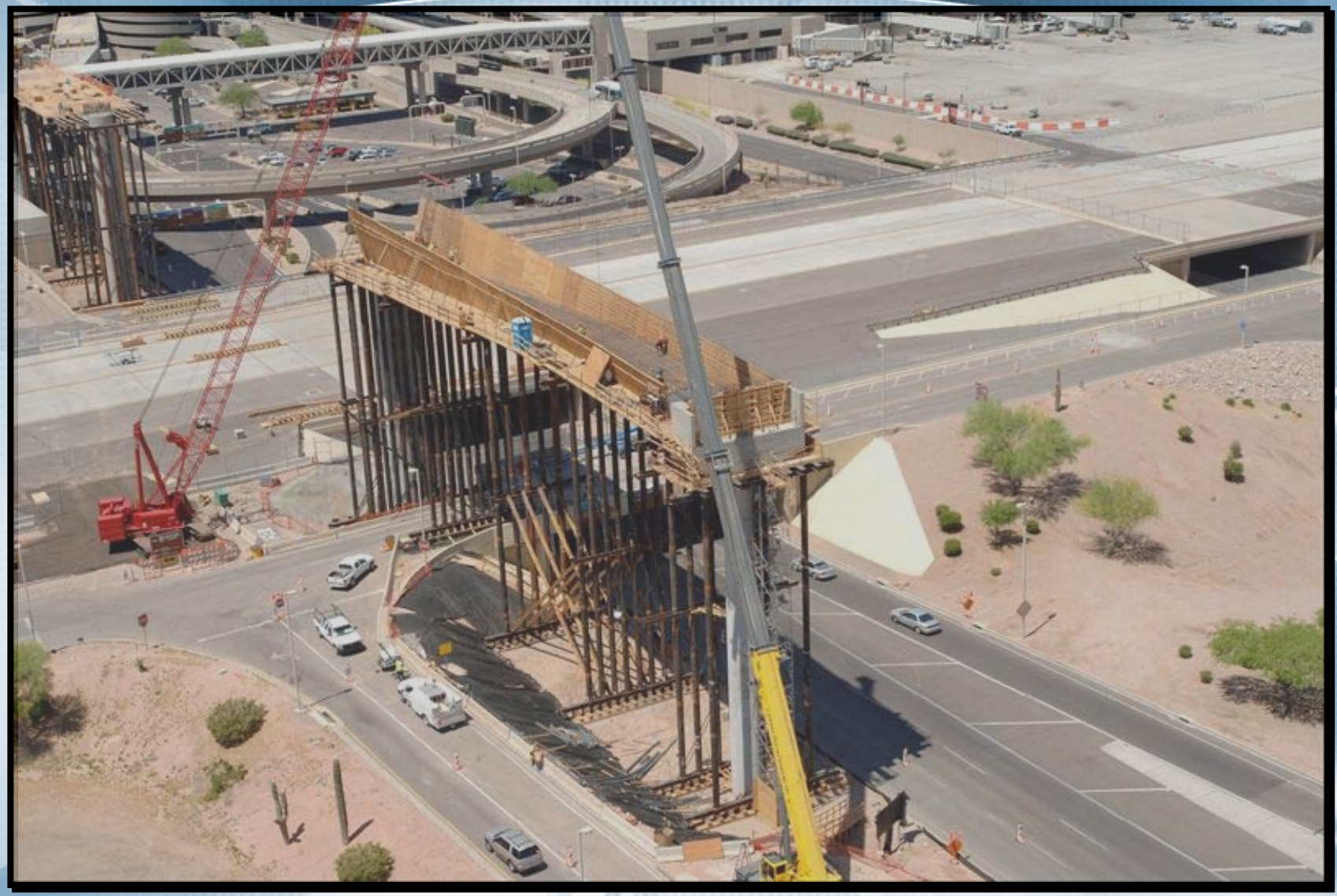
Lifting Over SWA Baggage Handling Area

Falsework Span 20

Falsework Span 20

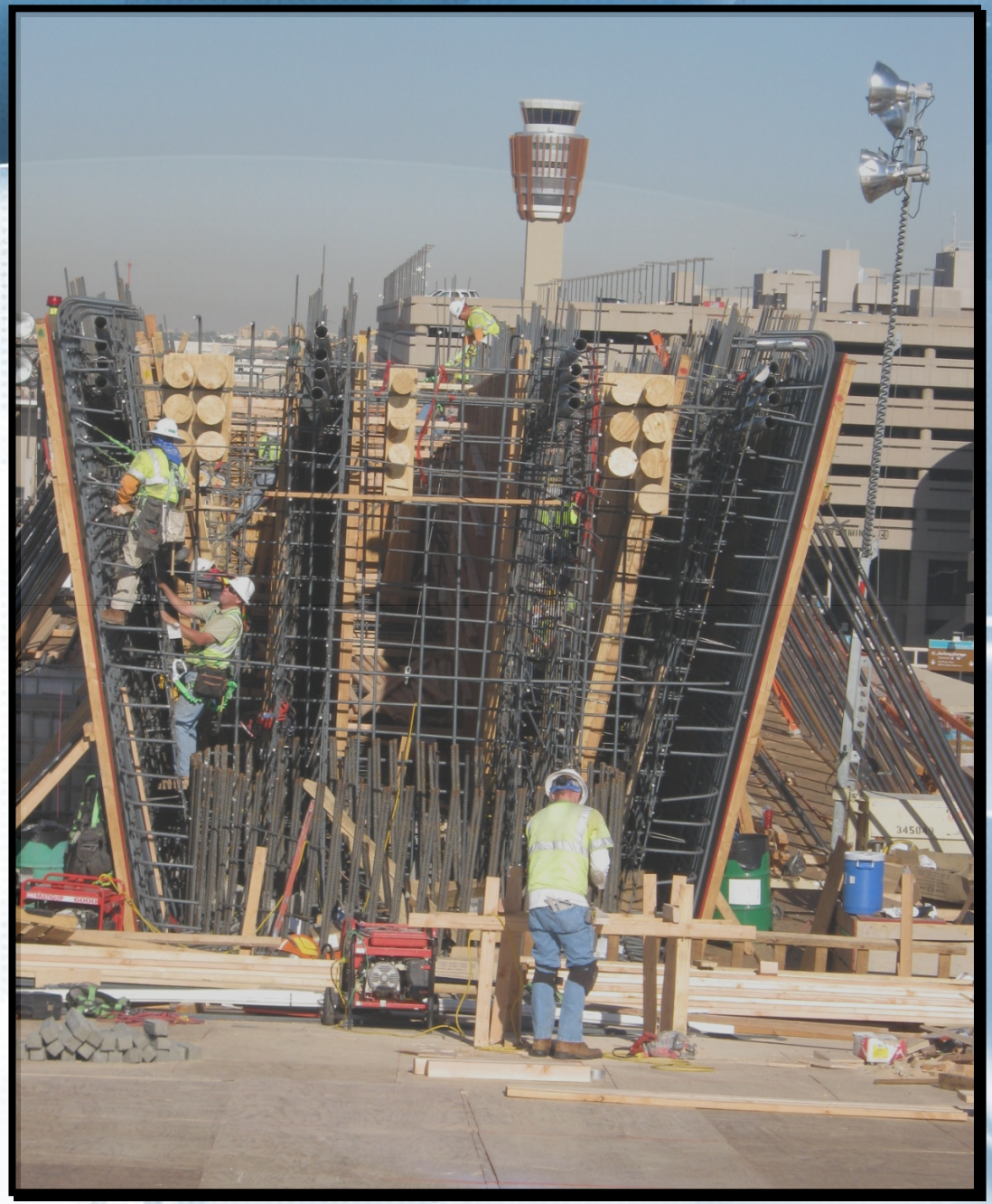
