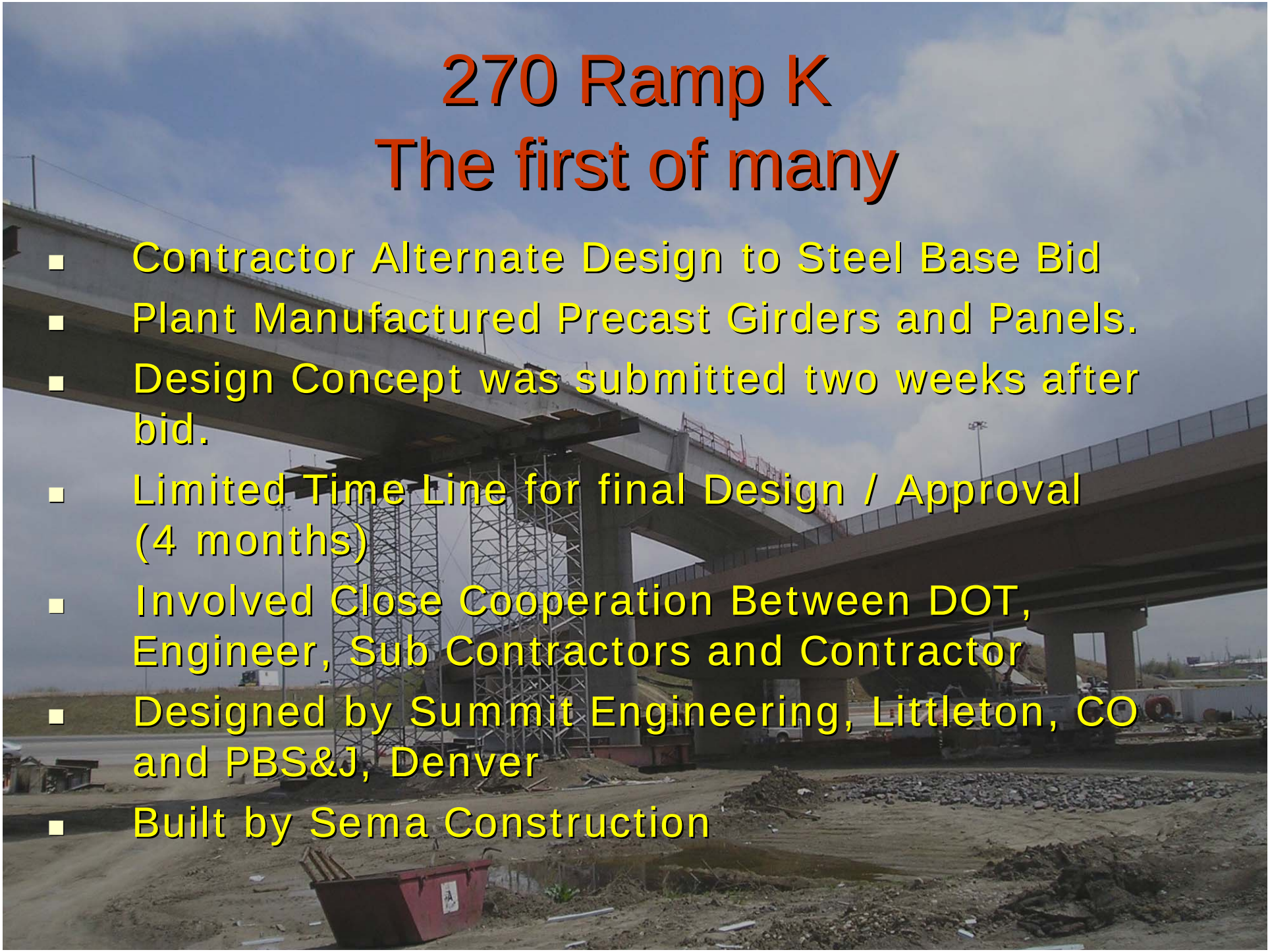
Design and Construction of Curved Precast Girder Bridge Projects in Colorado

Current Colorado Projects using Curved Precast Girders

1. IH25 / SH270 Ramp K, Denver
2. SH270 / IH76 Ramp Y, Denver
3. E470 / IH70, Ramp H, Denver
4. SH58 / IH70, Ramp A, Golden
5. Austin Bluffs Overpass, Colorado Springs
6. IH25 Viaduct, Trinidad



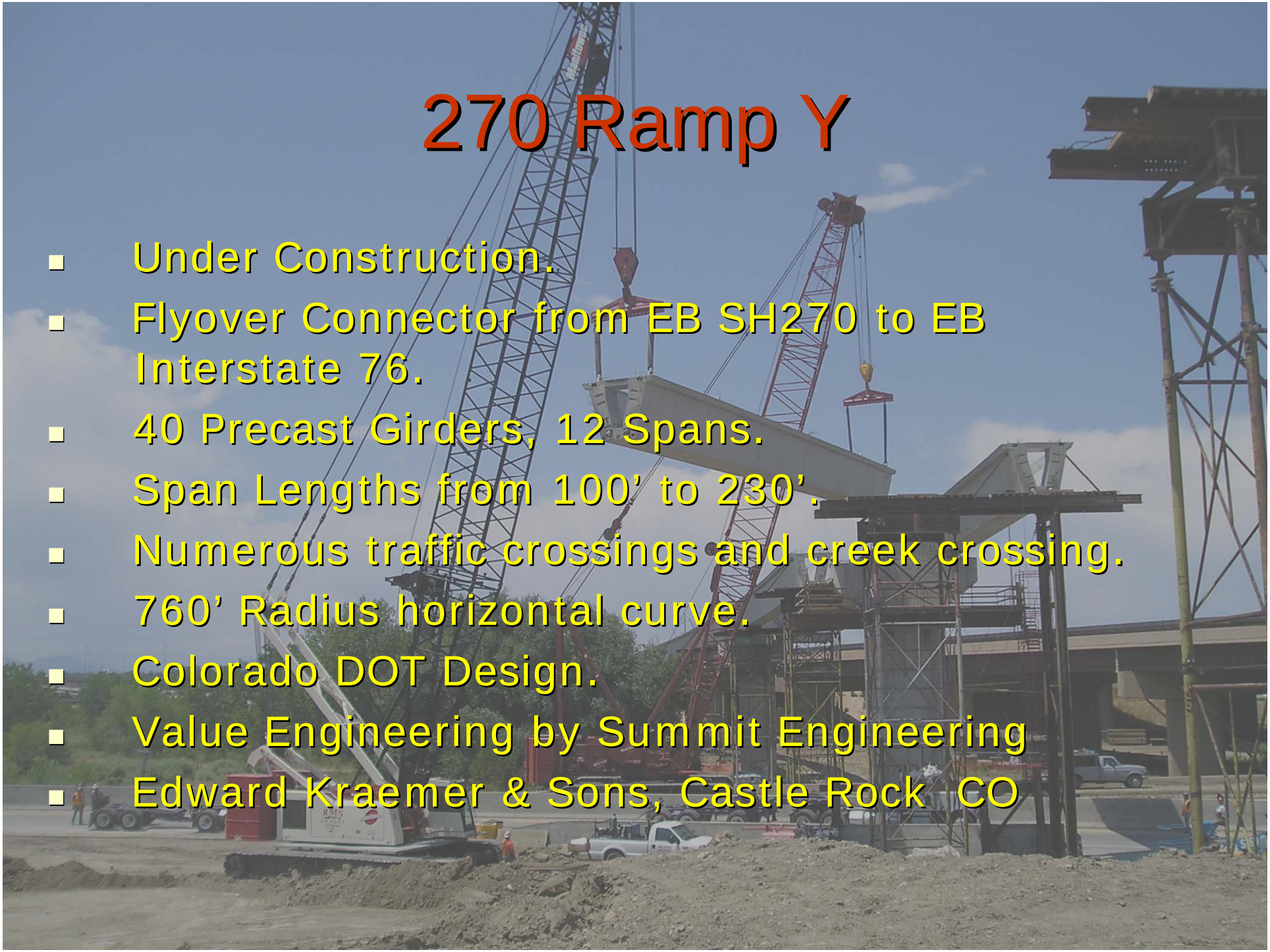
270 Ramp K
The first of many

- Contractor Alternate Design to Steel Base Bid
- Plant Manufactured Precast Girders and Panels.
- Design Concept was submitted two weeks after bid.
- Limited Time Line for final Design / Approval (4 months)
- Involved Close Cooperation Between DOT, Engineer, Sub Contractors and Contractor
- Designed by Summit Engineering, Littleton, CO and PBS&J, Denver
- Built by Sema Construction

E470 Ramp H

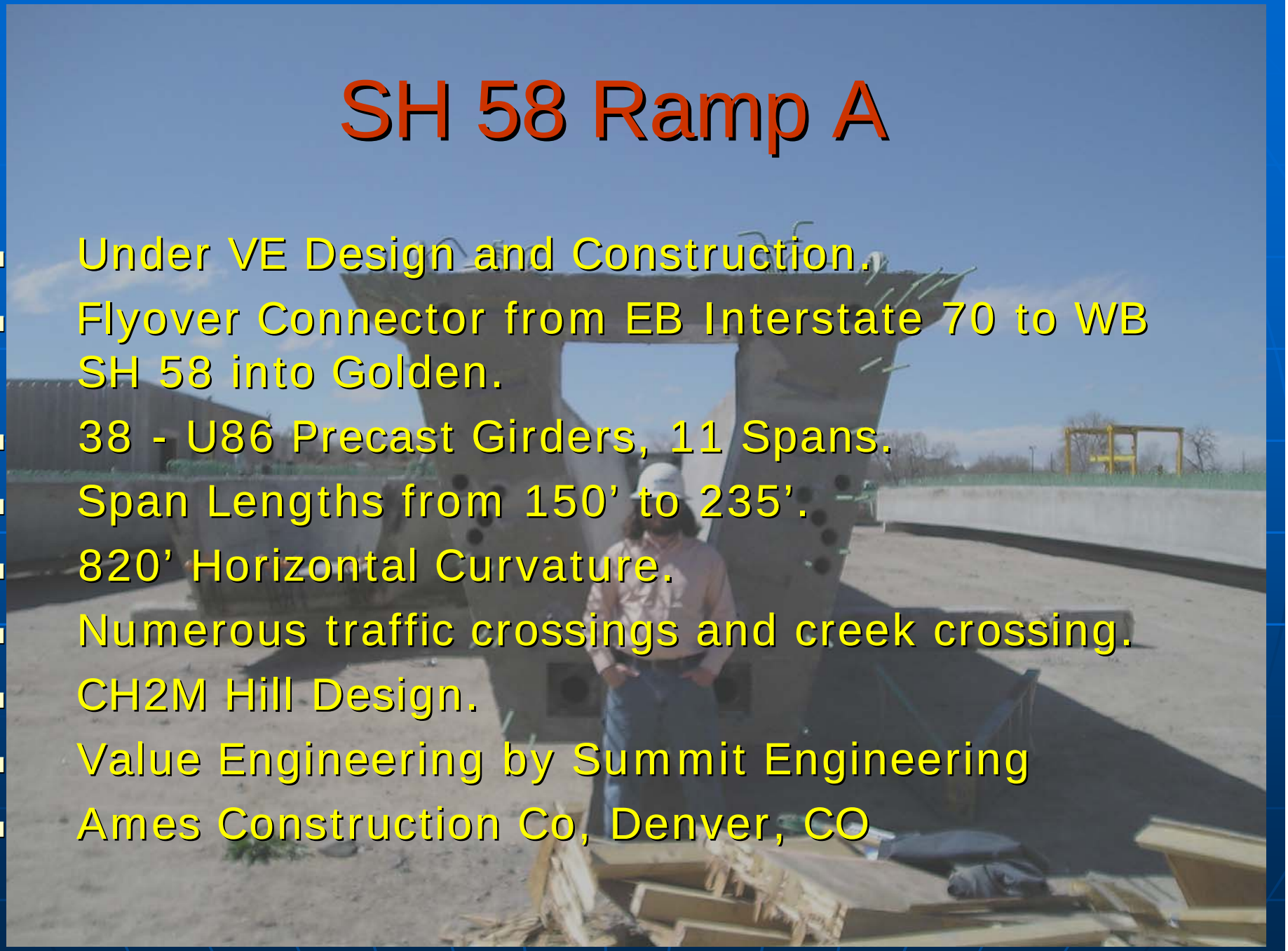
- Contractor Design/Build Project.
- Currently Under Construction.
- Connector Ramp from E470 Toll Road to Interstate 70.
- Combination of Simple Span and shored construction. Spans from 100’ to 200’
- 34 – U84 Girders, 11 Spans
- 1200’ Horizontal Curvature
- Designed by DMJM Harris, Denver
- Built by Lawrence Construction Co, Littleton, CO

270 Ramp Y



- Under Construction.
- Flyover Connector from EB SH270 to EB Interstate 76.
- 40 Precast Girders, 12 Spans.
- Span Lengths from 100’ to 230’.
- Numerous traffic crossings and creek crossing.
- 760’ Radius horizontal curve.
- Colorado DOT Design.
- Value Engineering by Summit Engineering
- Edward Kraemer & Sons, Castle Rock CO

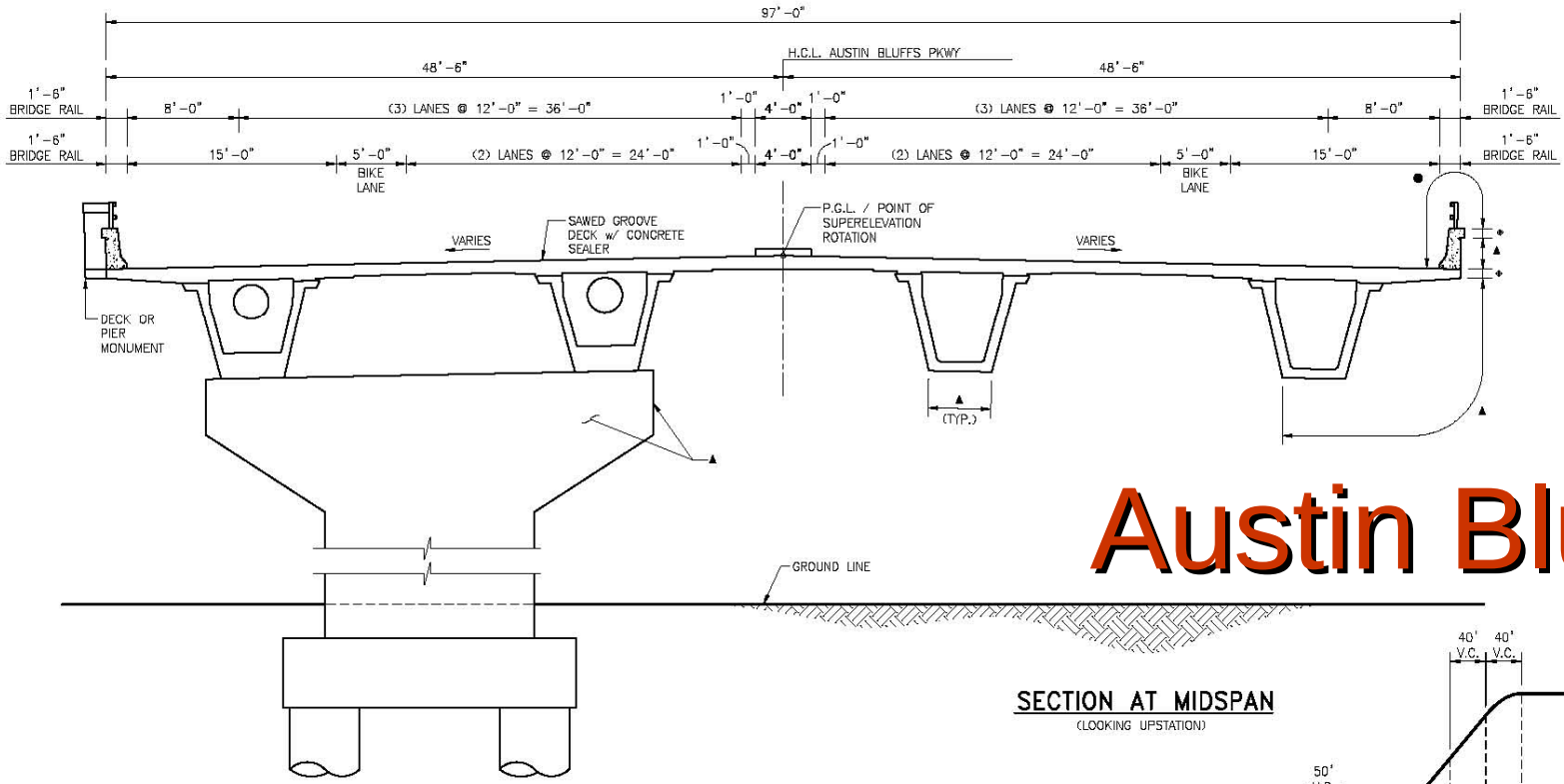
SH 58 Ramp A



- Under VE Design and Construction.
- Flyover Connector from EB Interstate 70 to WB SH 58 into Golden.
- 38 - U86 Precast Girders, 11 Spans.
- Span Lengths from 150’ to 235’.
- 820’ Horizontal Curvature.
- Numerous traffic crossings and creek crossing.
- CH2M Hill Design.
- Value Engineering by Summit Engineering
- Ames Construction Co, Denver, CO

