National Concrete Bridge Council

The Design and Construction of the Ohio Turnpike Bridges over the Cuyahoga River Valley

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Introduction:

The Ohio Turnpike Commission, in conjunction with their Third Lane Widening program, is reconstructing the twin, high-level, bridges over the Cuyahoga River Valley. The new structures are each 2660 feet in length and will be approximately 175 feet above the valley. HNTB Corporation designed the replacement structures and Dick Corporation is the Construction Manager for the project.

As part of a Bridge Type Study, both steel and concrete alternatives were optimized for the most cost-effective span arrangements. Numerous site constraints in the environmentally sensitive area below the structures, including the Cuyahoga Valley National Recreation Area, the Cuyahoga River, the Cuyahoga Valley Scenic Railroad, the historic Ohio and Erie Canal and numerous wetlands, were considered in the span arrangements and optimization process.

Contract documents were prepared for both alternatives and competitively bid against one another to provide additional cost savings for the Ohio Turnpike Commission. The concrete alternative was the low bid alternative at $51.1 million. It consists of a 900ft segmentally constructed pre-cast, post-tensioned concrete girder unit flanked by two pre-cast, pre-stressed concrete girder units. The 900 foot spliced girder unit consists of 2-150-foot spans and 3-200 foot spans. Spans lengths for the pre-stressed girder unitrange from 115 feet to 142 feet.

Two lanes of traffic are to be maintained at all times to allow for minimal impacts to the traveling public, resulting in alternating construction phases. These phases include constructing a new EB bridge, then demolishing the existing EB structure, constructing a new WB bridge in place of the existing EB structure and then demolishing the existing WB structure. The existing 1955 vintage structures, which are 250 foot-long simple span warren deck trusses, will be demolished using explosive demolition techniques.

Project challenges included wetland mitigation, rare or endangered species habitats, Cuyahoga Valley National Recreation Area, Cuyahoga River, Cuyahoga Valley Scenic Railroad, neighboring residents and right of way issues. The $51 million project realized a savings of over $1.4 million due to the steel and concrete alternative bid process.

Bridge Type Study:

HNTB was charged with identifying the most economical bridge types for the replacement of Ohio Turnpike bridges crossing the Cuyahoga River Valley. Both concrete and steel bridge configurations were studied and carried into final design so that competing bids could be received to optimize cost savings for the Ohio Turnpike Commission.

Studies focused on the optimum bridge length, superstructure arrangement and substructure arrangement, and augmented previous work performed by Greiner Engineering, Inc. - Ohio (May, 1996).

Initially pier placement was affected by three site constraints, the Cuyahoga Valley Scenic (CVS) Railroad, Riverview Road, and the Cuyahoga River. The initial roadway investigations established Riverview Road to be a “minor arterial,” and based on the type of road, the clearance and roadway width was established. Our initial contacts with the Railroad determined that normal AREMA or ODOT clearances to the pier would suffice. The obvious choice at the river was to place the pier outside the main water opening of the Cuyahoga River. Since all three of these constraints were located in the same immediate vicinity, economical pier placement would only be affected for this small portion of the bridge as compared to the overall length of the 2,660 foot bridge. Consequently, pier placement and the most economical span was not influenced greatly by these constraints. The most economical span could be determined based on the relative costs of the superstructure and substructure. The minimum span required to clear the Railroad and Riverview Road was determined to be 172 feet.

After these initial studies were investigated, HNTB was asked to evaluate the effects of possible additional environmental constraints. The two additional items that affect pier placements and bridge spans are (1) the avoidance of the former Ohio and Erie Canal and the adjacent tow path right-of-way, and (2) the request not to place a pier on CVS Railroad right-of-way. All of these resources are on the National Register of Historic Places.

The canal and tow path could be avoided by re-spacing the piers, while keeping the relative overall scheme and economical span arrangement. The requirement of keeping the pier off the CVS Railroad right-of-way, however, presented major adjustments in span arrangements previously investigated by HNTB. A tax map confirmed the Railroad property boundary as the Cuyahoga River. The result of not placing a pier on the CVS Railroad property, is that a span of over 300 feet must be introduced at this location to span not only the Railroad, but also Riverview Road and the Cuyahoga River, instead of the two spans previously proposed. This can be accomplished with a steel alternate, with some additional cost, but is very difficult for a conventional concrete alternate, regardless of cost. Since the maximum practical length for a pre-stressed post-tensioned spliced concrete girder is approximately 250 feet, either haunched post-tensioned concrete girders or steel girders have to be used for a span over 300 feet. Both of these alternates are more costly than conventional pre-stressed concrete I-girders. The steel girder interspersed with the concrete girders presents some future maintenance problems, and was not recommended.

HNTB expanded upon and supplemented the original pier configurations presented in Greiner's report. Various hammerhead type piers were considered for both the concrete and steel alternatives and included hollow and solid box-type shafts, a solid H-shaped shaft and a solid two column bent-type shaft. The additional concrete cost for the solid box-type shaft and the solid two column bent-type shaft did not offset the additional forming costs associated with the other pier types. Therefore, independent hammerhead type piers with a hollow box-type shaft and a solid H-shaped shaft were studied in detail to more accurately determine the cost and desired alternate of the piers.