Soffit & Ext. Webs Formwork Span 20

Soffit & Ext. Webs Span 20



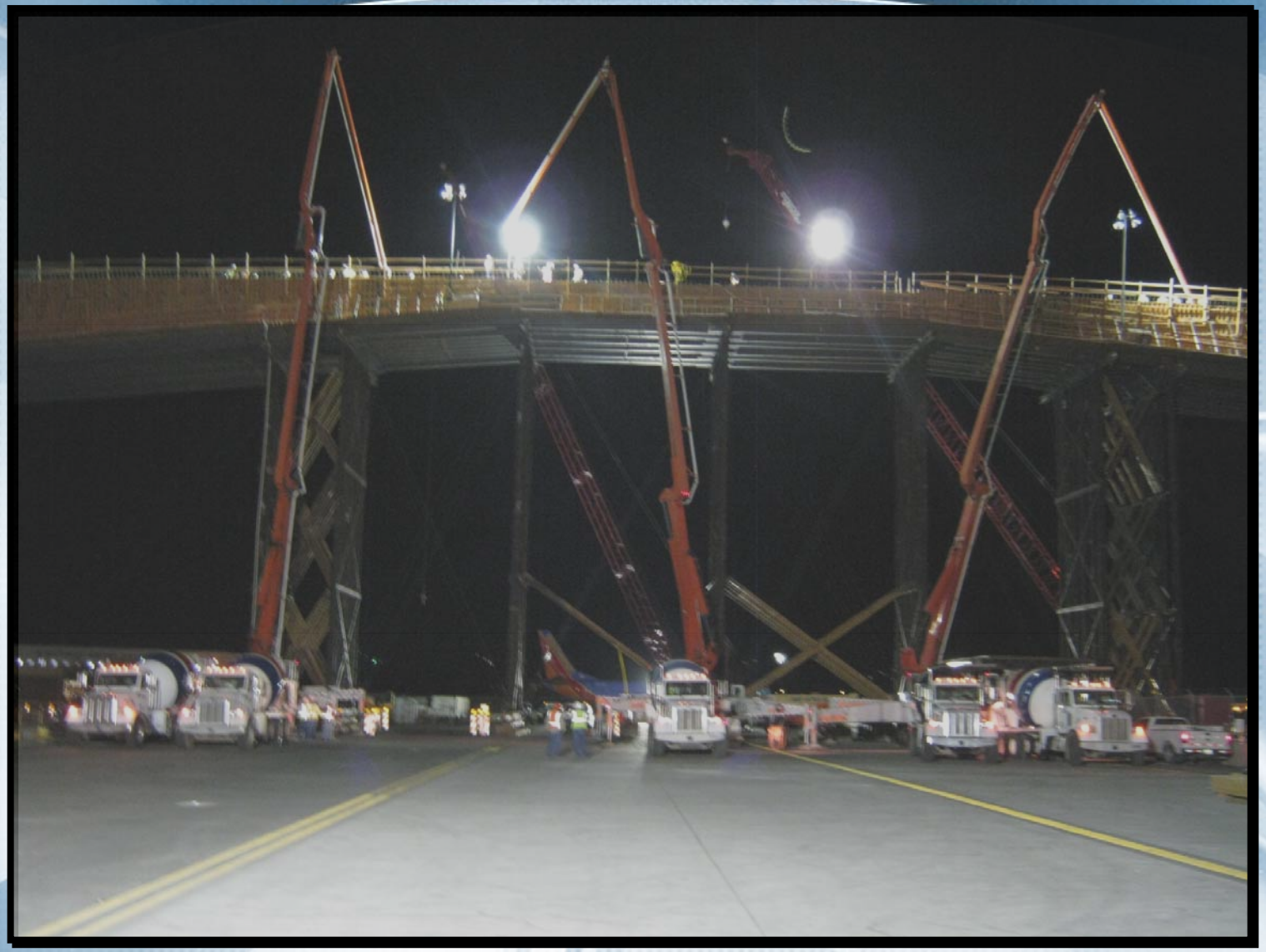
Center Span Falsework Complete

Pier 19 & 20 Diaphragm & PT Anchorage