Austin Bluffs Overpass

- Under VE Design and Construction.
- Overpass over Union Boulevard.
- 24 - U85 Precast Girders, Dual Bridges, 4 Spans.
- Span Lengths from 110’ to 210’.
- 950’ Radius Curve in two spans.
- Major Urban traffic crossing and creek crossing.
- CH2M Hill Design.
- Value Engineering by Summit Engineering
- Lawrence Construction Co, Littleton, CO



▲ STAIN EXTERIOR GIRDER AND RAIL AS SHOWN, BO
AND FACES OF PIERS AND ABUTMENTS.
COLOR = BASE COLOR

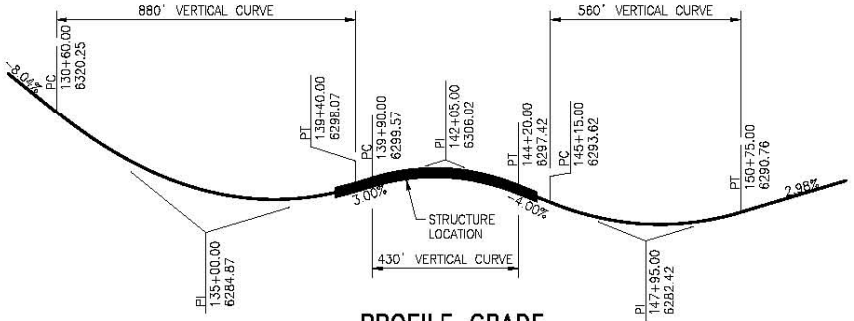
✦ STAIN VERTICAL SURFACE OF DECK AND UPPER C
COLOR = ACCENT COLOR

● SEE BRIDGE RAIL TYPE 7 (SPECIAL) FOR COLOR

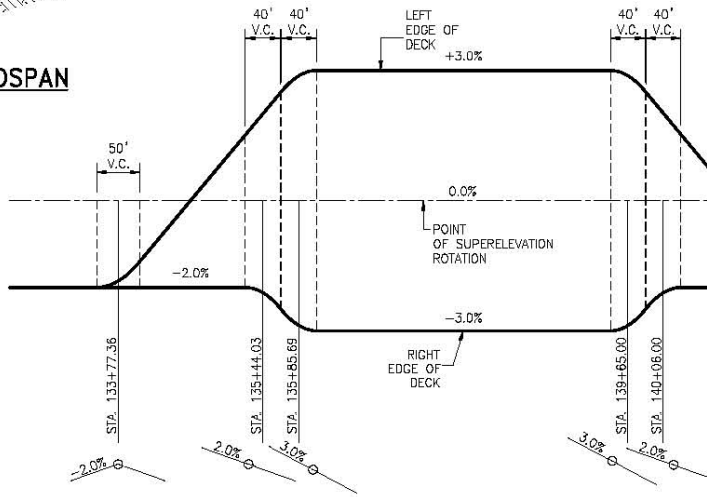
Austin Bluffs

SECTION AT PIER
(LOOKING UPSTATION)

SECTION AT MIDSPAN
(LOOKING UPSTATION)



PROFILE GRADE



SUPERELEVATION PROFILE

ENGINEERING GROUP, INCO
CONSULTING STRUCTURAL E

Computer File Information			
Creation Date:		Initials:	AML
Last Modification Date:		Initials:	BJA
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Drawing File Name:	B-5 General Layouts 3.dwg		

	Sheet Revisions	
0	8-16-07	Final Design Submittal

COLORADO REGISTERED 27508 PROFESSIONAL ENGINEER

AUSTIN BLUFFS PARKWAY OVER UNION BLVD.

Designer: G. REESE
Detailer: B. ALLEN
Checked:

GENERAL LAYOUT (3 OF 3)

Structure Numbers

IH25 Viaduct, Trinidad

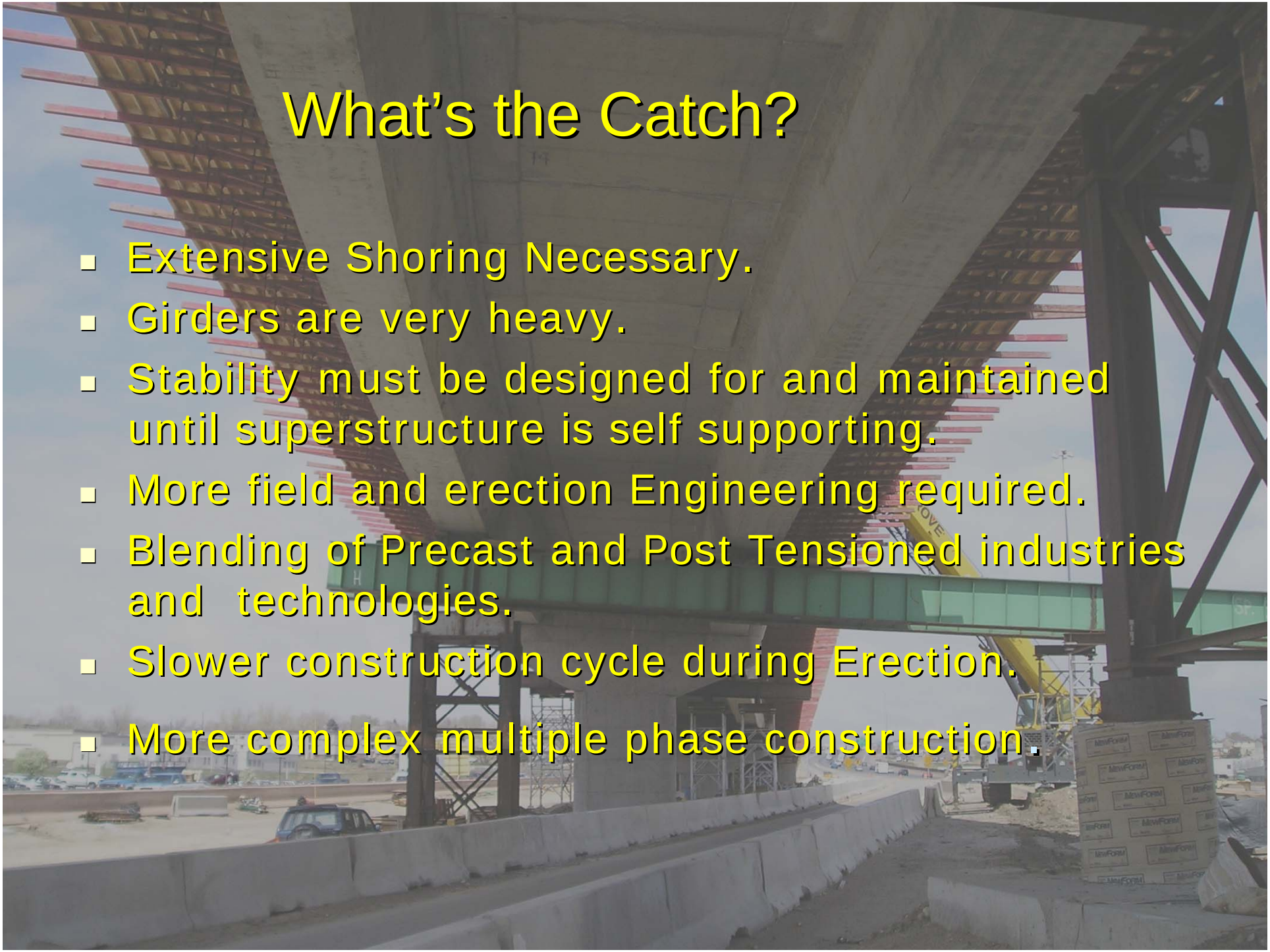
- Contractor Alternate Design and Construction.
- Early stages of construction.
- Elevated Viaduct through downtown Trinidad. 24 - U85 Precast Girders, Dual Bridges, 4 Spans.
- Span Lengths from 100’ to 265’.
- Major Urban project with numerous traffic, river and railroad crossings.
- Base design, precast segmental.
- Value Engineering by TSH Engineers and Summit Engineering
- Lawrence Construction Co, Littleton, CO

Curved Girder Bridge Quantities

Project	Bridge S.F.	L.F. Curved Precast
IH25 / SH270 Ramp K	66,740 s.f.	2,840 l.f.
IH76 / SH270 Ramp Y	77,248 s.f.	4,544 l.f.
IH70 / SH58 Ramp A	79,995 s.f.	4,095 l.f.
Austin Bluffs	57,715 s.f.	2,380 l.f.
IH25 Trinidad	65,728 s.f.	4,141 l.f.
IH70 / E470 Ramp H	75,952 s.f.	3,232 l.f.
Total	414,378 s.f.	21,232 l.f.

Why use Precast Concrete for these Types of Bridges?

- Colorado Preference for Concrete Structures.
- Setup Costs were nominal.
- Concrete Alternate less expensive.
- Speed of Fabrication.
- Design Impact not significant.
- Composite construction, splicing and post tensioning girders extends the span range
- Shoring not required over traffic.
- Design used established techniques on new application.
- Attractive appearance.



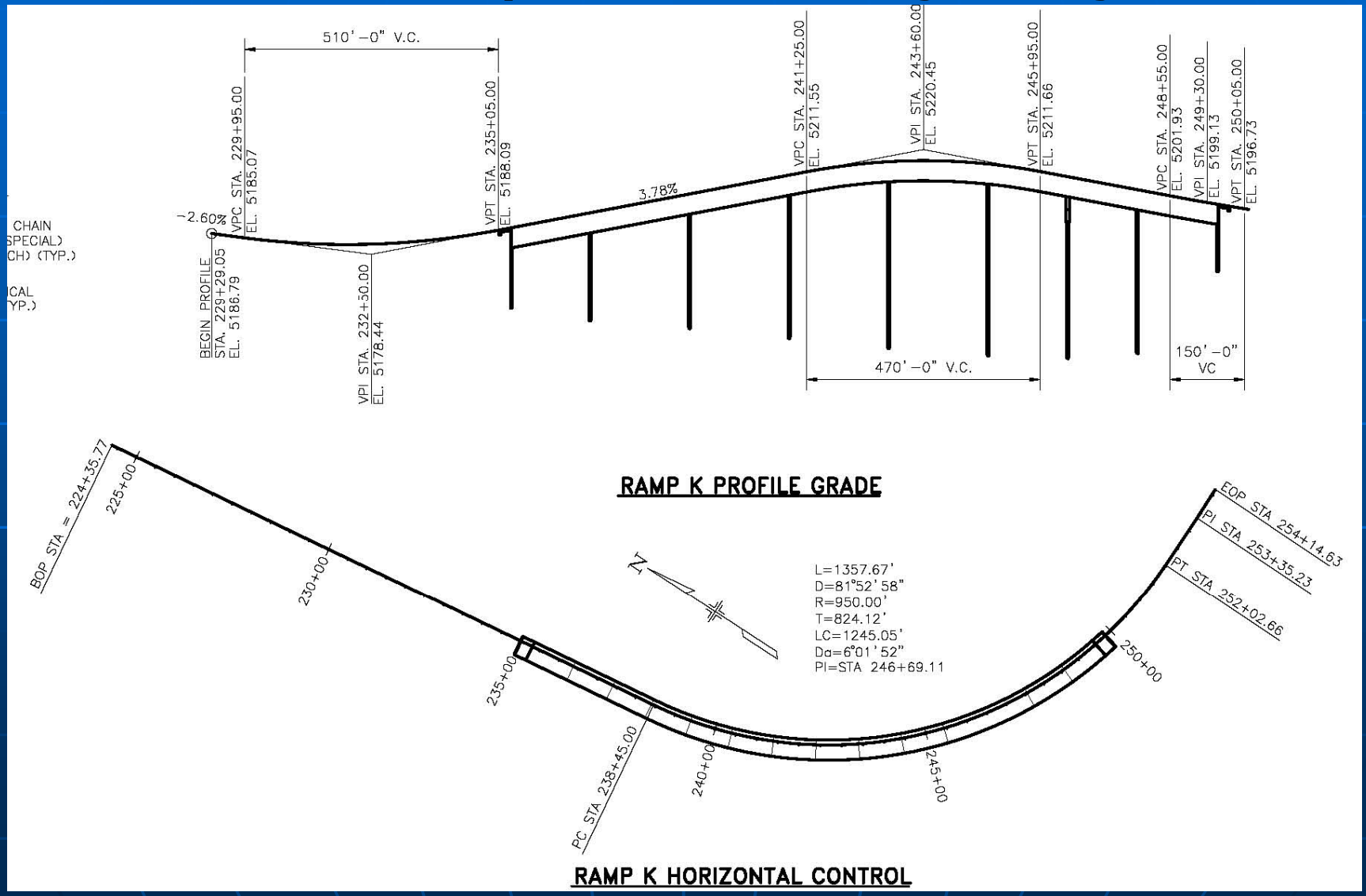
What's the Catch?

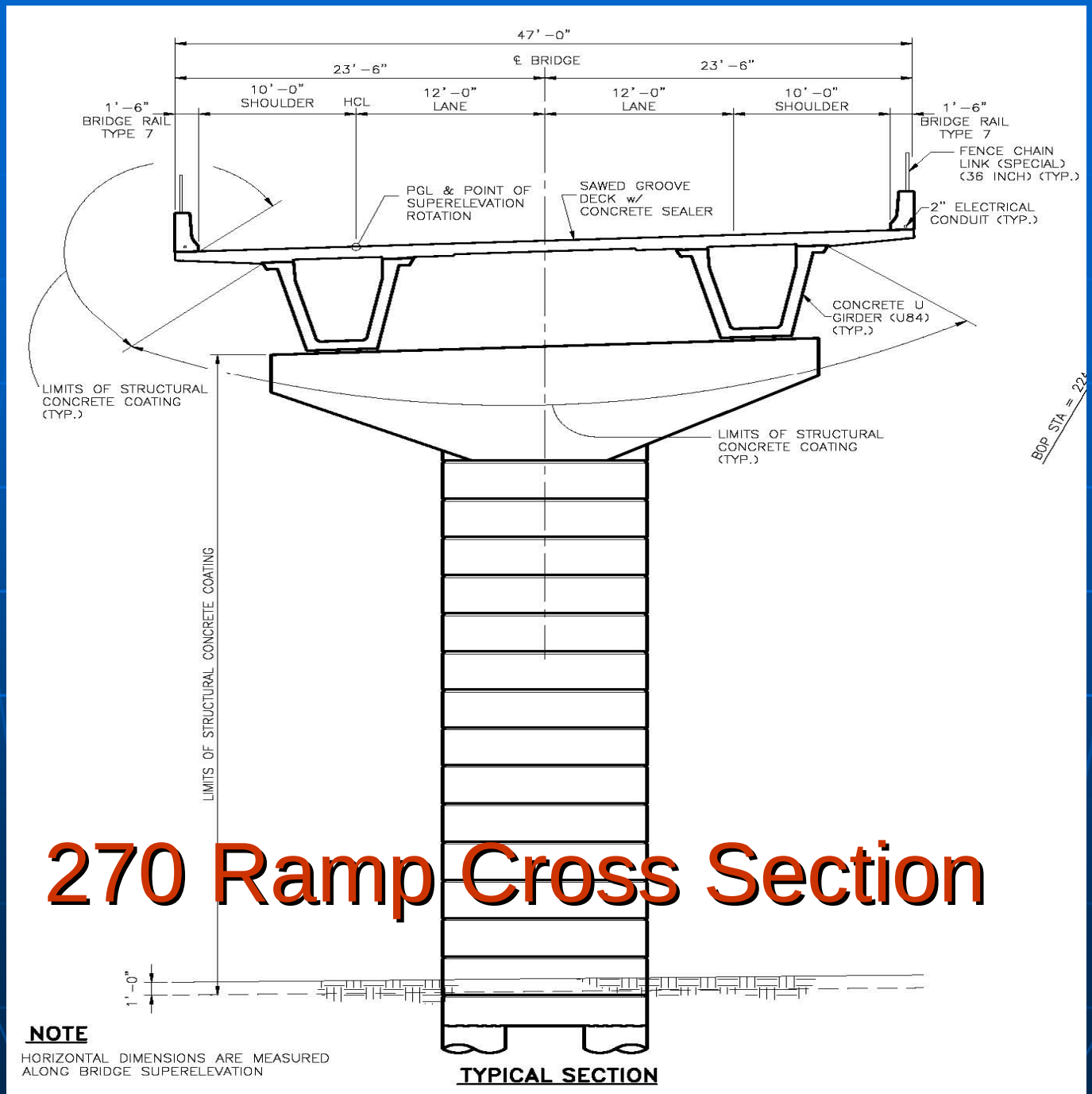
- Extensive Shoring Necessary.
- Girders are very heavy.
- Stability must be designed for and maintained until superstructure is self supporting.
- More field and erection Engineering required.
- Blending of Precast and Post Tensioned industries and technologies.
- Slower construction cycle during Erection.
- More complex multiple phase construction.

