Delta Girder Construction

- **PIER CAP CONCRETE**
  - Break pier cap into two separate pours to allow more control over PT bar alignment

- **POST TENSION BAR INSTALLATION**
  - Alignment critical

- **DELTA KNUCKLE ERECTION AND POST TENSIONING**
  - Alignment critical

- **DELTA GIRDER ERECTION**

- **DECK GIRDER ERECTION**
Pier Cap Concrete

- DELTA PIER CAPS
  - 12 Feet Thick
  - 16 Feet Tall
  - 87 – 113 Feet Long
  - 560 – 705 CY Concrete
Pier Cap Concrete

- PT bars cast 5 feet into pier cap
- No adjustment once cap is poured
- Elected to pour cap in two lifts to limit movement of formwork during pour
Pier Cap Concrete Placement in Two Lifts

PRIOR TO FIRST LIFT

PRIOR TO SECOND LIFT
Post Tension Bars

• Piers 8, 9, and 10
  o 1-3/4” diameter threaded bars
  o ASTM A772 Grade 150 ksi
  o 20 bars per delta frame
  o Design tension = 288 kips

• Piers 3-7 and 11-12
  o 2-1/2” diameter threaded bars
  o ASTM A772 Grade 150 ksi
  o 20-28 bars per delta frame
  o Design tension = 557 kips
Post Tension Bars

PT BAR ASSEMBLY

UPPER DETAIL

LOWER DETAIL
PT Bar Alignment Frames

• Preassemble all bars for each delta leg group
• Erect as a unit
PT Bar Alignment Plates

- Holes drilled in alignment plate to same dimensions and spacing as knuckle base plate
- Alignment plates installed on top and bottom of PT bars
Post Tension Bars

Upper Pier Cap Lift Rebar Installation
Post Tension Bars

Pier Cap Second Lift Concrete Placement
Post Tension Bars

Pedestal Placement

Trumbull-Great Lakes-Ruhlin
a joint venture

WSP
PARSONS BRINCKERHOFF
AECOM (URS)

George V. Voinovich Bridge
U.S. Department of Transportation
**Delta Knuckle**

- Lower bearing point of delta frame
- Post Tensioned and fixed to pier cap prior to erecting the rest of the delta members
- 32 feet long x 9 feet tall
- 2 inch thick x 42 in wide flanges
- 1 inch thick x 48 inch deep web
- 49,000 lbs
Knuckle Erection and Post Tensioning

Knuckle Erection

• Level and Align Knuckle
• Install Diaphragms
Knuckle Erection and Post Tensioning

Knuckle Grout
• Knuckle base plate 6’-0” x 7’-5”
• Grout pad thickness 3” average
• Grout pad approx. 12 cubic feet
• 5,000 psi min compressive strength
• BASF 928 Non-shrink grout
Knuckle Erection and Post Tensioning

What do these have in common?

Manitowoc 2250 Crawler Crane

Bolttech Mannings CST-1053
Hydraulic Tensioner
Knuckle Erection and Post Tensioning

Knuckle Post Tensioning

- Elected to use hydraulic center hole tensioners
- Standard post tensioning jacks too heavy and cumbersome to use in tight spaces between knuckle stiffeners
- Center hole tensioners can be linked together to simultaneously operate more than one tensioner at a time
- Compact and lightweight
- Short bar length and small elongations
Knuckle Erection and Post Tensioning

Tensioning Equipment

1-3/4” Tensioner - CST-052

- Max Load: 510,038 lbs
- Max Pressure: 21,750 psi
- Max Stroke: ½ Inch
- Weight: 65 lbs
Knuckle Erection and Post Tensioning

Tensioning Equipment

2-1/2” Tensioner – CST-1053

- Max Load: 819,758 lbs
- Max Pressure: 21,750 psi
- Max Stroke: ½ Inch
- Weight: 110 lbs
Knuckle Erection and Post Tensioning

**Tensioning Equipment**

**Pump – TP30K**

- Max Input Pressure: 136 psi
- Ratio: 220:1
- Max Output Pressure: 30,000 psi
Knuckle Erection and Post Tensioning

How the Tensioners Work
Knuckle Erection and Post Tensioning

TGR’s Approach – Utilize 4 Tensioners at a Time

DELTA KNUCKLE - PLAN OPTION 2 - MANIFOLD
Knuckle Erection and Post Tensioning

- Tensioning Bars – 980 Each
  - Tension 4 bars at a time – reduced tensioning time by 75% compared to tensioning 1 bar at a time
  - Jacking force – 17% - 30% higher than design load to account for creep, shrinkage, and steel relaxation
  - Specified jacking sequence working from center of knuckle outward
Knuckle Erection and Post Tensioning

- **Lift Off Test**
  - Perform lift off test at specified locations to design load to verify bars are properly tensioned

- **Grout**
  - Annulus between duct and bar was grouted for corrosion protection
Knuckle Erection and Post Tensioning

- Monitor jacking force by pump output pressure
  - Required pressure = Target Load \div \text{Ram Area}
- Tensioners were calibrated to verify accuracy
Knuckle Erection and Post Tensioning

- Grout annulus between duct and bar for corrosion protection
- Used BASF 1205 PT Grout
• Erect remainder of delta frame once knuckle is post tensioned
• Delta frame consists of:
  o Knuckle
  o 2 EA – Delta Legs Tension Tie
  o 45 total delta frames
Delta Frame Erection

- **Delta Legs**
  - 68 Feet Long
  - 2” thick x 42” wide flanges
  - 1” thick x 48” deep web
  - 56,000 lbs
- **Erect and release delta legs**
Delta Frame Erection

- Tension Tie
  - 107 Ft Long
  - 2” thick x 42” wide top flange
  - 2” thick x 24” deep legs
  - 68,000 lbs