Pier 19 & 20 Diaphragm

Center Span Floor & Webs



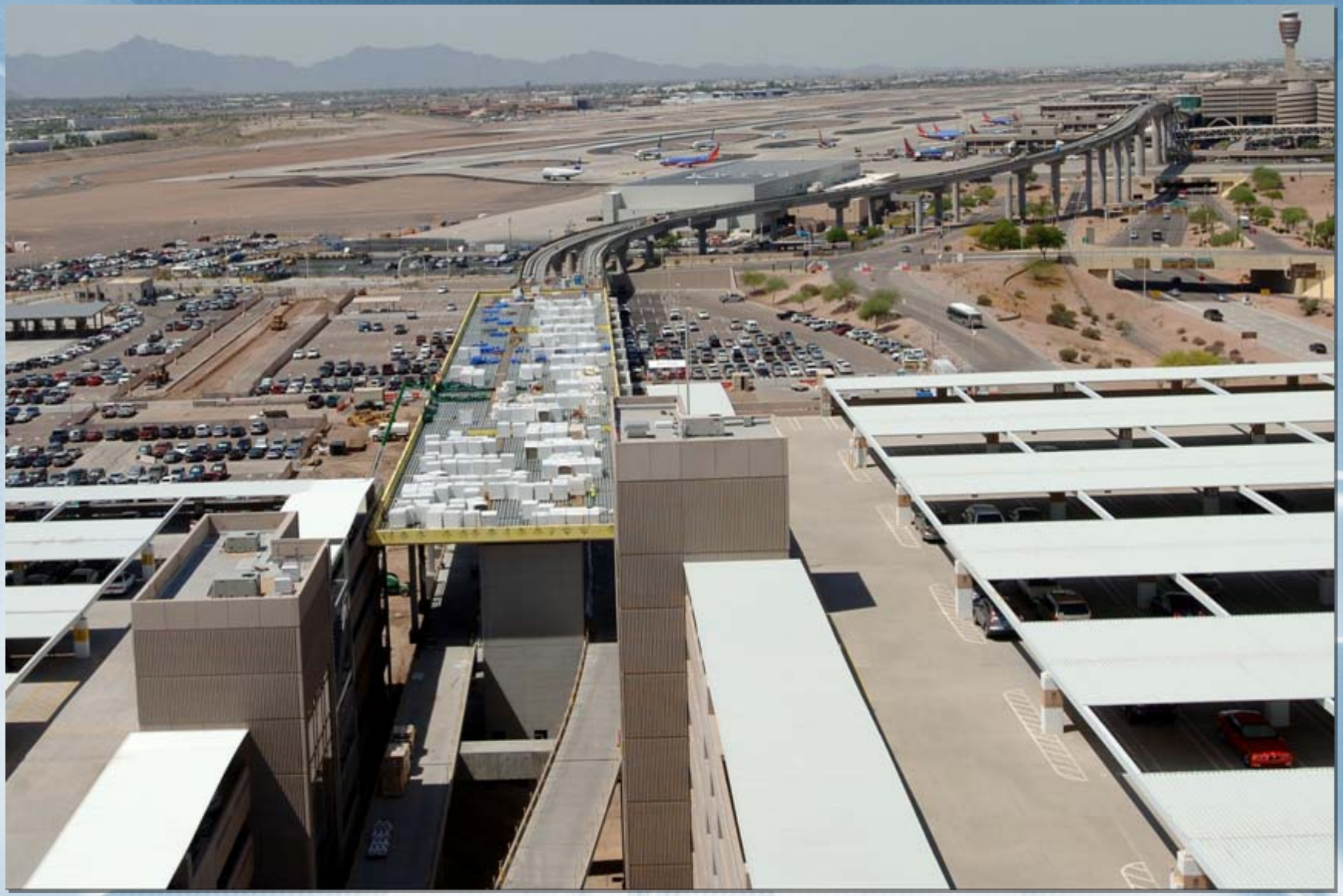
Center Span Floor & Webs Complete

July 2nd 2010

Post Tensioning Challenges

Taxiway 'R' Reopens

October 10, 2010
(Just under 6 months from Taxiway closure)



East Economy Lot Station

Looking West Toward Terminal 4

Approaching Taxiway "R"

QUESTIONS?