270 Ramp Y Cost Comparisons

Item	Steel Design	Curved Precast
Girder Cost	$5,125,000	$3,086,240
Erection Costs	$1,025,000	$890,000
Falsework	$50,000	$250,000
Post Tensioning	$0	$506,000
Total	$6,200,000	$4,732,240
Cost / Ft.	$1393 / lf	$1063

270 Ramp Roadway Layout



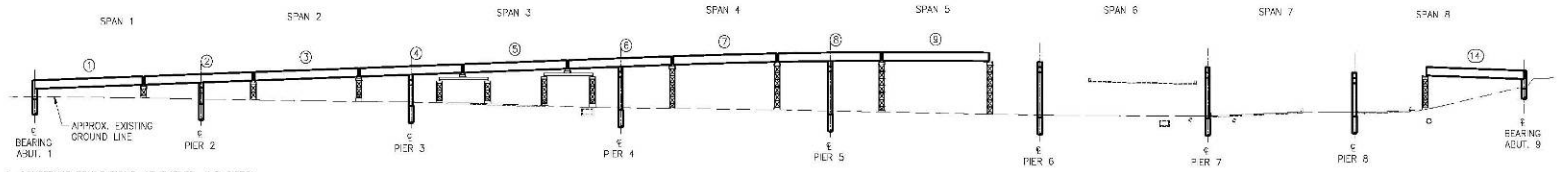


270 Ramp Cross Section

Bridge Configuration

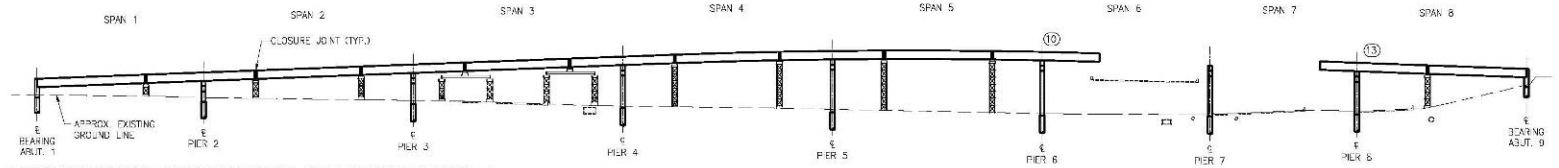
- 8 Spans, 6 and 2 span continuous units.
- Span Lengths from 140’ to 200’
- Pier Heights from 10’ to 45’
- Spliced Construction
- Phased Erection w/ staged post tensioning

Phased Construction



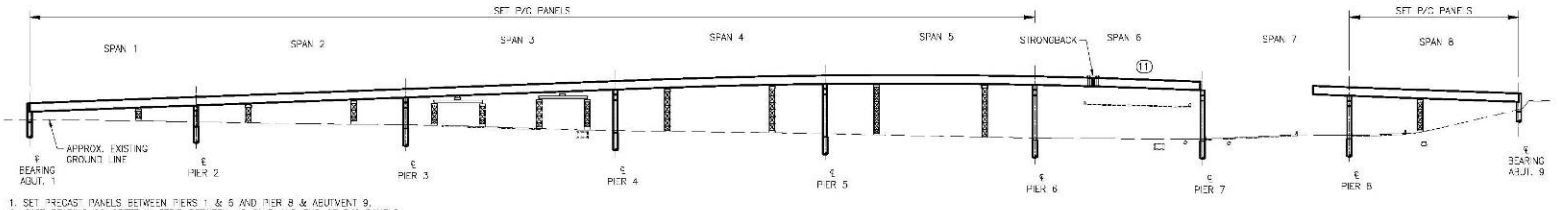
1. CONSTRUCT FOUNDATIONS, ABUTMENTS, AND PIERS.
2. ERECT SHORING TOWERS.
3. SET GIRDER SEGMENTS 1–9, AND 14 ON FALSEWORK AND INSTALL TEMPORARY BRACING.
4. CAST BEARING CONCRETE UNDER SEGMENTS 2, 4, 6, & 8 AND HAUNCHES AT PIERS 2–5.
5. SET SEGMENTS 10 AND 13 ON TEMPORARY PADS AT MID SPAN AND LIFT LOCATIONS ON THE GROUND.
6. CAST ANCHORAGE BLOCKS, LID SLAB, AND PIER DIAPHRAGM FOR SEGMENTS 10 & 13.
7. DE-STRESS BOTTOM SLAB TENDONS IN PIER SEGMENTS 4, 6, & 8.
8. CAST DIAPHRAGMS, BOTTOM SLAB HAUNCH, LID SLAB AND CLOSURES FOR SEGMENTS 1–9 & 14 ON FALSEWORK.
9. USE PS GIRDER CONCRETE FOR BOTTOM HAUNCHES AND CLOSURES.
10. USE CLASS D CONCRETE FOR DIAPHRAGMS ABOVE BOTTOM SLAB HAUNCH OVER PIER.
11. USE S4D CONCRETE IN LID SLABS.

PHASE 1



1. STRESS TENDONS 8 & 9 IN LID SLAB OF SEGMENTS 10 & 13, WHEN CONCRETE REACHES 4000 psi.
2. ERECT SEGMENTS 10 AND 13.
3. SUPPORT SEGMENTS 10 & 13 AT PIERS 6 & 8 AND INSTALL TEMPORARY BRACING.
   SEGMENT 10 MUST BE RESTRAINED TO SEGMENT 9 @ CLOSURE PRIOR TO RELEASING CRANES.
4. DE-STRESS BOTTOM SLAB TENDONS IN SEGMENTS 10 & 13.
5. CAST PIER DIAPHRAGMS AT PIERS 5 & 6, BOTTOM SLAB HAUNCHES IN SEGMENTS 10 & 13, AND CLOSURES BETWEEN SEGMENTS 9 & 10 AND 13 & 14.
6. STRESS AND GROUT TENDONS 1, 2, & 5 (ERECTION TENDONS) WHEN $f'_c \geq 5000$ psi.
7. DESTRESS TENDONS 8 & 9 IN SEGMENTS 10 & 13.
8. USE PS GIRDER CONCRETE FOR BOTTOM HAUNCHES AND CLOSURES.
9. USE CLASS D CONCRETE FOR DIAPHRAGMS ABOVE BOTTOM SLAB HAUNCH OVER PIER.
10. USE S4D CONCRETE IN LID SLABS.

PHASE 2



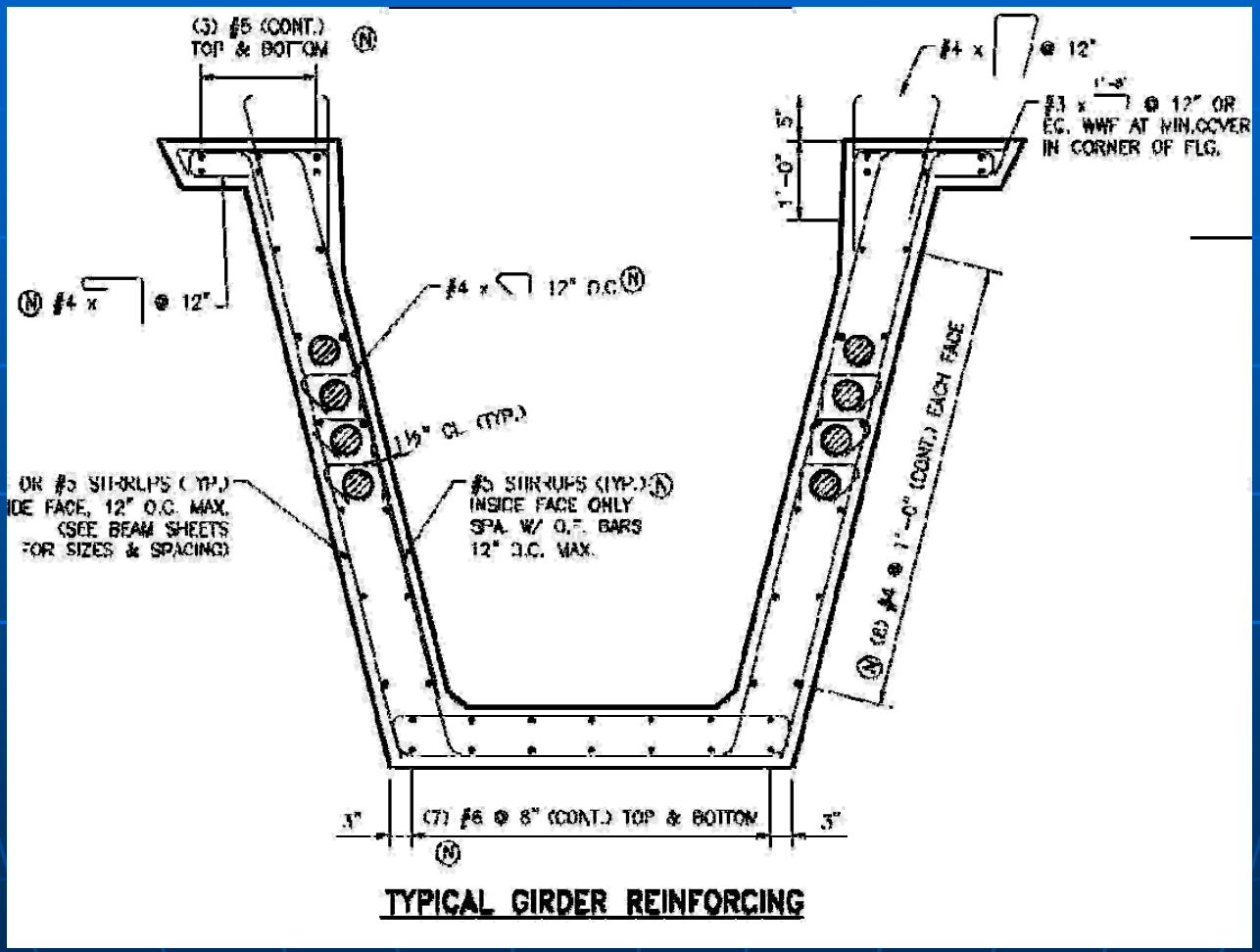
1. SET PRECAST PANELS BETWEEN PIERS 1 & 5 AND PIER 8 & ABUTMENT 9.
2. CAST BEARING CONCRETE IN STRIP BETWEEN LID SLAB AND END OF P/C PANELS.
3. ERECT SEGMENT 11, SET ON STRONGBACKS @ CLOSURE AND TEMPORARY BEARINGS @ PIER 7 FALSEWORK.

PHASE 3A

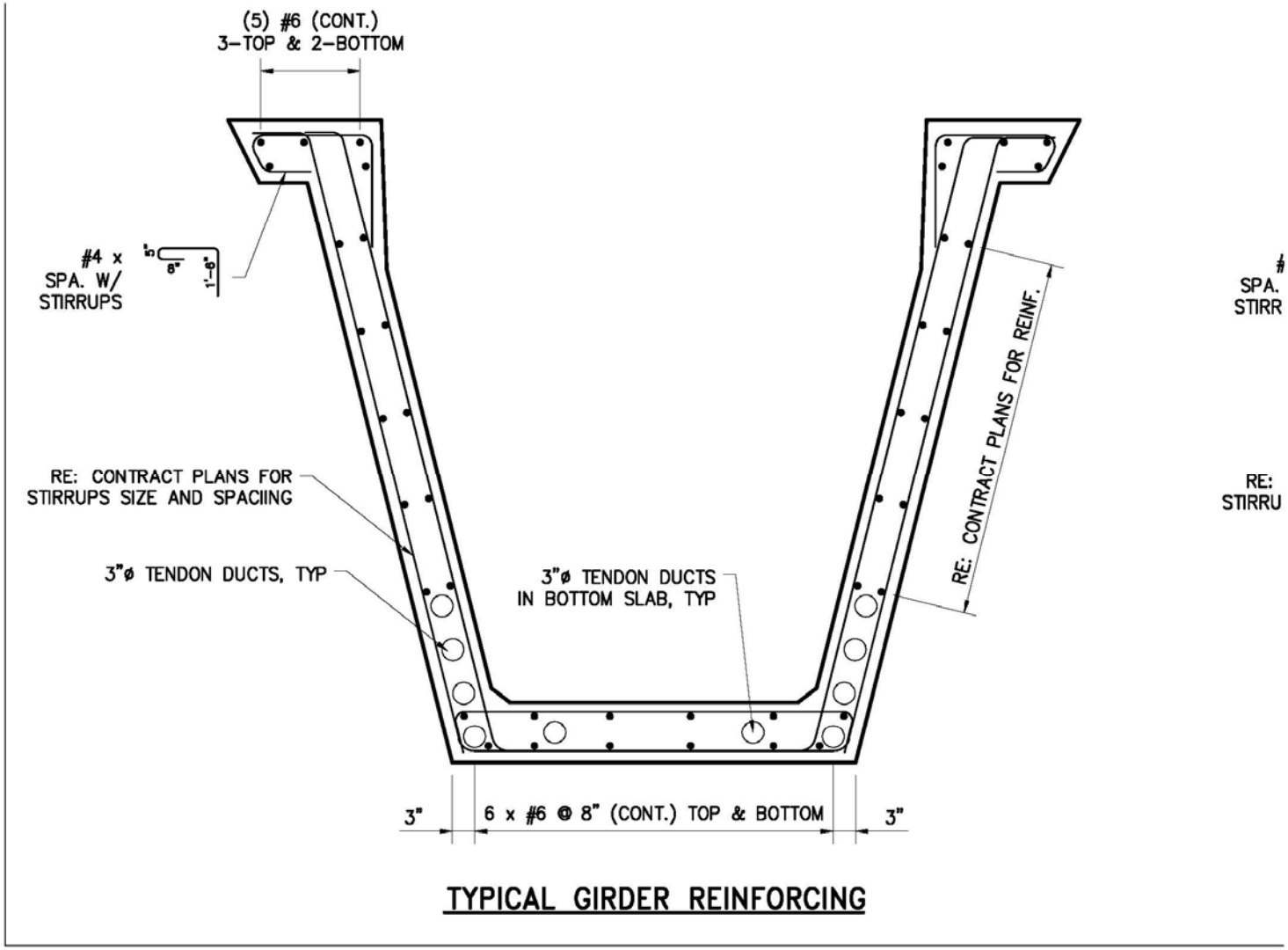
Design Features

- Curved, Precast Girders, CDOT U84
- 26’-4” Girder Spacing
- Large overhangs and long span deck panels
- Composite Girder / Lid Slab construction
- Secondary concrete pours for lid slabs, diaphragms and bottom slab haunches.
- Integral abutments and piers
- Single expansion joint and bearing location at Pier 7.
- Access provided for inspection inside of box girders.