Since the piers vary in height to approximately 170 feet (with an average pier height of 115 feet) the cost of the piers greatly influences the most economical type of bridge. The piers were optimized by decreasing the pier cap thickness from 10 feet to 7 feet as the design span length was reduced. The pier shafts were tapered in the longitudinal direction on a 1 to 48 batter to provide greater stiffness for the longitudinal moments which typically controlled preliminary designs.

The pier foundations consist of spread footings founded on rock, as well as, footings founded on a group of steel H-piles driven to rock.

Aesthetics, constructability, economics, maintenance and inspection access influenced the recommendation of the pier type. It is generally considered that H-shaped shafts are more aesthetically pleasing than the hollow box-type shafts. Both pier types are equally constructable, although the hollow box-type shaft requires more forming than the H-shaped shaft. The additional forming cost should be negligible since the piers shafts would be detailed with typical panels. For example, the base panel, or first panel constructed, would be the only panel that would require the contractor to vary the forming. The remaining panels from the base panel to the top panel, or final panel constructed, would be identical. The H-shaped shaft provides for better maintenance and inspection access than the hollow box-type shaft. A maintenance and inspection access door and ladder rungs must be provided for the interior wall faces of the hollow box-type shaft. The average pier cost for the H-shaped pier was estimated at $400,000 versus $310,000 for the hollow box-type pier.

A hammerhead pier with a hollow box-type shaft was subsequently the recommended pier.

Optimum Cost Study:

Using the design results, superstructure cost per square foot was plotted for the corresponding span lengths. Structural steel, shear connectors, deck, and bearing costs were included in the superstructure cost. The cost curves generated indicate that a 9" deck slab supported by the constant depth seven (7) girder configuration is the most economical bridge superstructure. While the structural steel costs for the five (5) and six (6) girder configurations are lower, the larger girder spacing for these alternates increases the deck costs and results in a higher overall superstructure cost.

In order to determine the optimum span length for the 7-girder configuration, superstructure cost, substructure (piers and abutments) cost, and total cost per square foot were plotted for various span lengths. The summation of the ordinates of the superstructure and substructures cost form the total cost curve. The total cost curve generated indicates that the most economical spans are in the range of 120 to 180 feet. Furthermore, the curves show that as the span lengths increase, the superstructure costs increase while the substructure costs decrease. Based on the vertex of the optimization curve, the theoretical optimum span is 140 feet.

The Replacement of the Ohio Turnpike Bridges over the Cuyahoga River Valley

HNTB

October 2002

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Overview

- Bridge Type Study
  - Design Criteria
  - Site Constraints
  - Alternatives
- Concrete Alternative
  - Precast Spliced Girder Design

Bridge Type Study

- Expanded upon the original work performed by Greiner
- Used Greiner established alignments
- Studied most economical superstructure and substructure types

Bridge Type Study: Design Criteria

- **Loading:**
  - **HS25 with Alternate Miltitary**
  - **30 psf FWS**
  - **7 Michigan Truck Loadings**
- **Materials:**
  - **Concrete I-Girder - 7,500 psi**
  - **Welded Plate Girders - A588 50 ksi, unpainted**