Typical Girder Cross Section – Ramp K

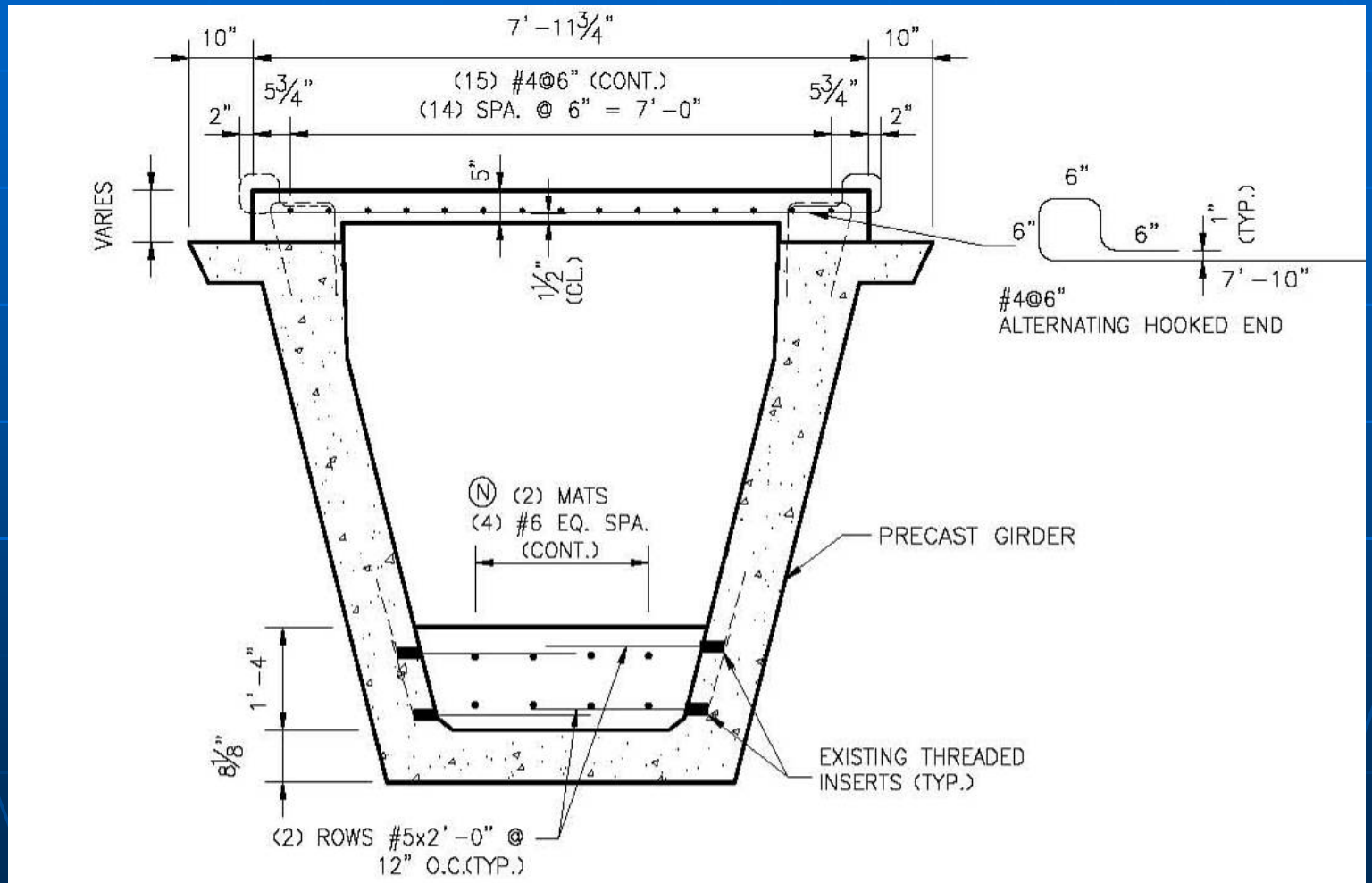


Typical Girder Cross Section – Ramp K



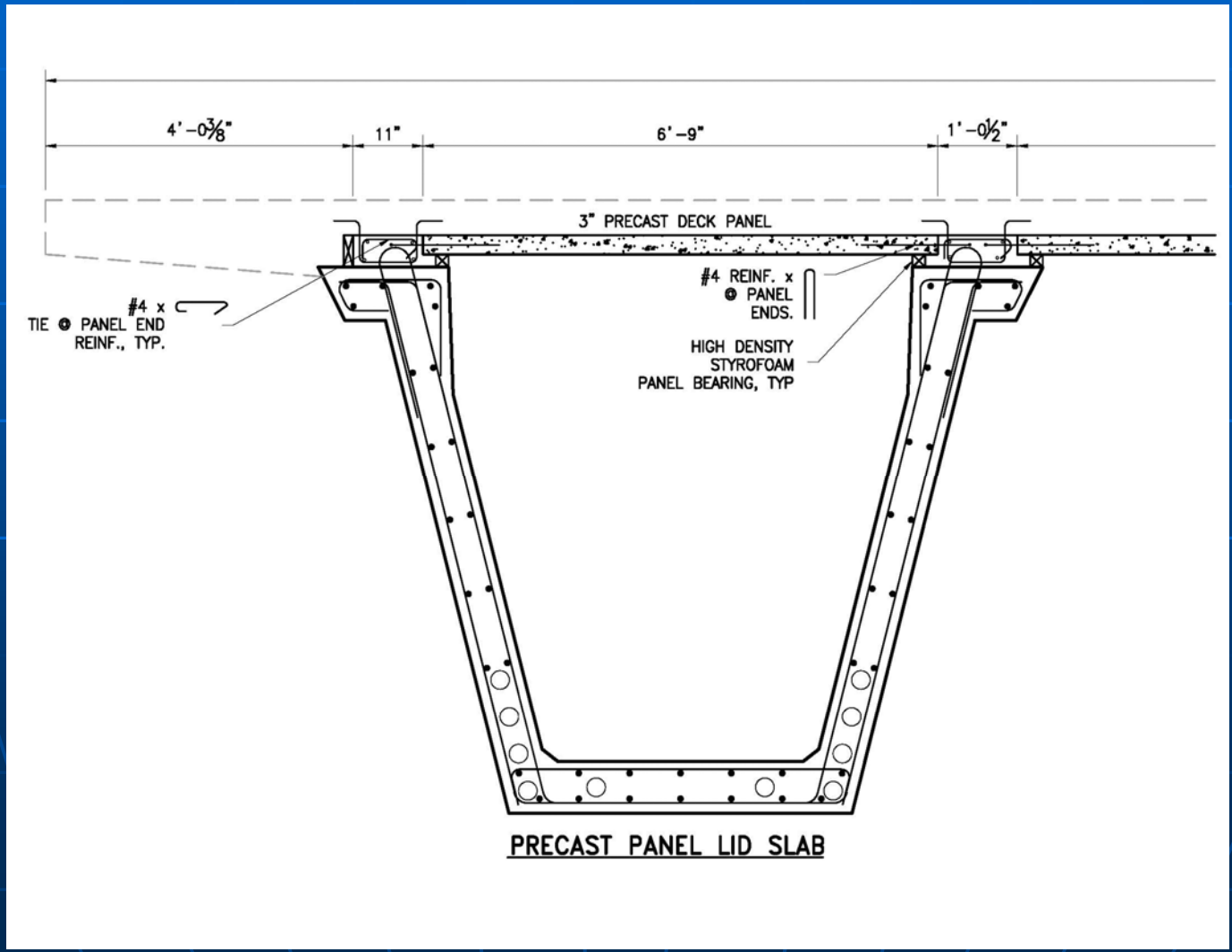
TYPICAL GIRDER REINFORCING

Ramp K CIP Lid Slab



TYPICAL LID SLAB AND 1'-4" C.I.P.
BOTTOM HAUNCH SECTION

Ramps A & Y
Precast Panel Lid Slab



Pre-Casting of Girders

- Up to 120’ long, 265 Kip max weight
- Curved Forms
- Post Tensioned
- Precast Anchor Blocks
- Block Outs for CIP Anchor Blocks
- Secondary Casting of Diaphragms, Bottom Slab Thickening and Lid Slab
- “Tongue” at Expansion Diaphragms

Curved Girder Formwork

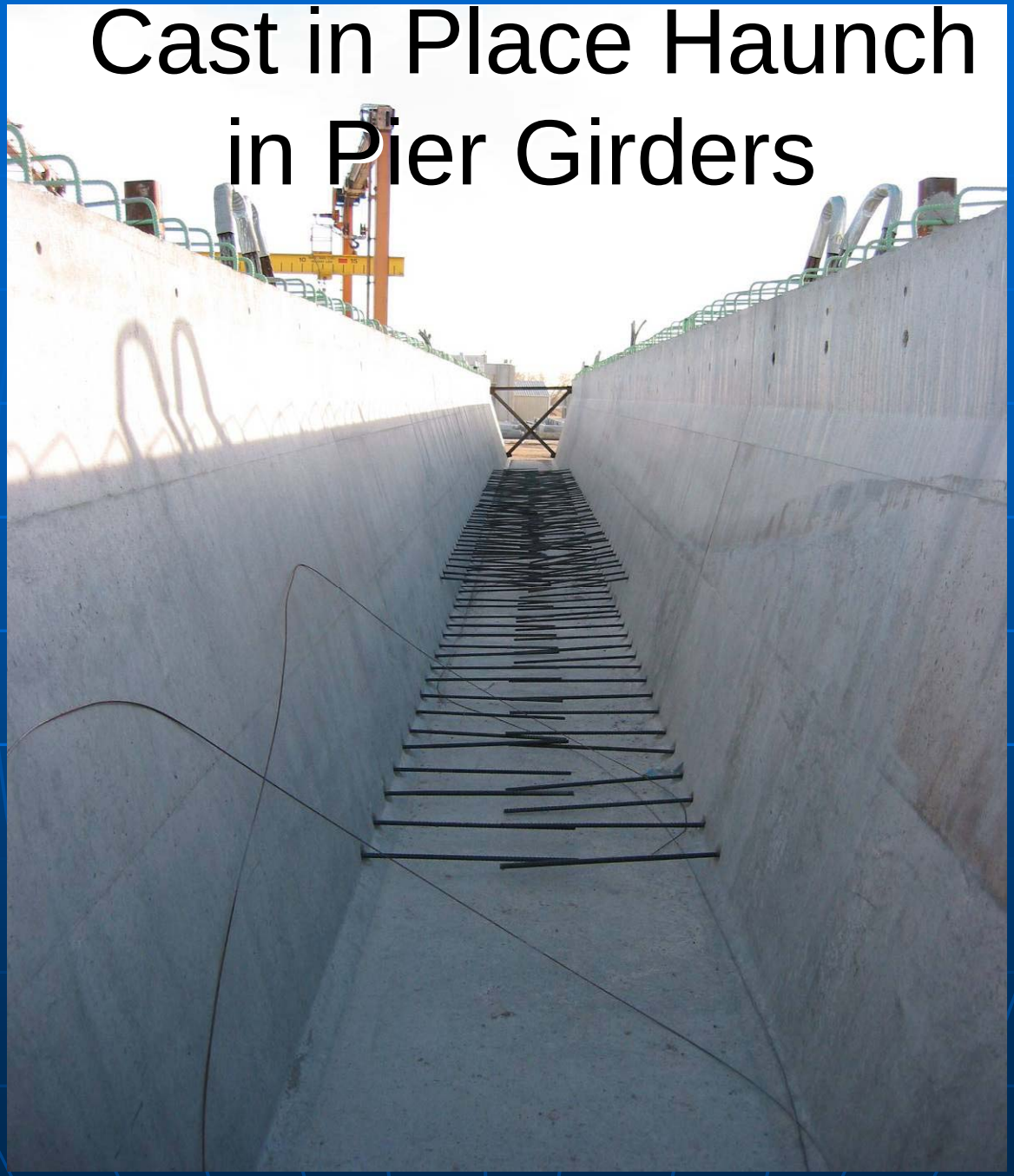
Precaster: Encon Bridge

Reinforcing Cage in Forms Prior to Casting

Typical Girder Cross Section

Girders in Storage Area

Cast in Place Haunch in Pier Girders



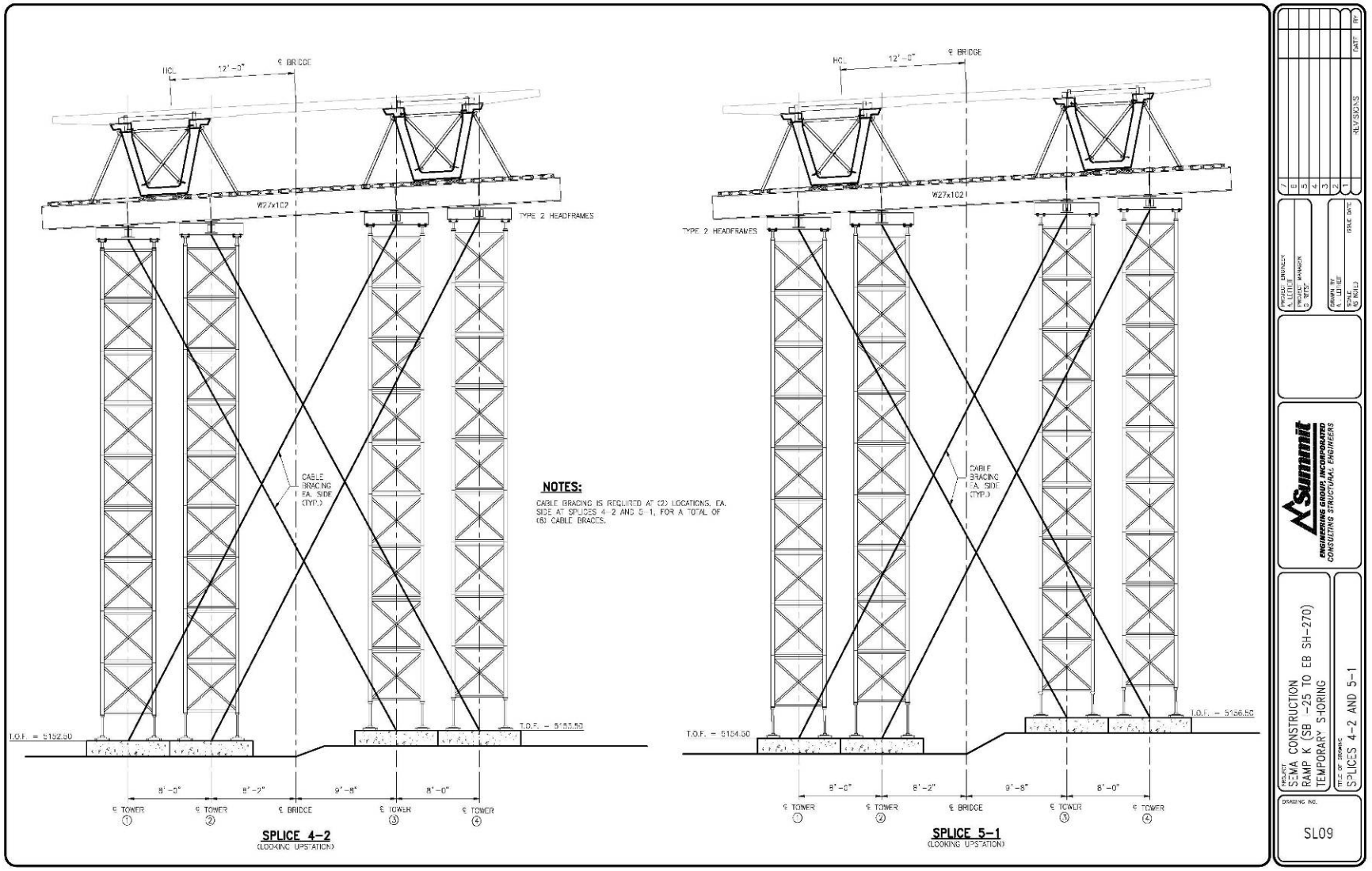
Erection Conditions

- Girders supported on Falsework towers and Straddle Bents
- Torsional Bracing at ends of girders for stability.
- CIP lid slabs to control torsional deflections and stresses.
- Cantilevered construction w/ temporary post tensioning
- Final 4 girders hung over 270 and IH25 prior to making closure
- Heavy lifts with limited crane radii
- Complicated site conditions.
- Multiple traffic closures
- Staged Post Tensioning.
- Long tendons installed at site.

Girders Supported on Falsework

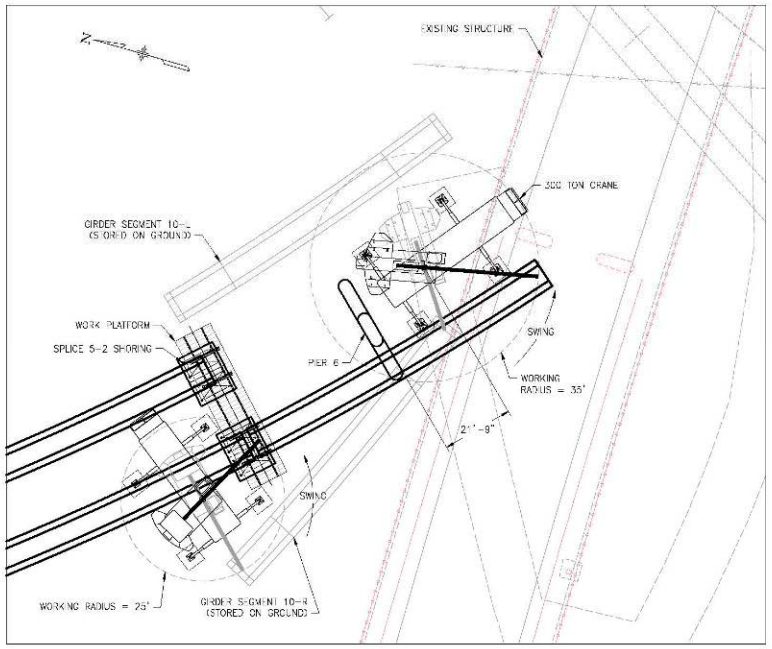
- Conventional 160 K Shoring Towers for typical applications.
- Special Bents at Traffic openings.
- Concrete footings
- Torsional Bracing During Erection.
- Girders not self supporting until post tensioned.

Falsework Design at Pier 5

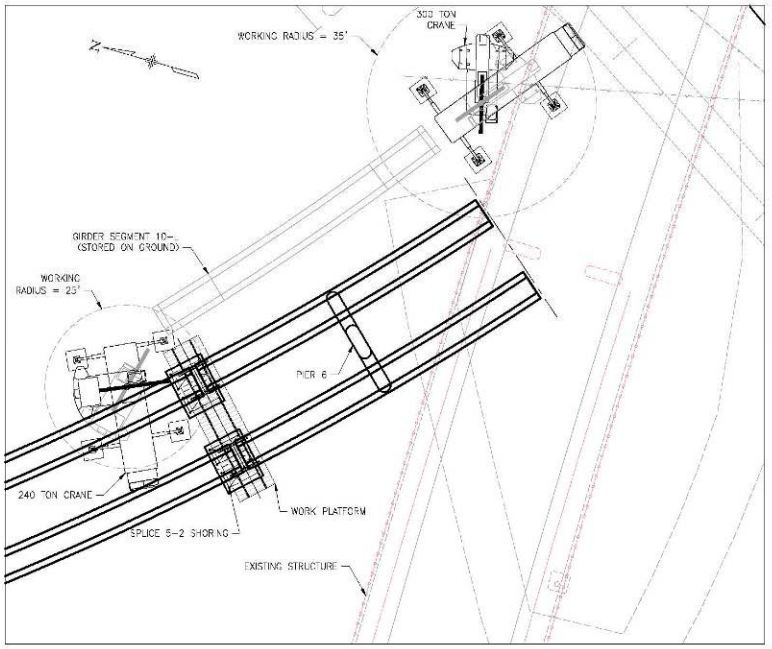


Erection procedures developed in conformance to new CDOT Specification Section 618

Erection Plan – Girders 10 L&R



GIRDER 10–R STAGING (SET 1ST)



GIRDER 10–L STAGING (SET 2ND)

ERECTION SEQUENCE GIRDER 10–L

1. STAGE CRANES IN POSITION TO RECEIVE AND SET GIRDER SEGMENT 10–L AS SHOWN AND NOTED.
2. LIFT AND MOVE GIRDER 10–L TO SETTING POSITION.
3. GRADE GIRDER ENDS TO PROPER ELEVATIONS AND SET GIRDER ON SHORING.
4. RE–LIFT GIRDER TO A LOAD OF 60,000 lb. PER CRANE.
5. WELD DIAGONAL END BRACES TO GIRDER AT BOTH ENDS AS SHOWN ON SHORING LAYOUT SHEET SL06.
6. RELEASE GIRDER FROM THE CRANES.
7. WELD LONGITUDINAL ANGLE BRACES BETWEEN GIRDERS 9–L & 10–L AT SPLICE 5–1 AS SHOWN ON SHORING LAYOUT SHEET SL04.

ERECTION SEQUENCE GIRDER 10–R

1. STAGE CRANES IN POSITION TO RECEIVE AND SET GIRDER SEGMENT 9–R AS SHOWN AND NOTED.
2. LIFT AND MOVE GIRDER 9–R TO SETTING POSITION.
3. GRADE GIRDER ENDS TO PROPER ELEVATIONS AND SET GIRDER ON SHORING.
4. RE–LIFT GIRDER TO A LOAD OF 60,000 lb. PER CRANE.
5. WELD DIAGONAL END BRACES TO GIRDER AT BOTH ENDS AS SHOWN ON SHORING LAYOUT SHEET SL06.
6. RELEASE GIRDER FROM THE CRANES.
7. WELD LONGITUDINAL ANGLE BRACES BETWEEN GIRDERS 8–R & 9–R AT SPLICE 5–1 AS SHOWN ON SHORING LAYOUT SHEET SL04.

GIRDER NUMBER	GIRDER MARK NUMBER	GIRDER LENGTH (ft)	TOTAL GIRDER WEIGHT (lbs)	MAX LIFT WEIGHT 240 TON CRANE ◇ (lbs)	Rmax 240 TON CRANE ▽ (ft)	EXmax 240 TON CRANE ☆ (ft)	MAX LIFT WEIGHT 300 TON CRANE ◇ (lbs)	Rmax 300 TON CRANE ▽ (ft)	EXmax 300 TON CRANE ☆ (ft)
10–L	10–L	99.82	305,000	172,000	25.0	90.0	172,000	35.0	87.0
10–R	10–R	102.6	314,000	176,000	25.0	90.0	176,000	35.0	87.0

◇ LIFT WEIGHT INCLUDES 4,000 lbs FOR BLOCKING AND RIGGING PER CRANE & 10% IMPACT ON GIRDER WEIGHT
▽ Rmax = THE MAXIMUM WORKING RADIUS AT MAX LIFT WEIGHT
☆ EXmax = THE MAXIMUM BOOM EXTENSION AT MAX LIFT WEIGHT

PRELIMINARY
NOT FOR CONSTRUCTION

NO.	REVISIONS	DATE
7		
6		
5		
4		
3		
2		
1		

PROJECT ENGINEER: G. REISS
PROJECT MANAGER: G. REISS
DRAWN BY: M. KEITH
CHECKED BY: M. KEITH
ISSUE DATE: AS NOTED

Summit
ENGINEERING GROUP, INCORPORATED
CONSULTING STRUCTURAL ENGINEERS

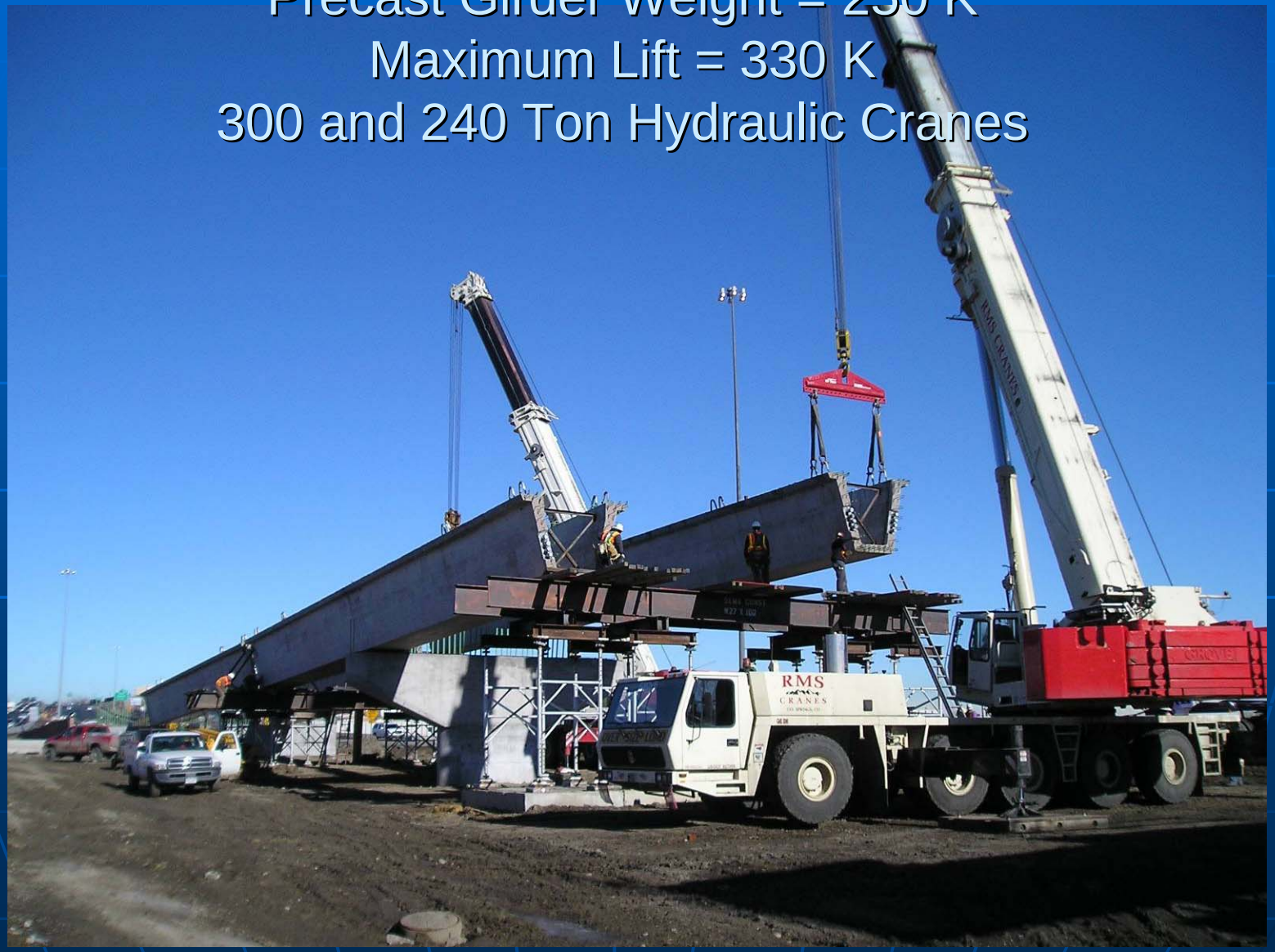
PROJECT: ROCKY MOUNTAIN STRUCTURES RAMP K (SB I–25 TO EB SH–270) ERECTION PLAN
SHEET TITLE: SEGMENTS 10L & 10R
DRAWING NO.: EP10