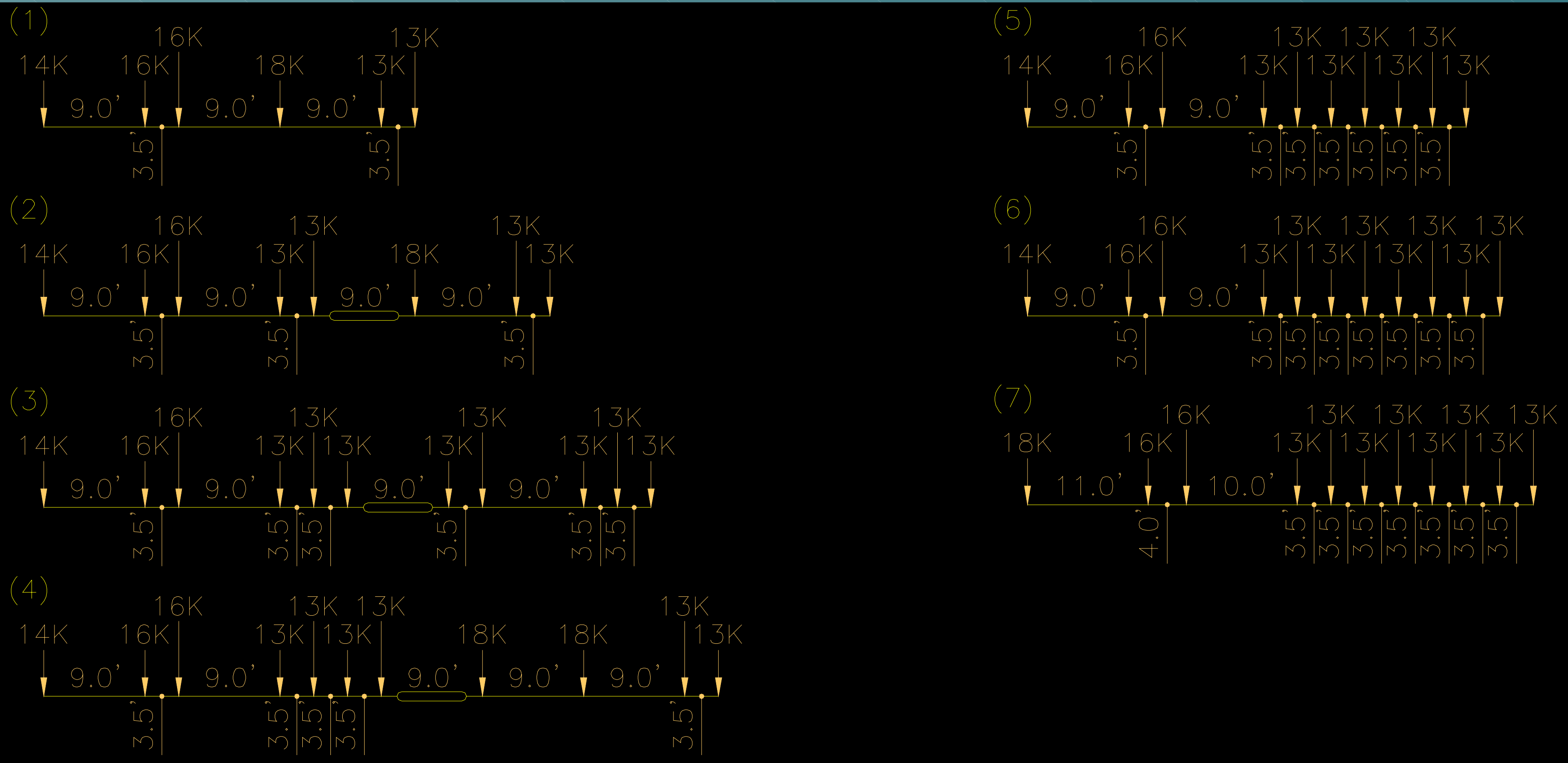
Bridge Type Study: Design Criteria

- Typical Section
  - 3 - 12’ lanes
  - 10’ outside & 14’-2” median shoulders
  - 60’-2” toe-to-toe of barrier

Bridge Type Study: Design Criteria

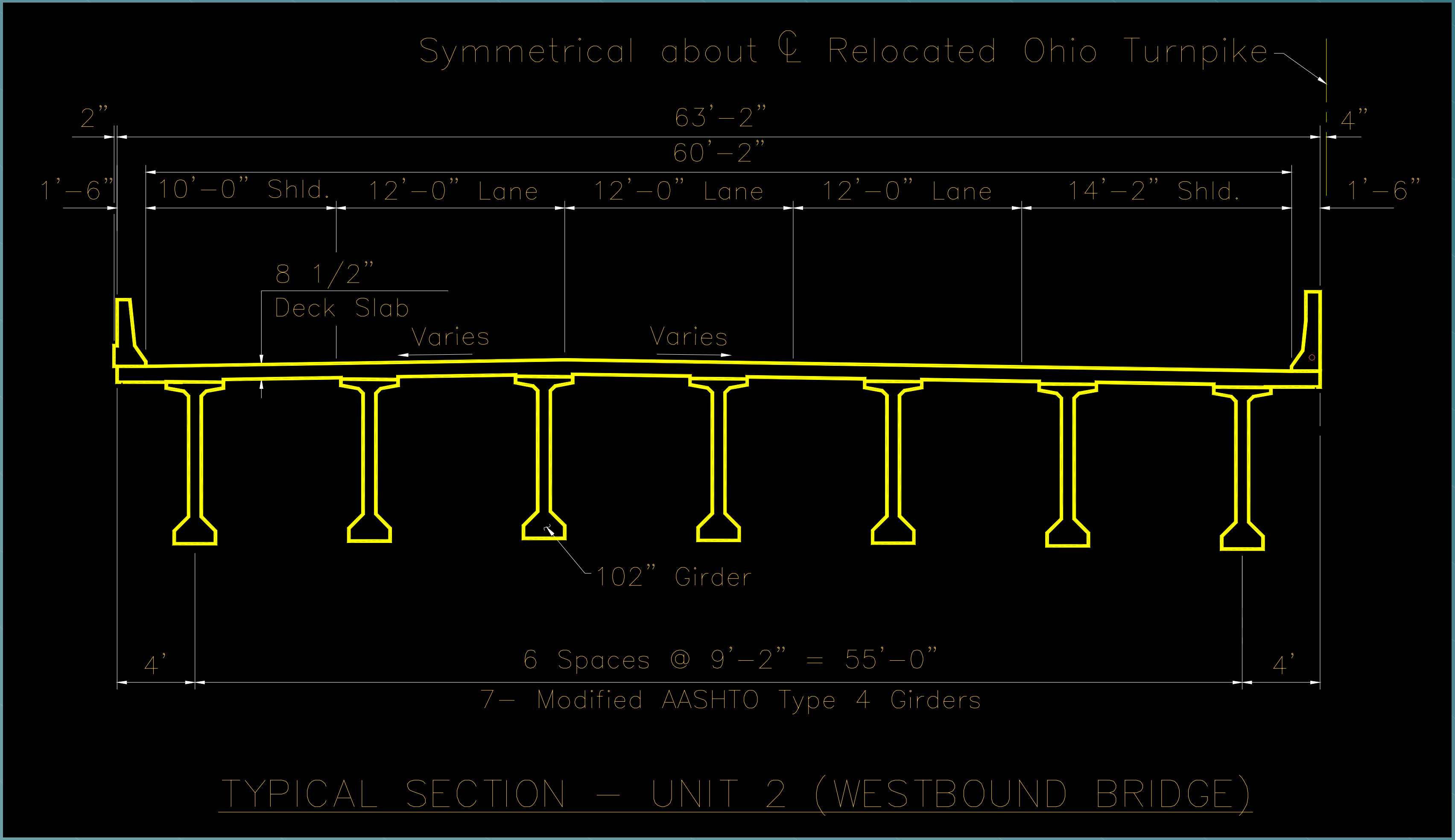
- Horizontal/Vertical Alignment
  - New alignment shifted 100’ south of the existing
  - maintain 2-lanes of traffic on the existing bridges during construction