Girder Erection

Precast Girder Weight = 250 K

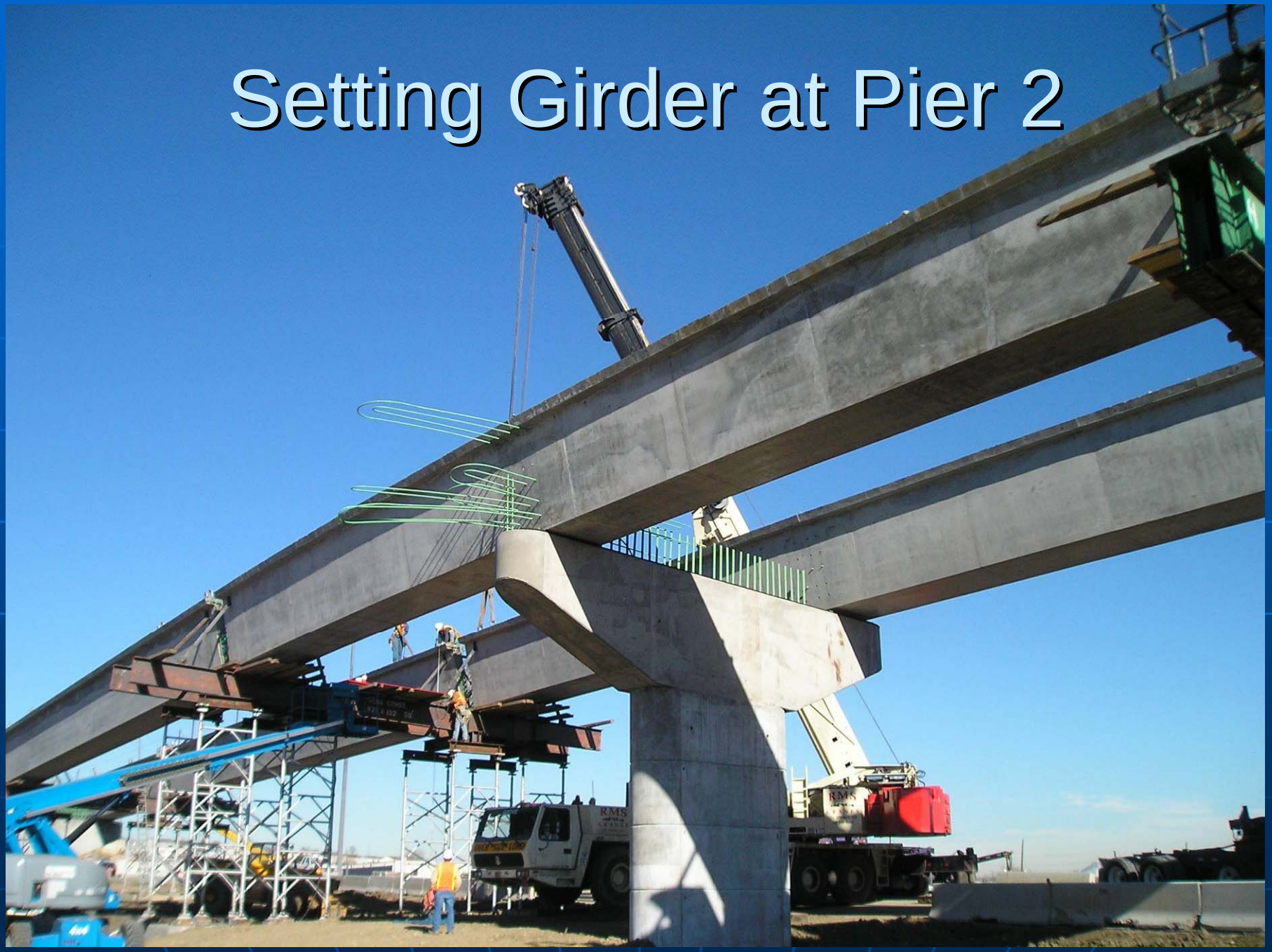
Maximum Lift = 330 K

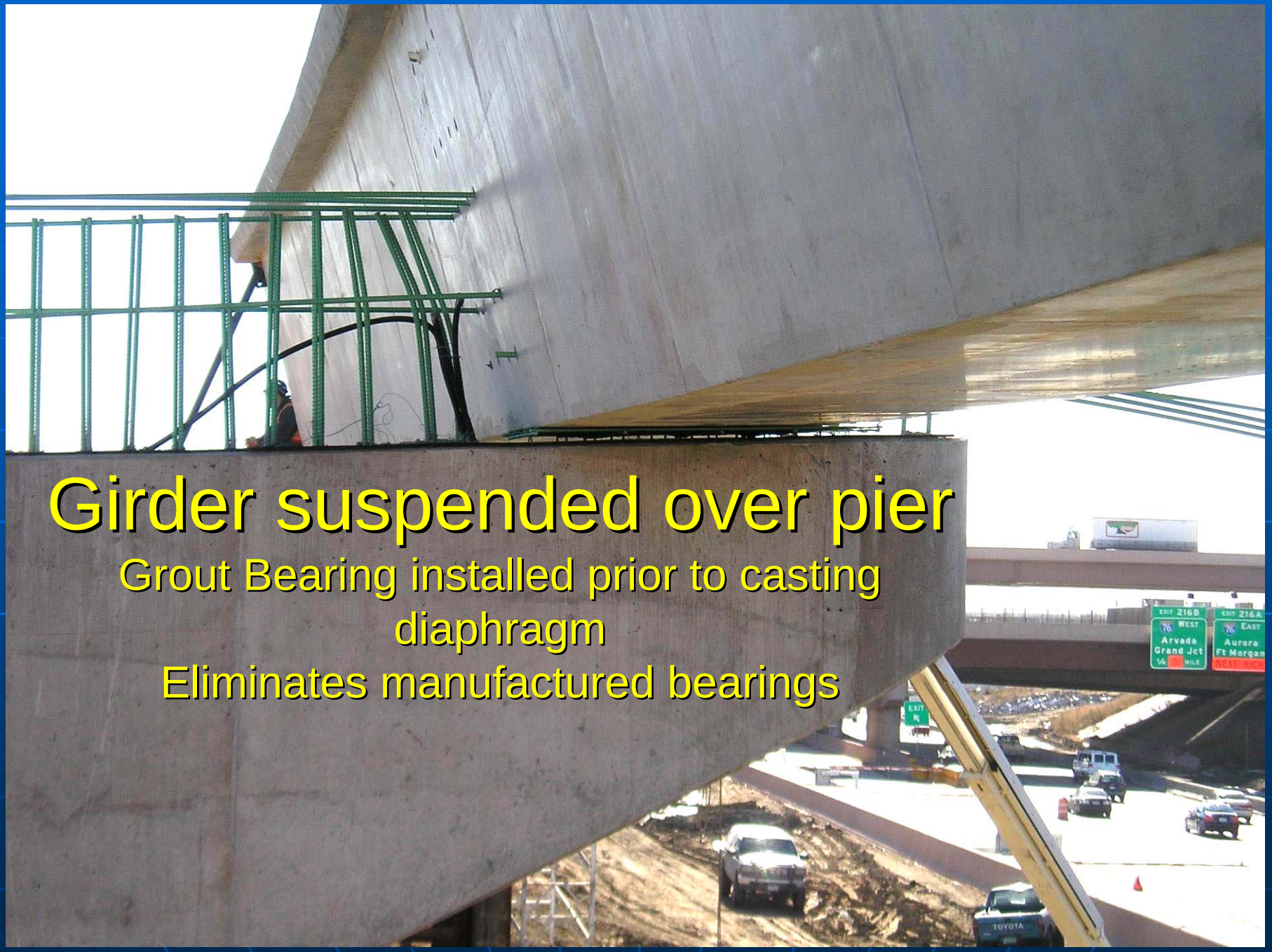
300 and 240 Ton Hydraulic Cranes



Initial Erection at Span 1

Setting Girder at Pier 2



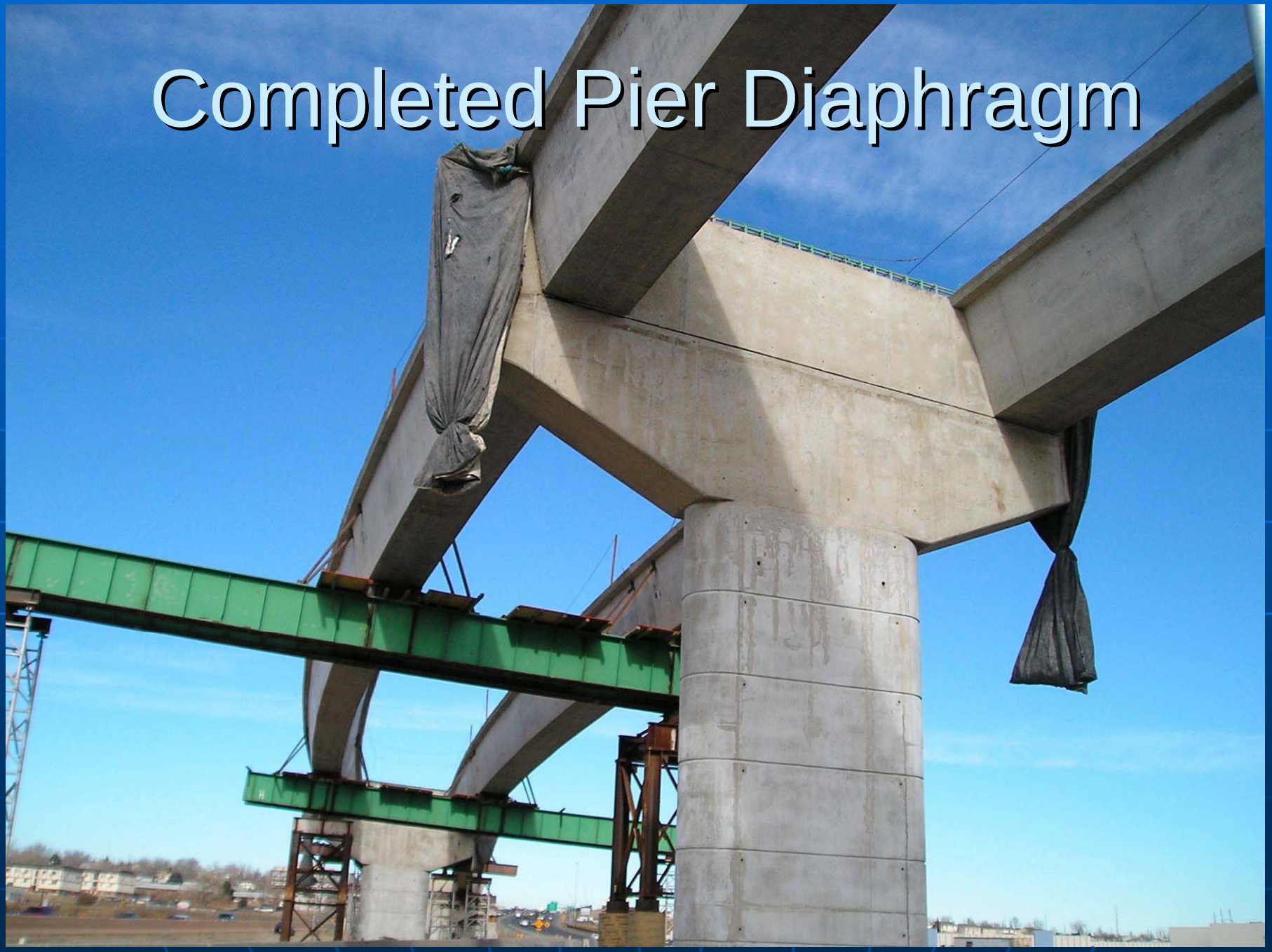


Girder suspended over pier

Grout Bearing installed prior to casting diaphragm

Eliminates manufactured bearings

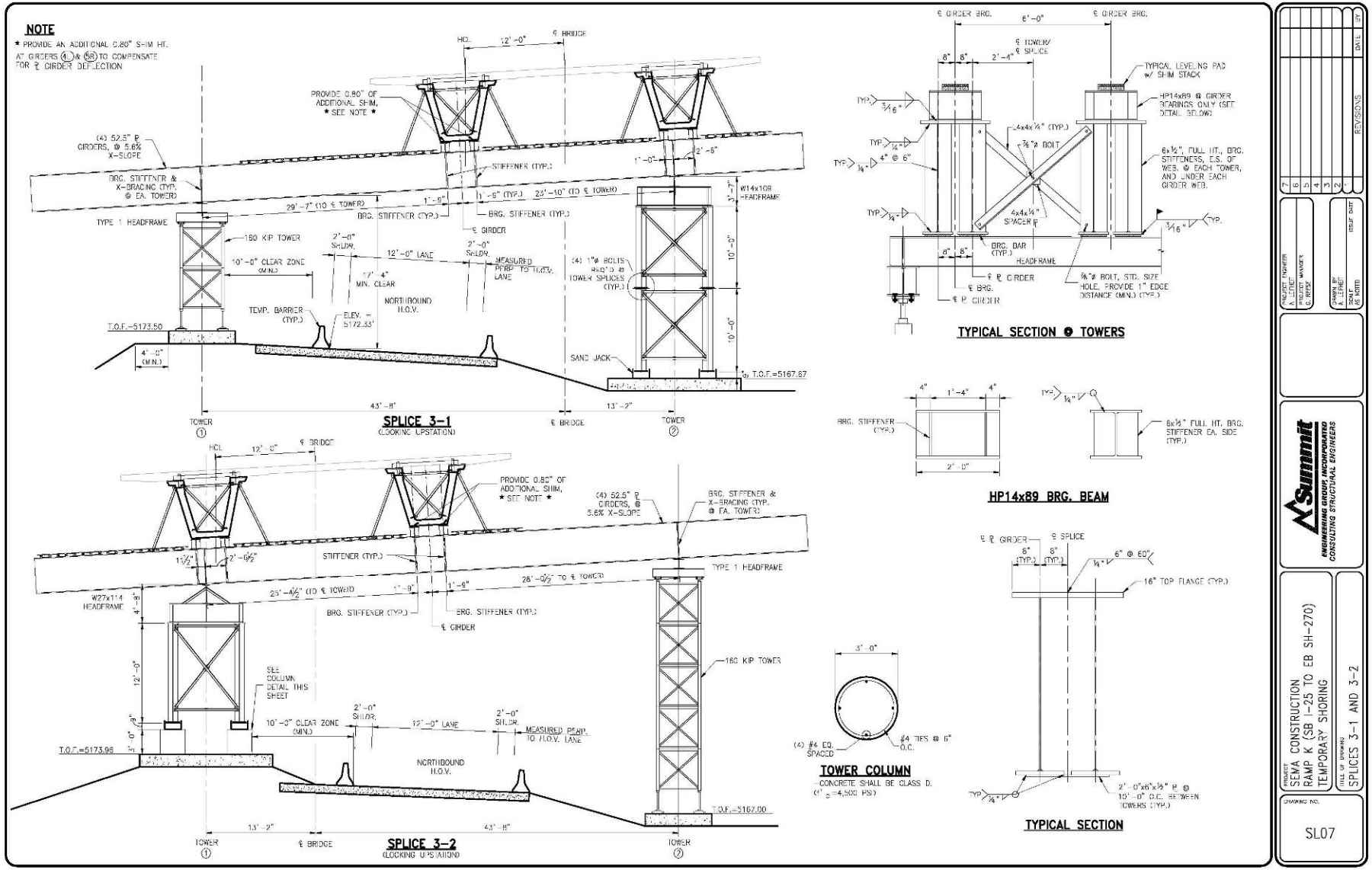
Completed Pier Diaphragm



Straddle Bents over HOV Lane

- Continuous traffic maintained during construction
- Erection over HOV during lane closures