Bridge Type Study: Design Criteria

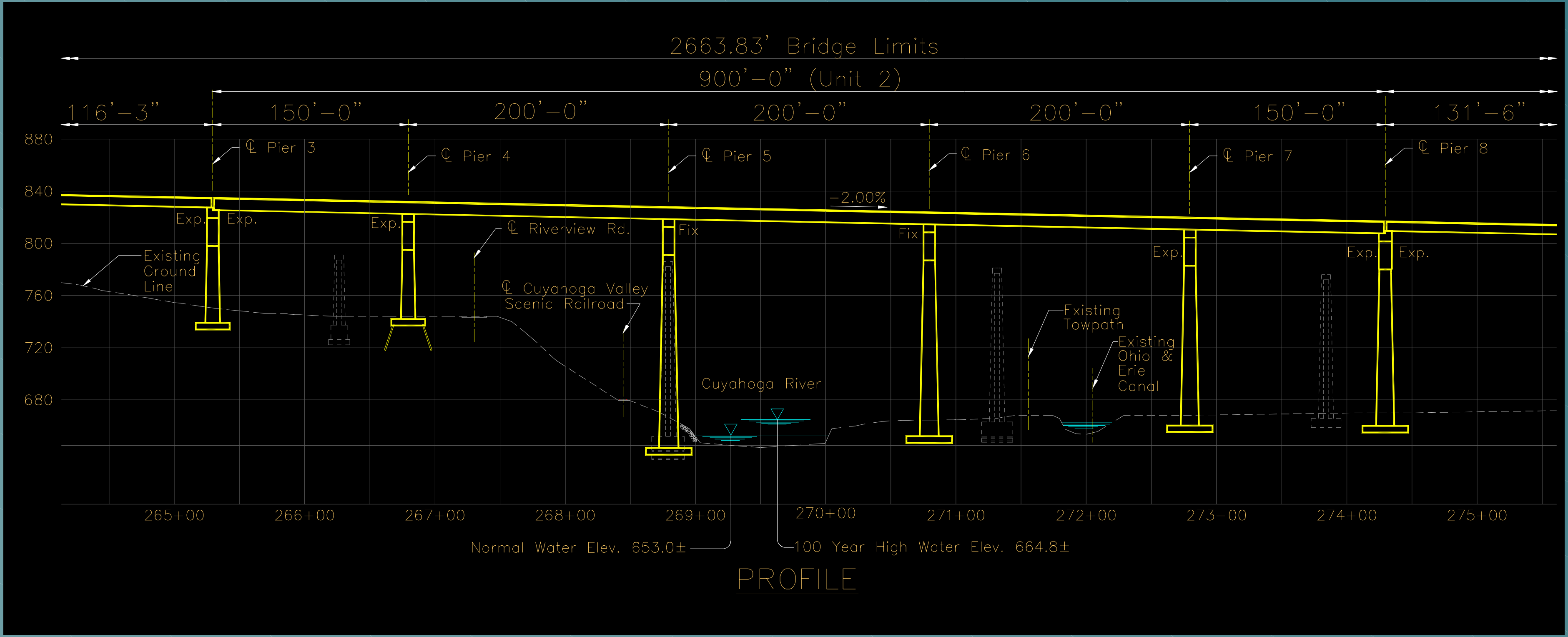


7 Michigan Truck Loadings

Bridge Type Study: Design Criteria



Bridge Type Study: Site Constraints



Unit 2 (Concrete Alternate)

Bridge Type Study: Site Constraints

- **Riverview Road**
- **Cuyahoga Valley Scenic Railroad**
- **Cuyahoga River**
- **Historic Ohio & Erie Canal and Towpath**
- **Cuyahoga Valley National Recreation Area**
- **Numerous Wetlands**
- **Span of 300’ required to clear Riverview Road, CVSR, & Cuyahoga River**