Straddle Bent Design at HOV Lanes



Girder Erection over HOV Lane

HOV Open to Traffic

Erection to Pier 4

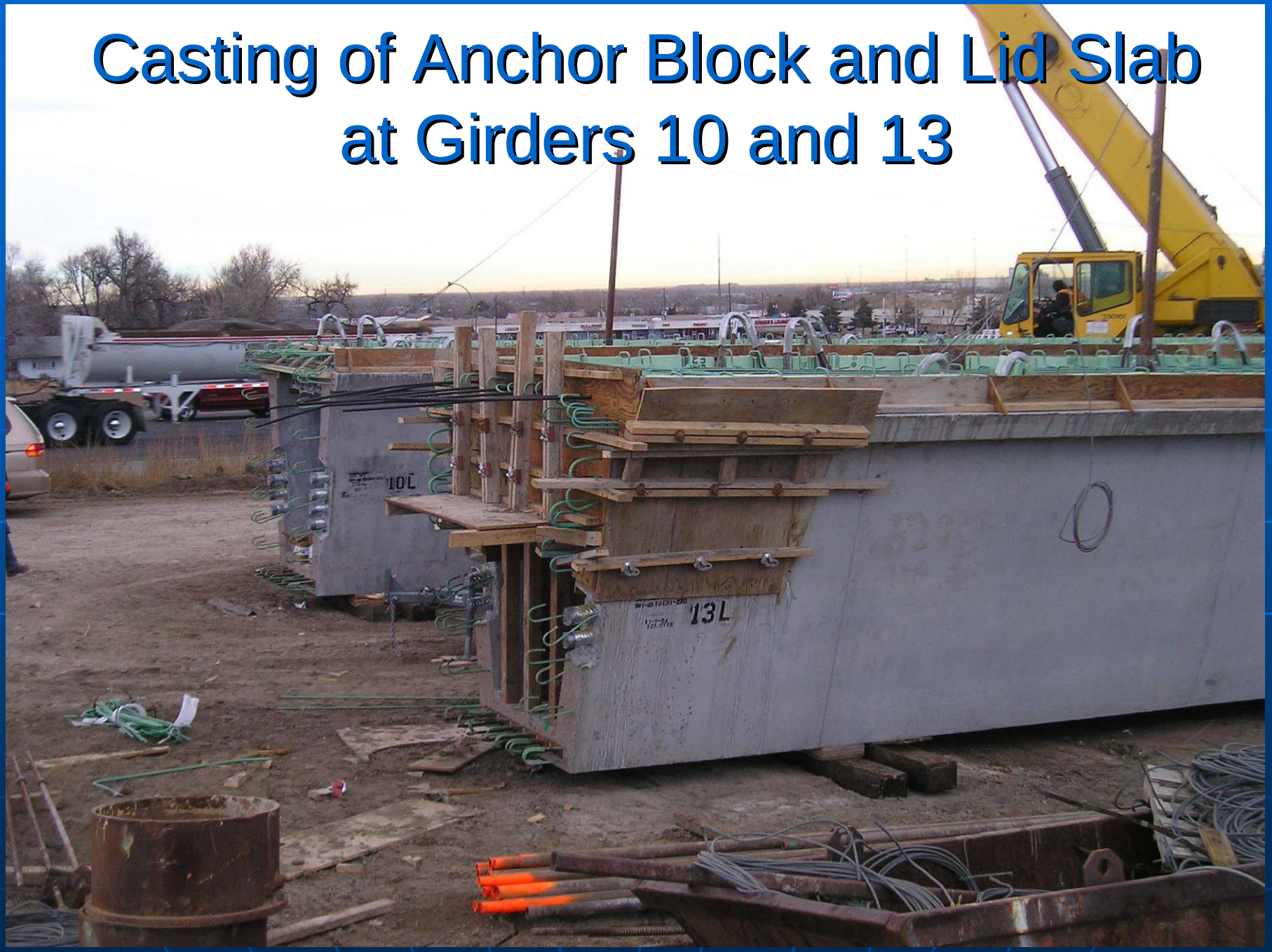
Falsework at Pier 5

- Extensive Site Preparation Required
- Varying Site Conditions

Erection through Span 5

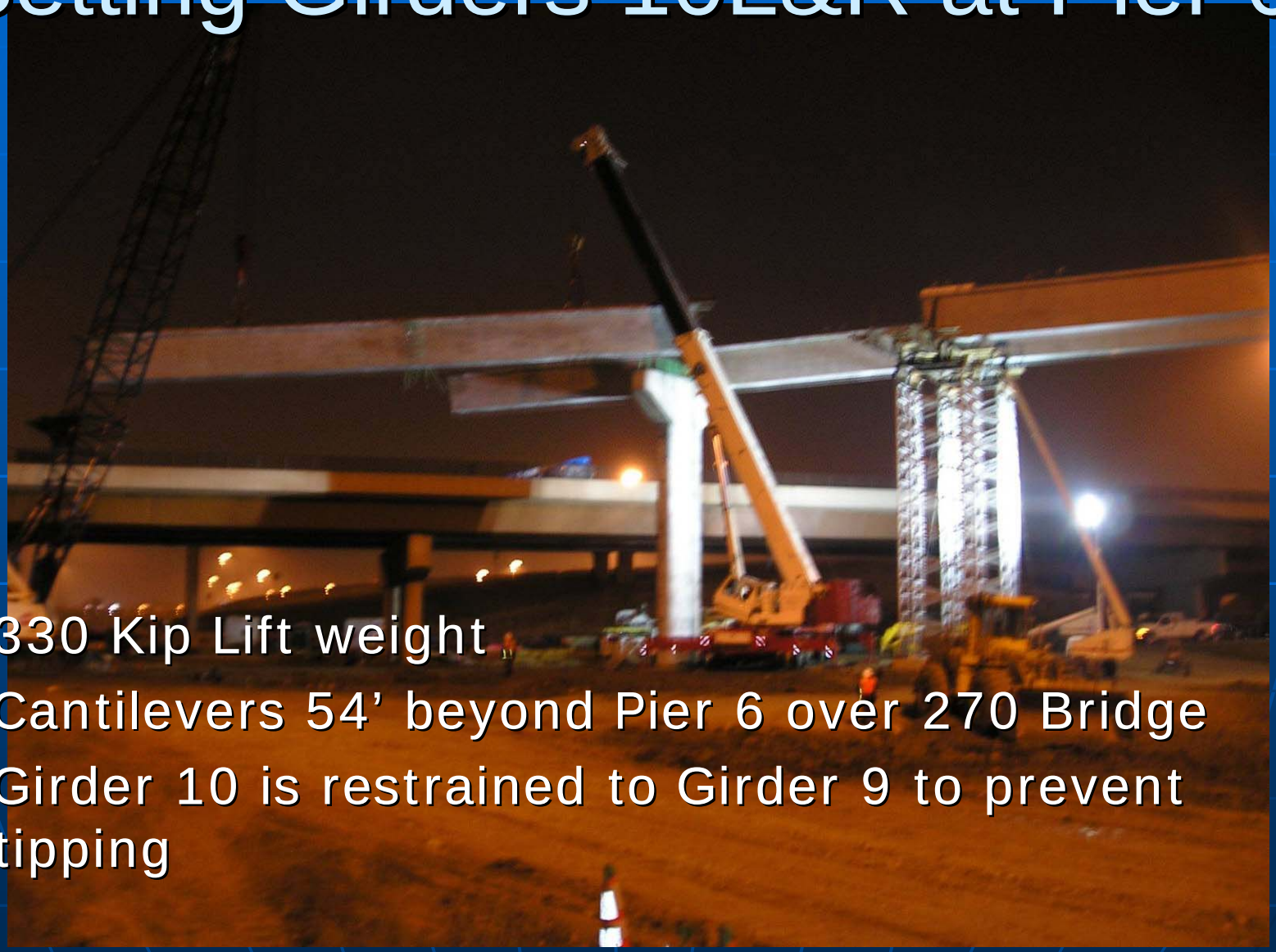
Erection Approaches 270 Bridge and IH25

Casting of Anchor Block and Lid Slab at Girders 10 and 13



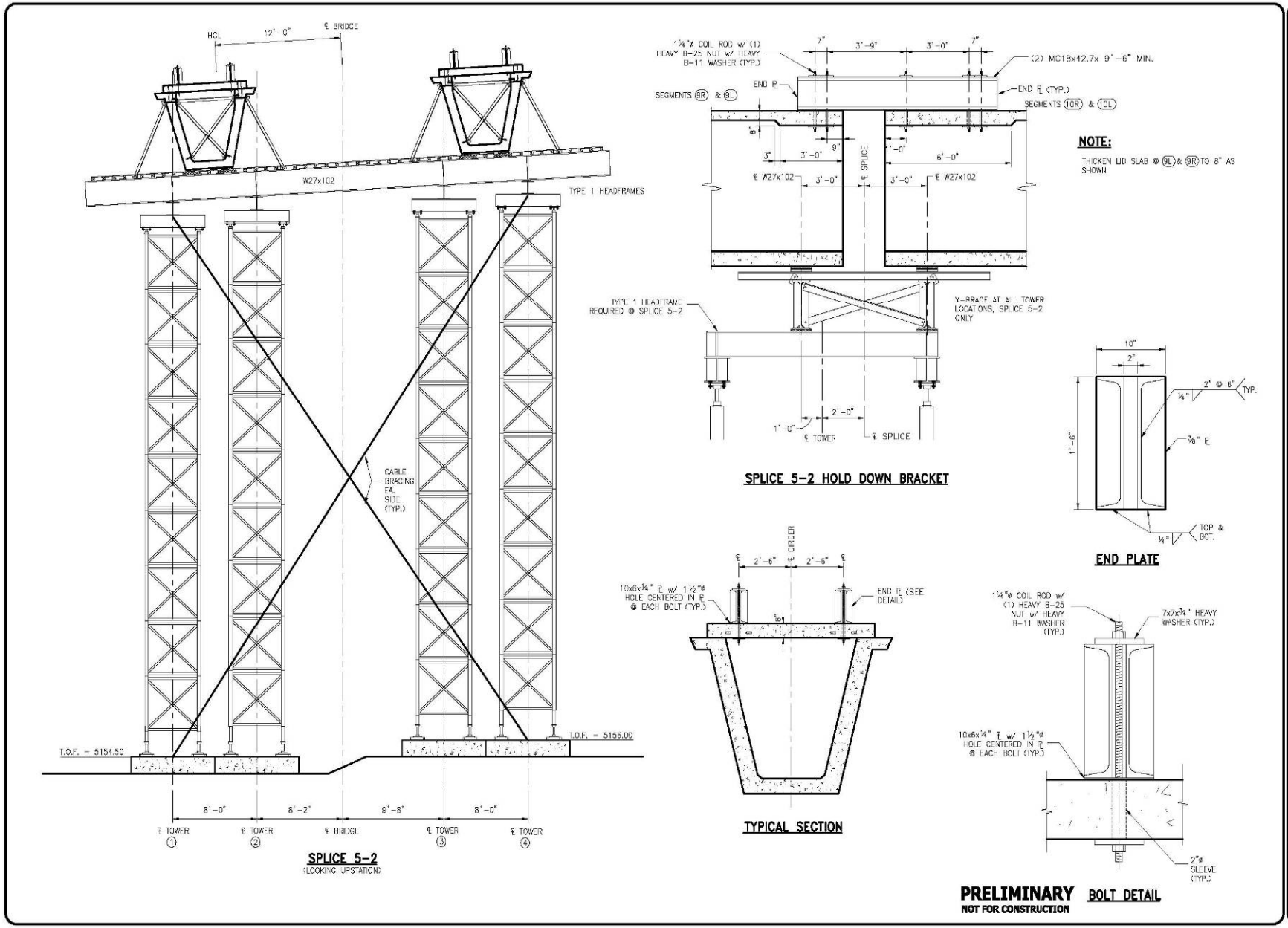
Anchor Block Reinforcing

Setting Girders 10L&R at Pier 6

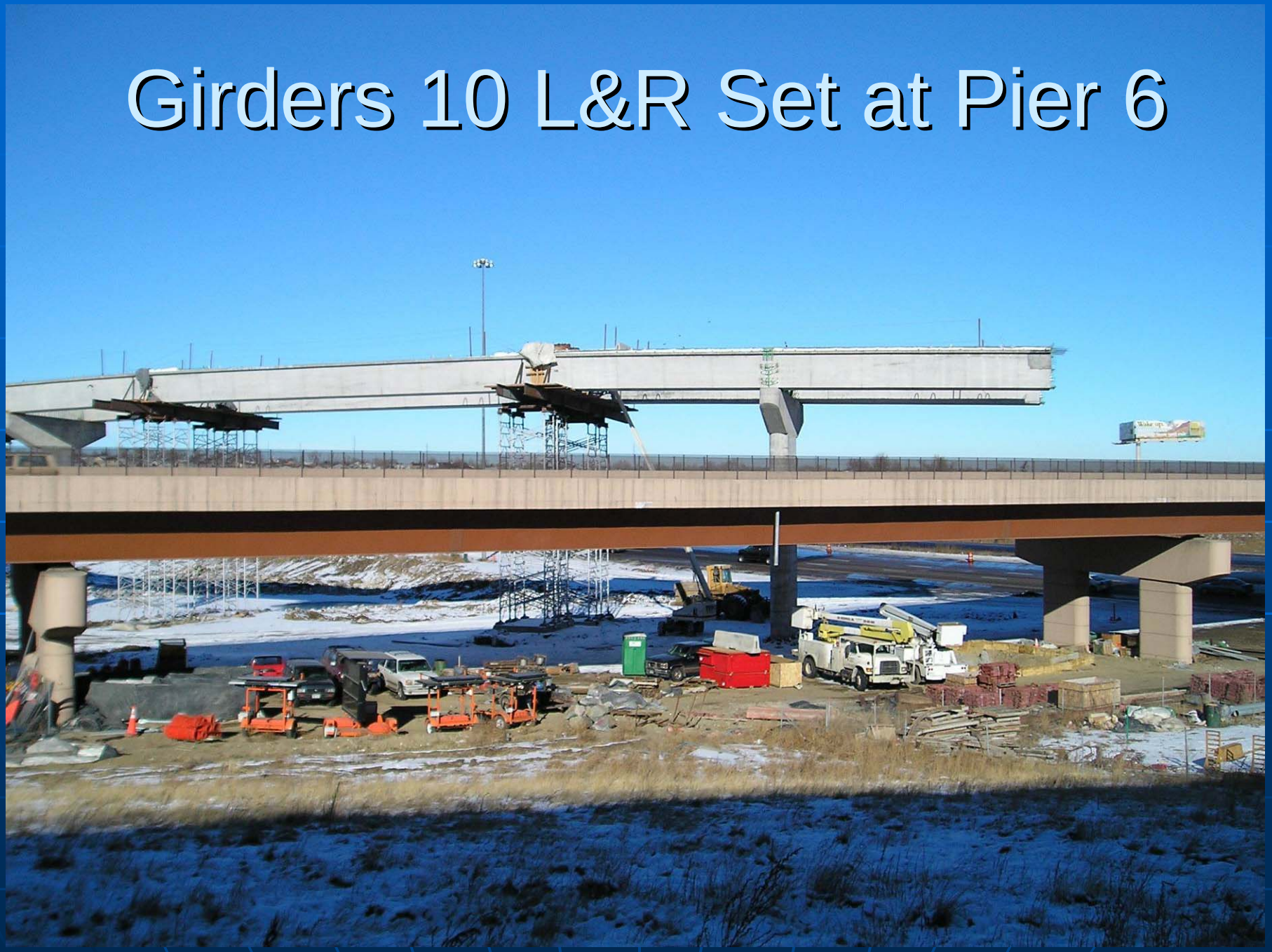


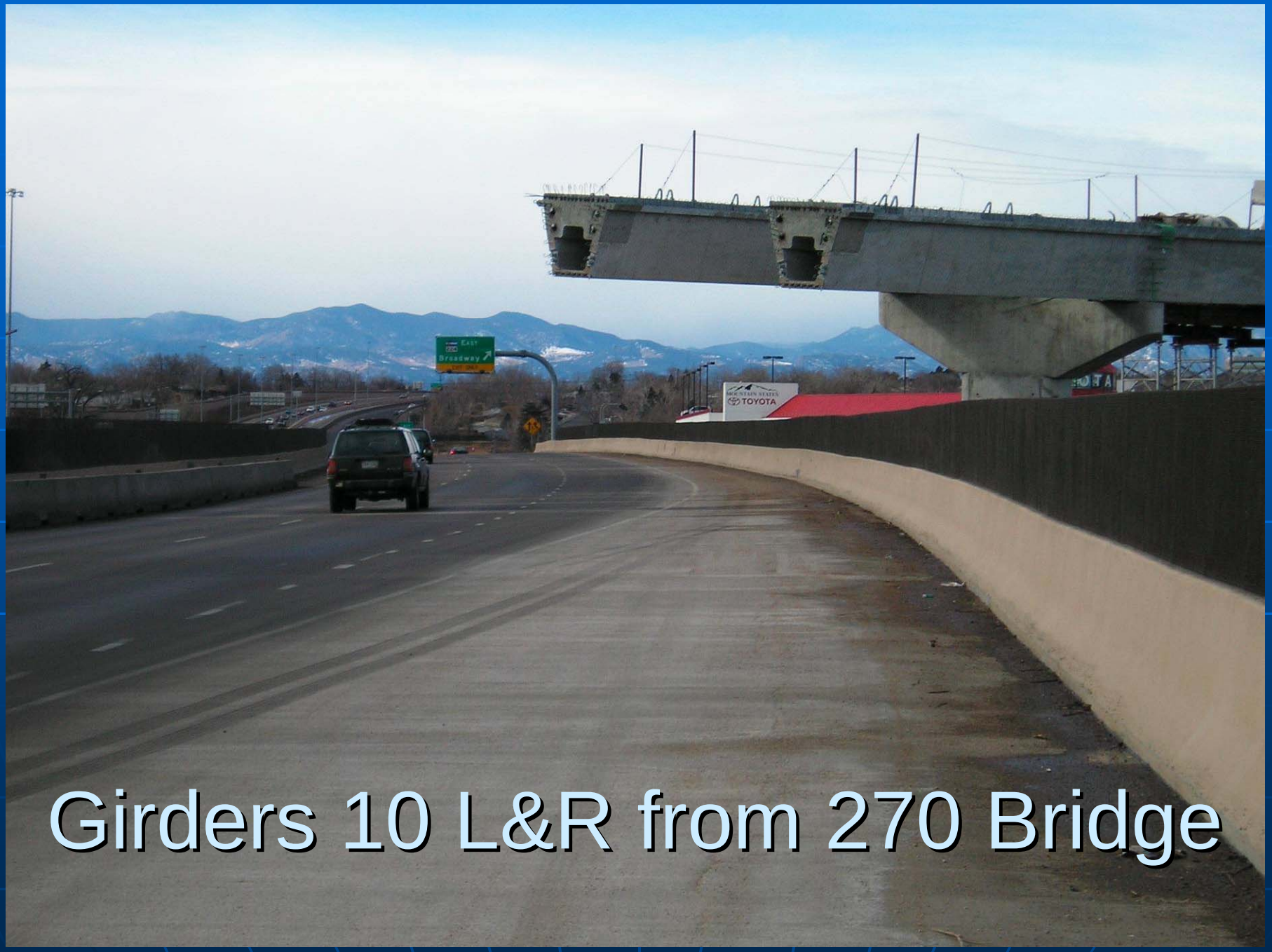
- 330 Kip Lift weight
- Cantilevers 54’ beyond Pier 6 over 270 Bridge
- Girder 10 is restrained to Girder 9 to prevent tipping