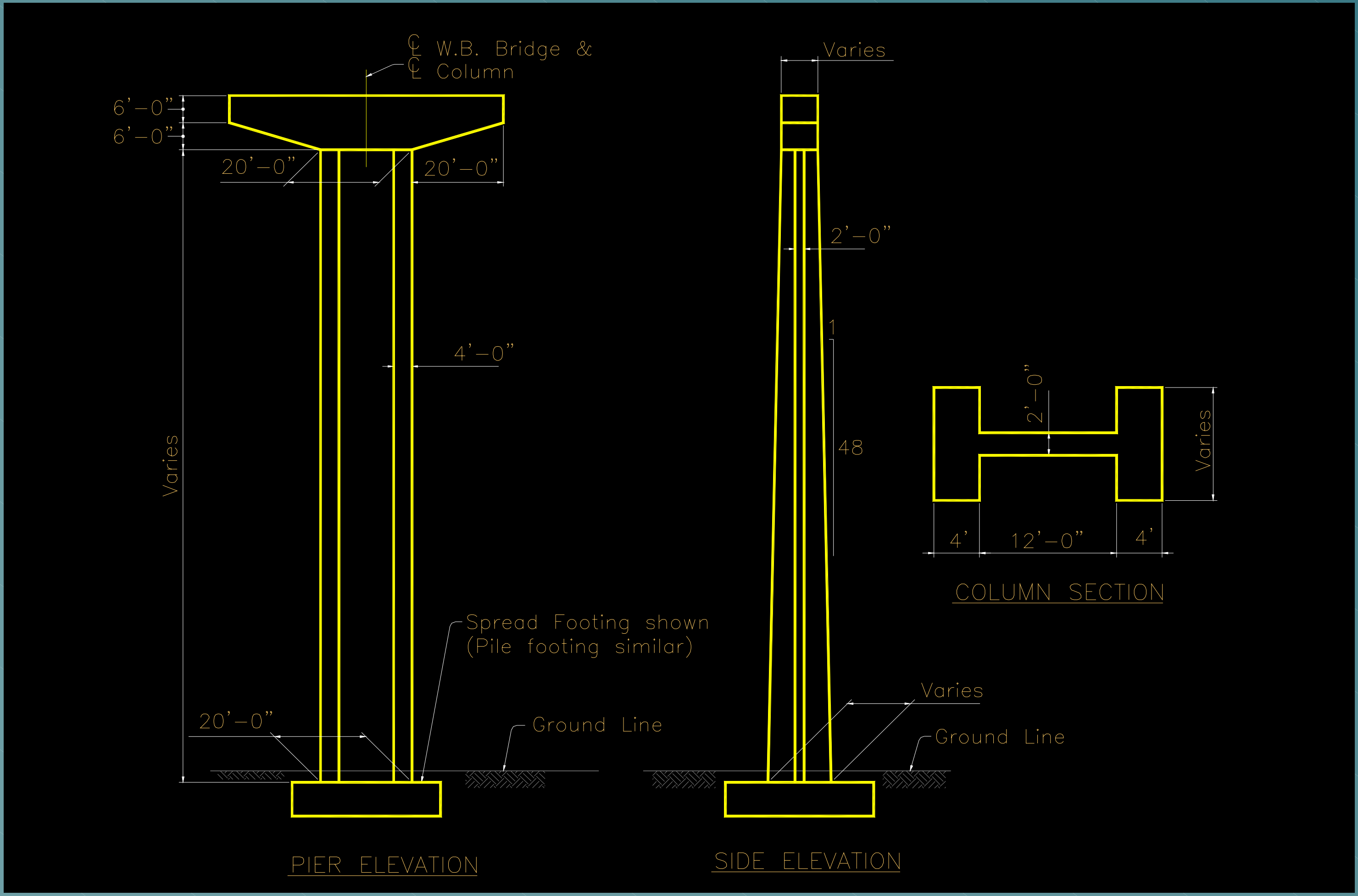
Bridge Type Study: Alternatives

- **Substructure**
- **Steel Superstructure**
- **Concrete Superstructure**

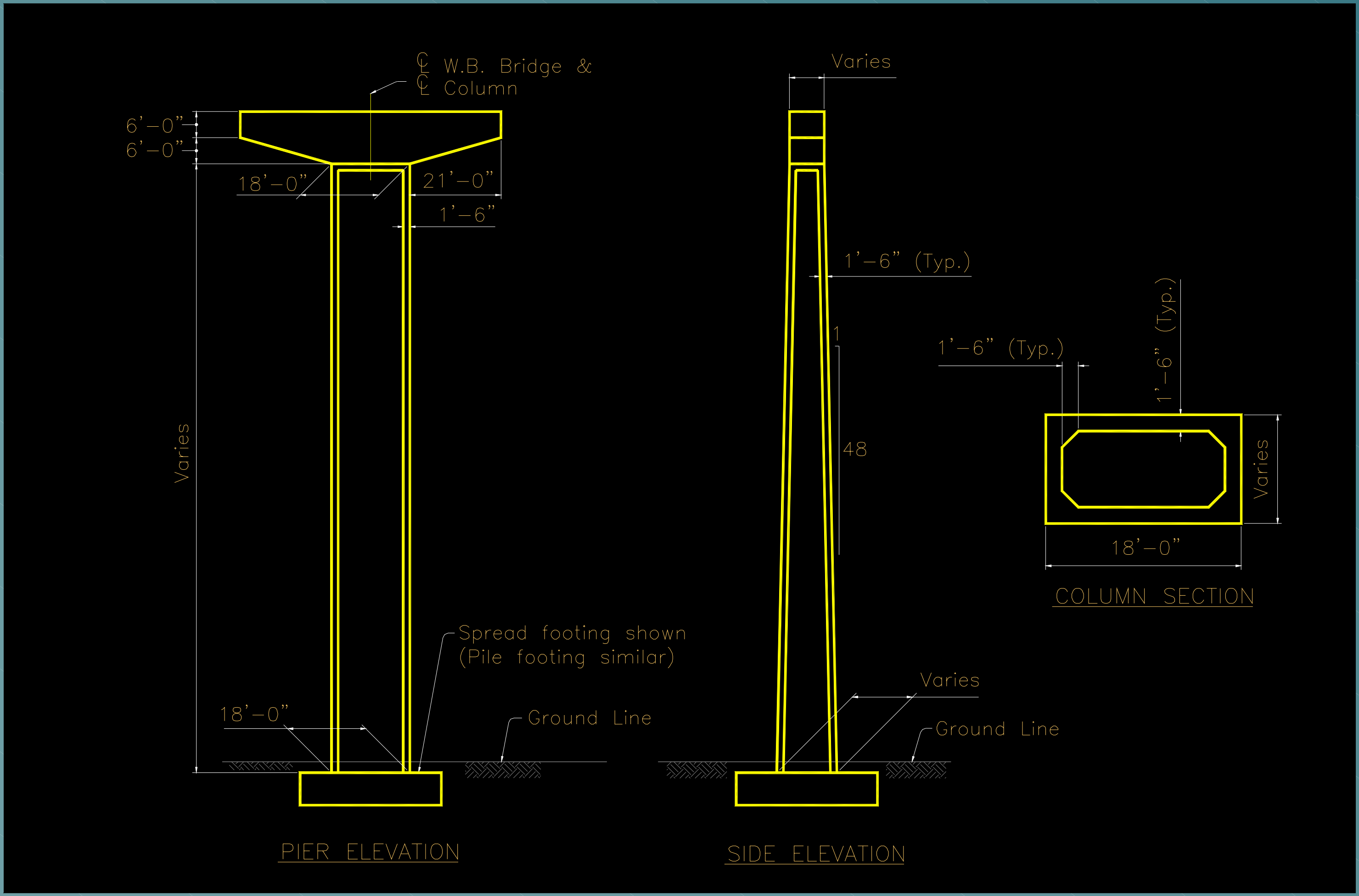
Bridge Type Study: Alternatives

- **Substructure (Piers)**
  - **Heights vary up to 170’**
  - **Average height of 115’**
  - **Most economical types**
    - **H-shape & Hollow box**
  - **Hollow box type chosen with hammerhead caps**
  - **Aesthetic features added later at the TS&L stage**

Bridge Type Study: Alternatives



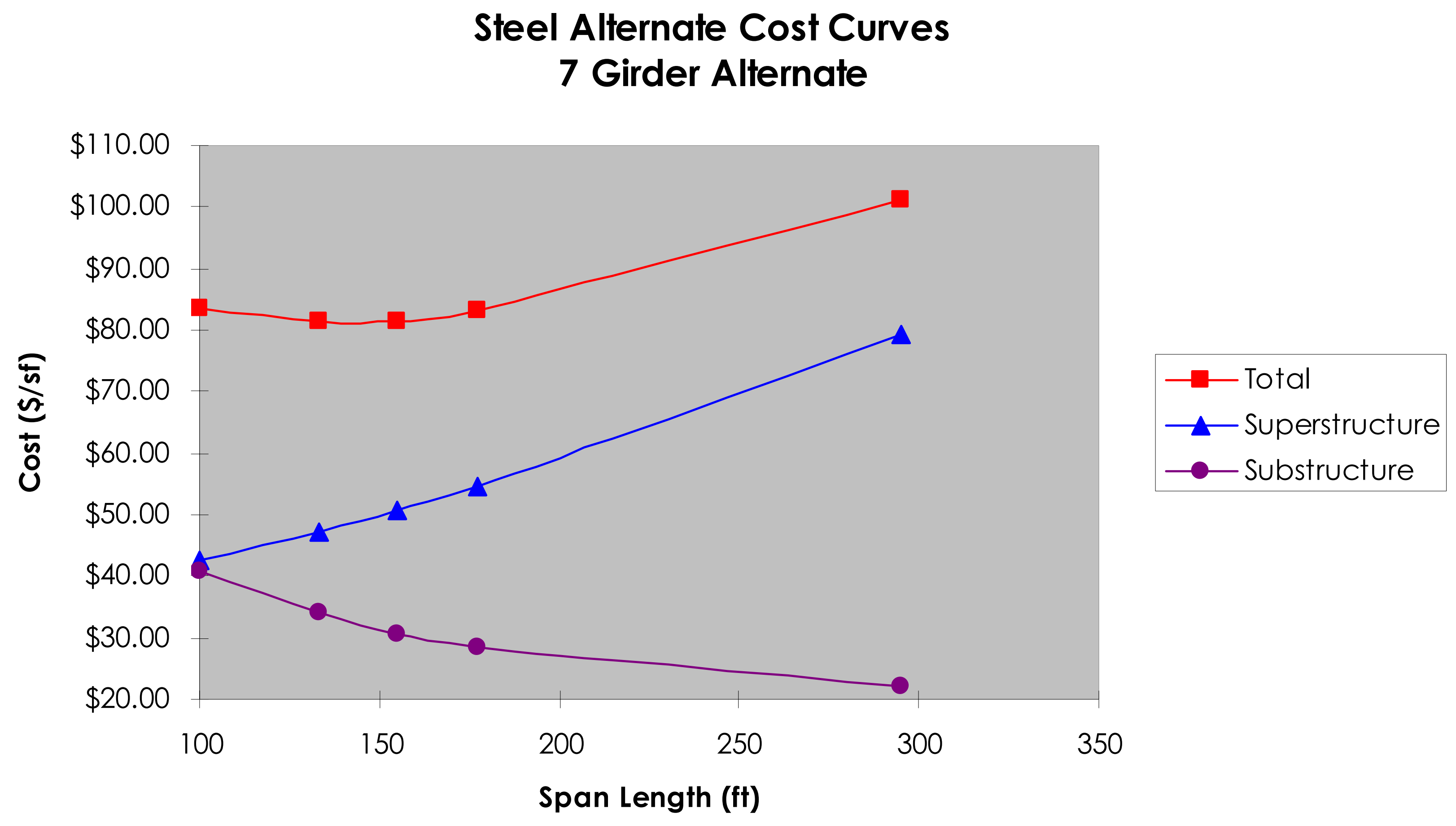
Bridge Type Study: Alternatives



Bridge Type Study: Alternatives

- **Steel Alternate**
  - **Various multiple girder arrangements**
    - **Constant depth girders**
    - **Haunched girders**
    - **Girders with sub-stringers**
  - **Spans from 100’ to 315’**