Girder 10 Tie Down

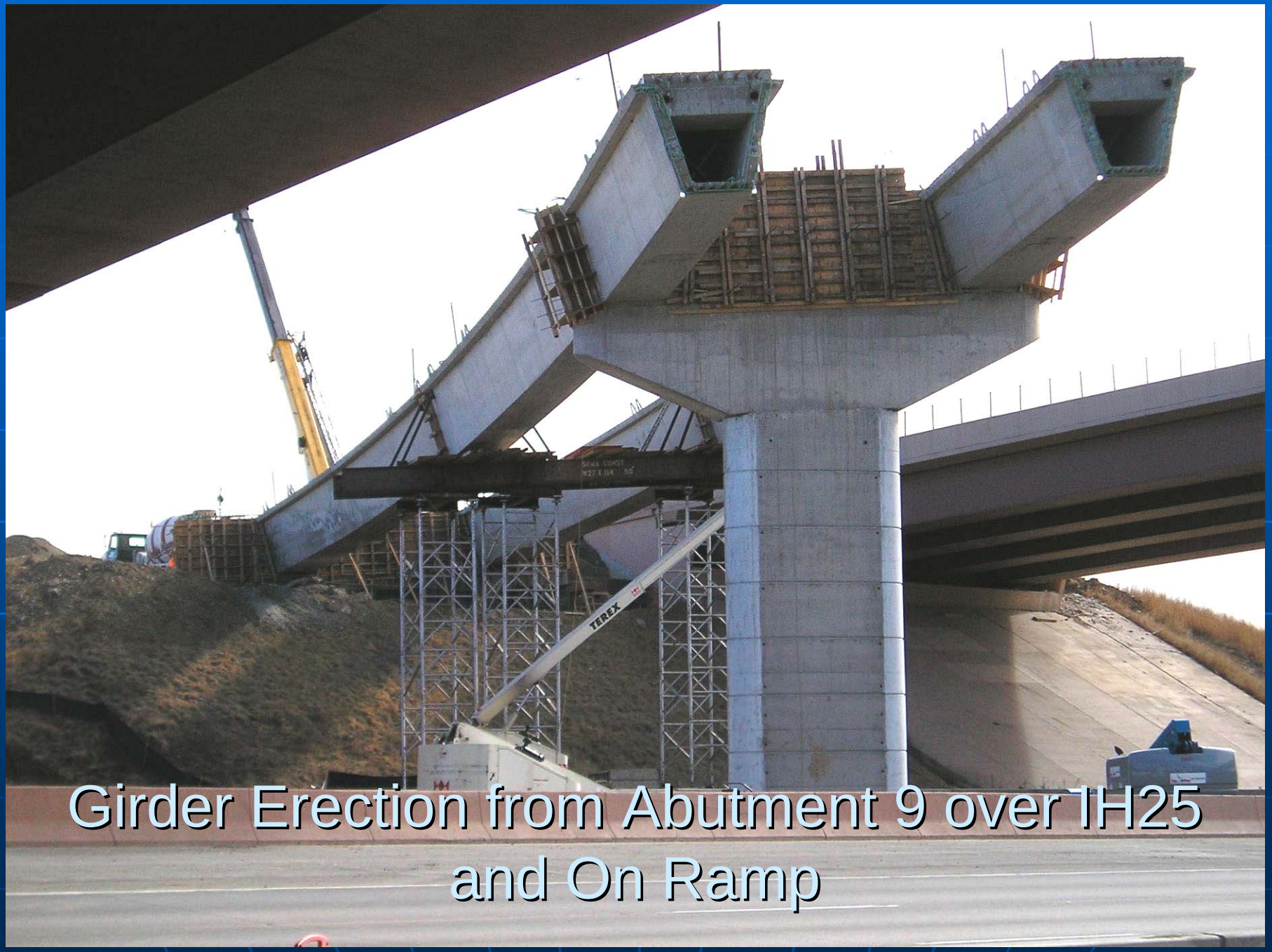


Girders 10 L&R Set at Pier 6



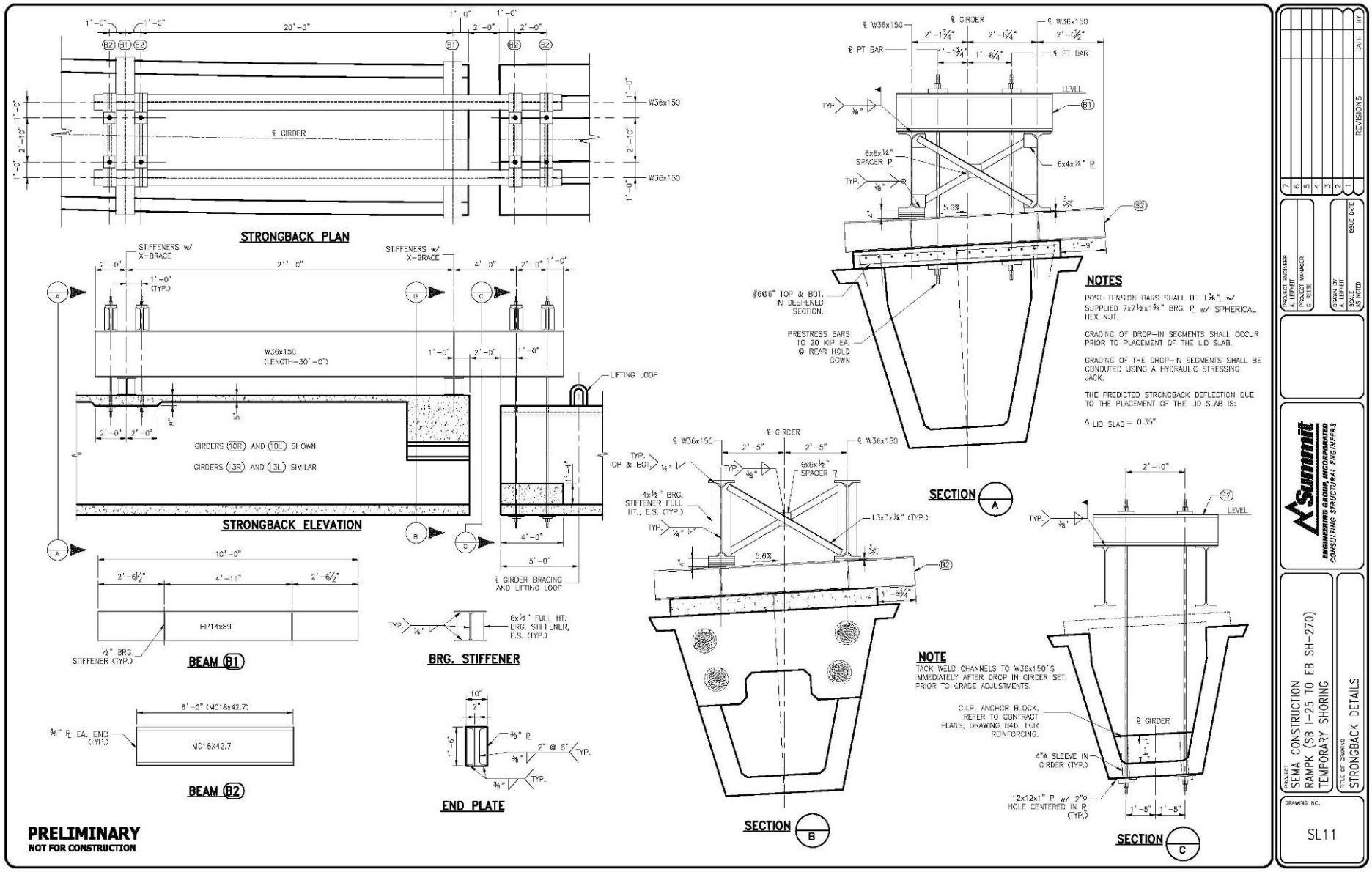


Girders 10 L&R from 270 Bridge



Girder Erection from Abutment 9 over IH25 and On Ramp

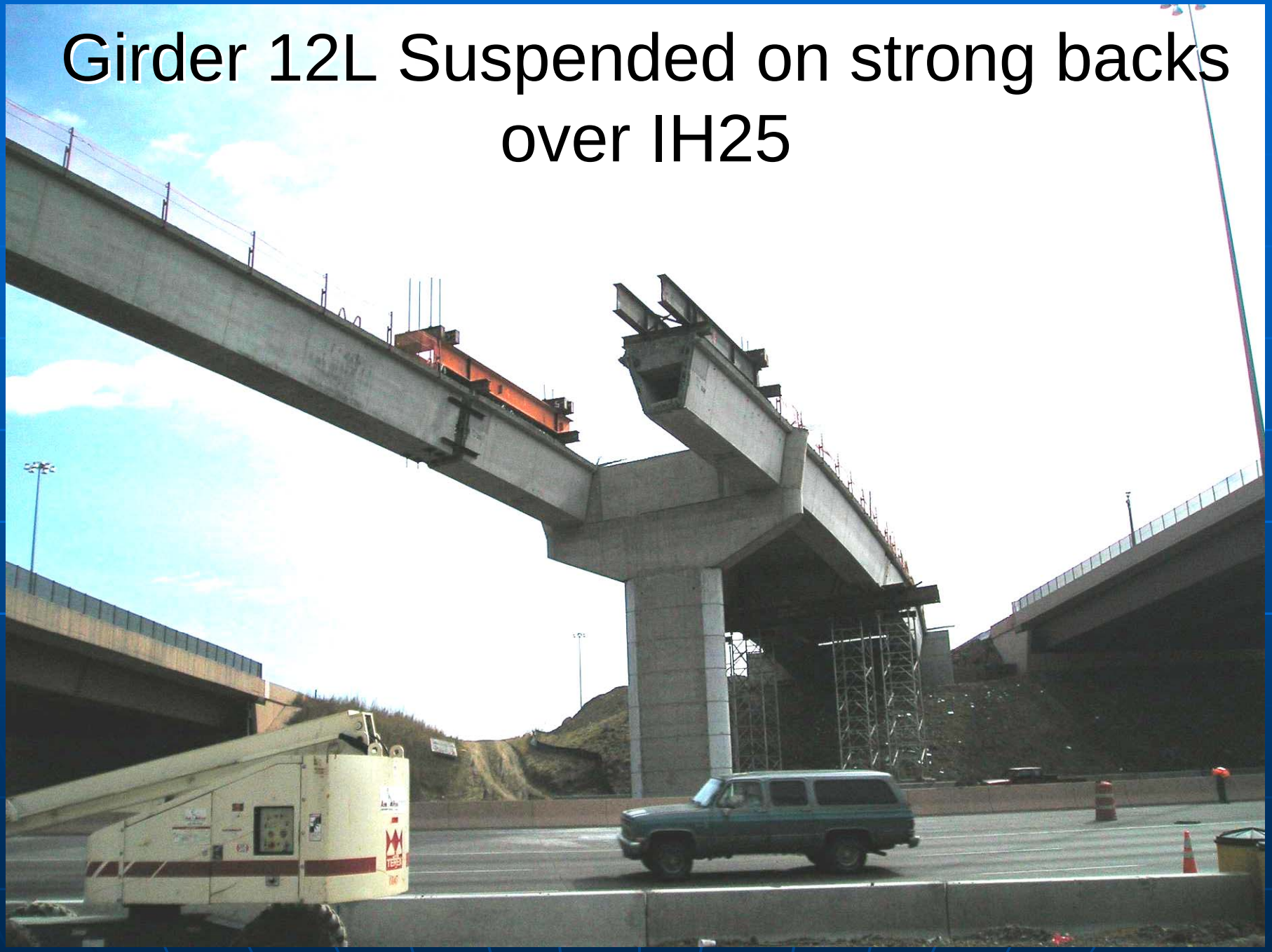
Girder Strong Back Design



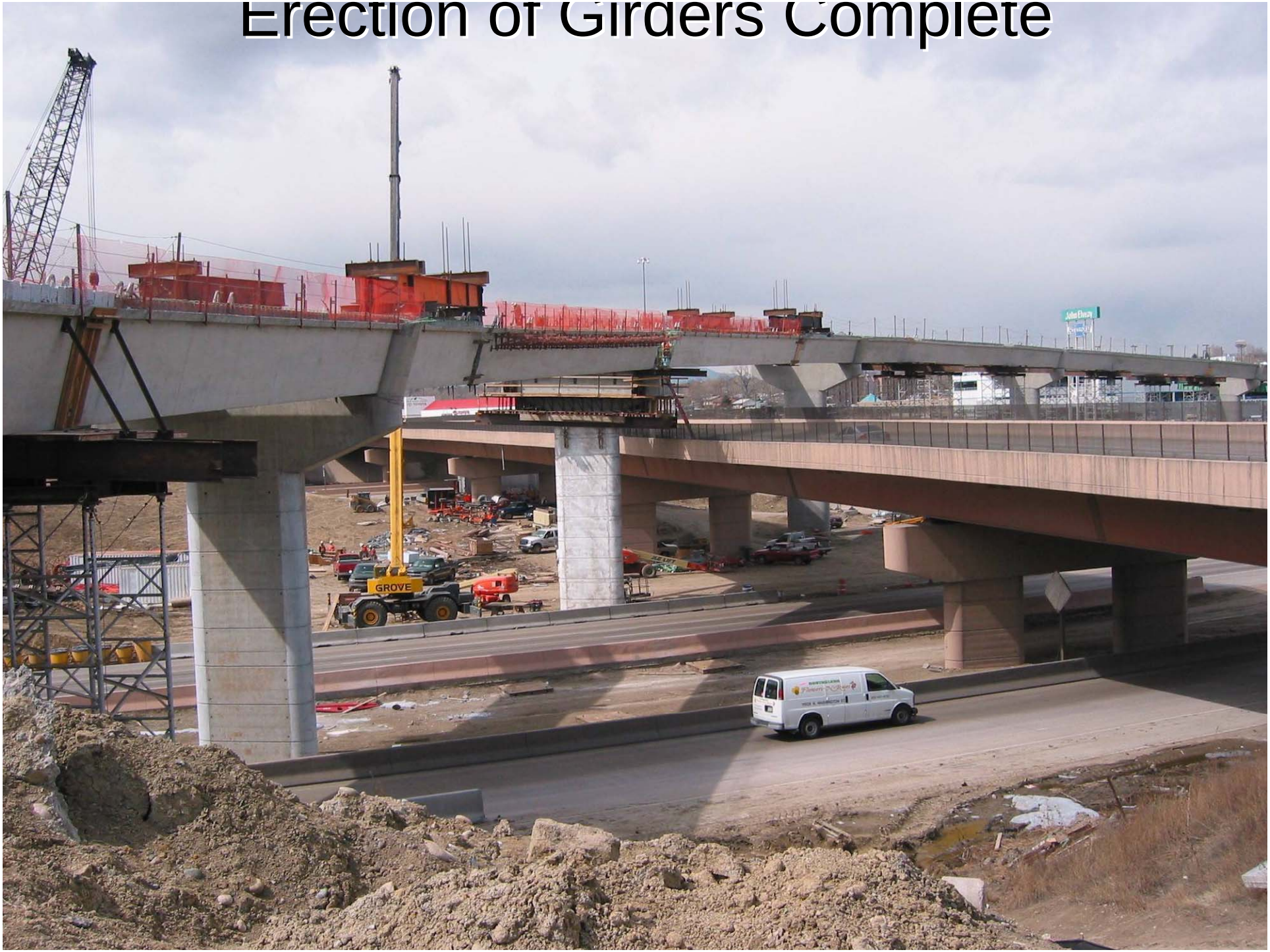
Girder Strong Backs In Place

Girders 11 L&R Set over 270 Bridge

Girder 12L Suspended on strong backs over IH25



Erection of Girders Complete



Ramp K, CIP Lid Slab Reinforcing

Erected Girders w/ Lid Slab

Bridge Ready for Final PT

Setting Precast Panels

Precast Panels on Girder Flanges

Panels installed, overhang forms set and deck cast

Completed Structure

Design Lessons Learned

- Torsional deflections and stresses during erection were critical.
- Haul weight and girder torsion limit the girder erection more than any other factor.
- Long continuity tendons were difficult to install
- Friction losses impacted the design.
- Limited eccentricity of web tendons.
- Local tendons were effective in long spans.
- Negative moments at interior piers were critical design condition.
- Strain compatability analysis necessary due to limited compression block.
- Compression steel in girders for negative moments was effective.
- Service stresses in deck steel is important.
- Shear design not critical.
- Lightweight Concrete can significantly impact

Construction Solutions

- Quality control is number one.
- Design of economical handling reinforcing and post tensioning in precast yard.
- Temporary structure design is critical to project success.
- Incorporate torsional bracing in falsework design.
- Establish continuity with closures and diaphragms first after erection.
- Create a closed box section early after erection.
- Quality Control is number one.
- Simplify precast forming as much as possible.
- Use CIP anchor zones.
- Precasters understand precast, post tensioners understand post tensioning.
- Make significant allowances for heavy cranes during erection to handle heavy loads.
- Quality control is number one.

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