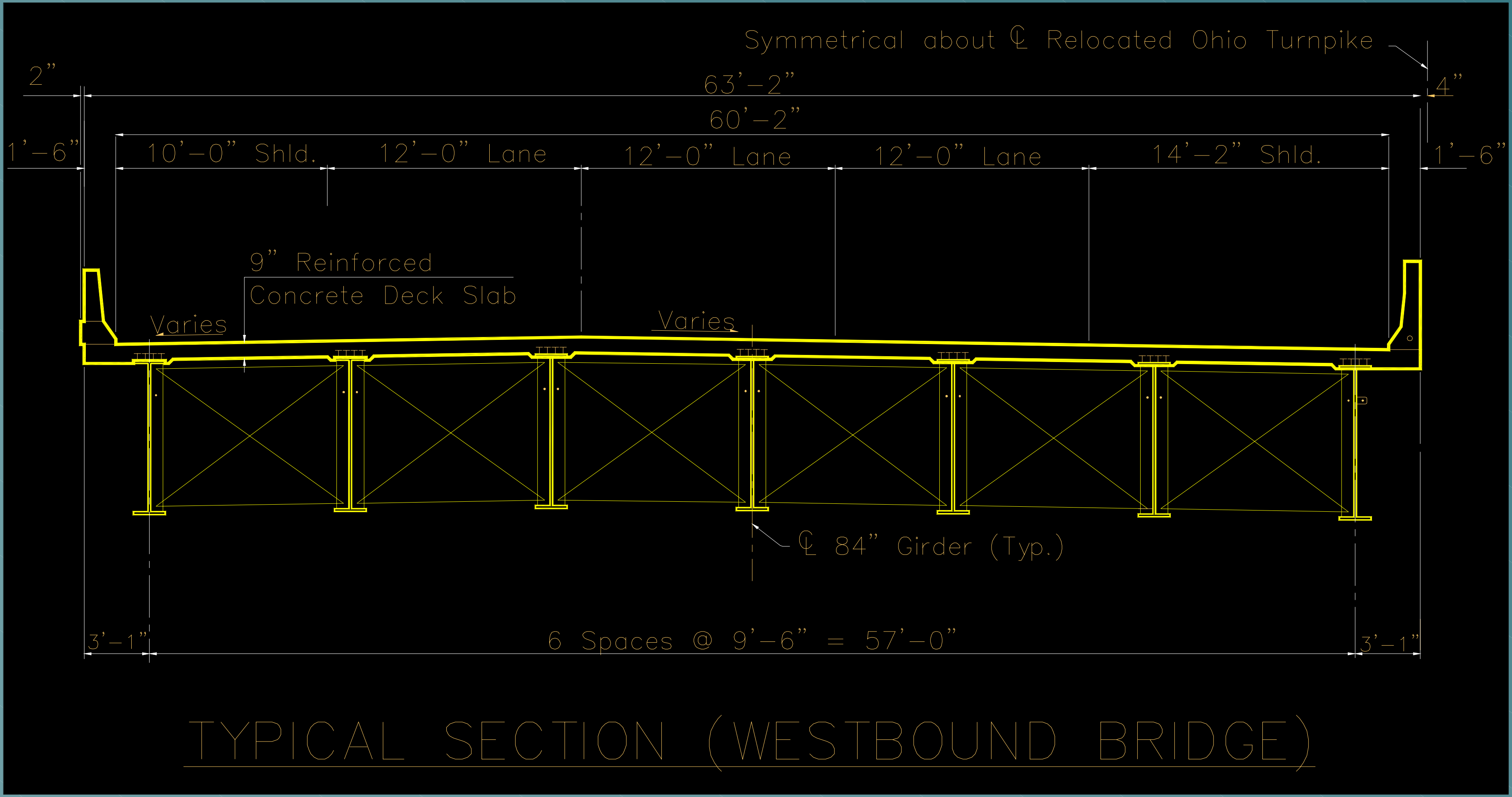
Bridge Type Study: Alternatives



Bridge Type Study: Alternatives

- ♦ Steel Alternate
  - Most Economical Superstructure
    - 9” reinforced concrete deck slab
    - 7 constant depth girders @ 9’-6” spacing
      - A588 steel, unpainted
    - ~180’ span length
  - Based on site constraints and optimum span length
    - 135’, 2@185’, 3@200’, 8@178’, 127’

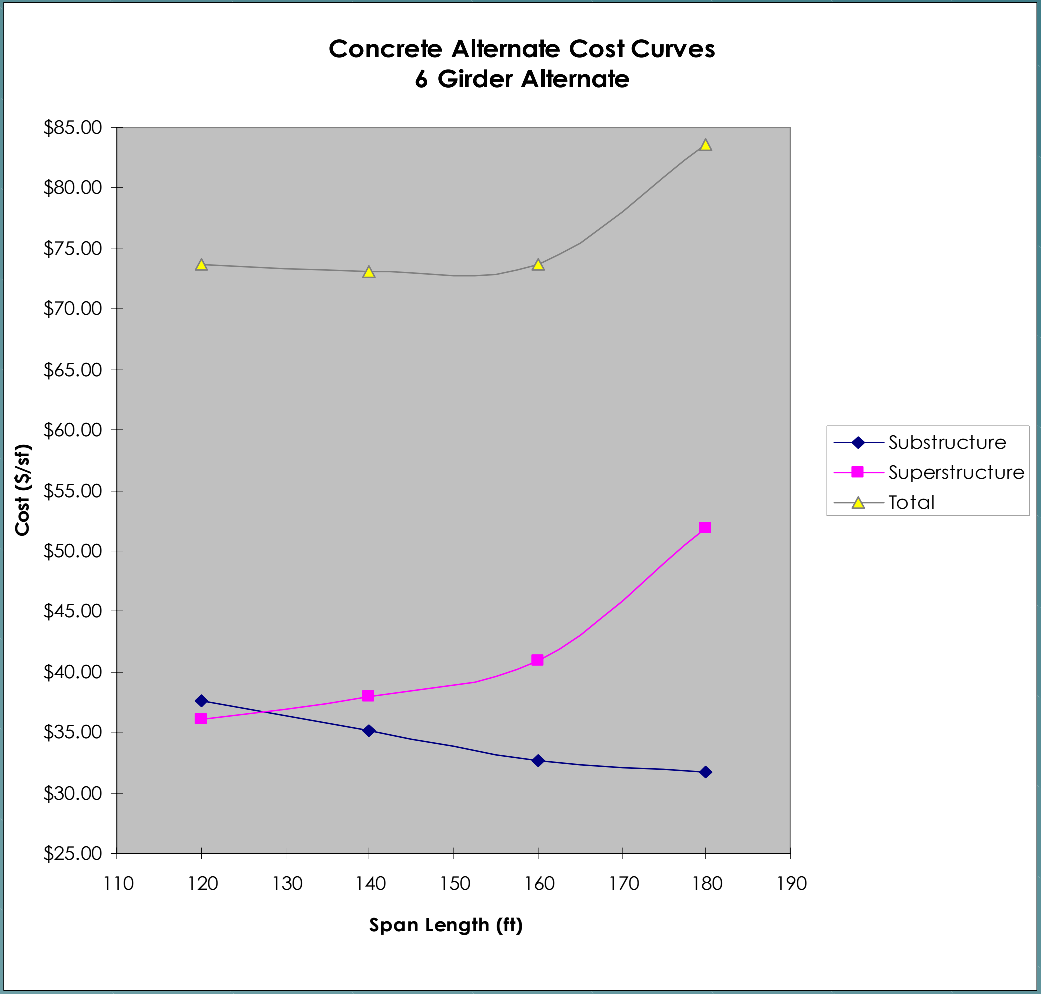
Bridge Type Study: Alternatives



Bridge Type Study: Alternatives

- **Concrete Alternate**
  - **Precast Prestressed Concrete Girders**
    - **Spans up to 160’ (max. transp. length)**
    - **5, 6 and 7 girder arrangements**
  - **Precast Prestressed Spliced Concrete Girders for longer spans**
    - **Spans evaluated up to 300’**
    - **6 and 7 girder arrangements**

Bridge Type Study: Alternatives



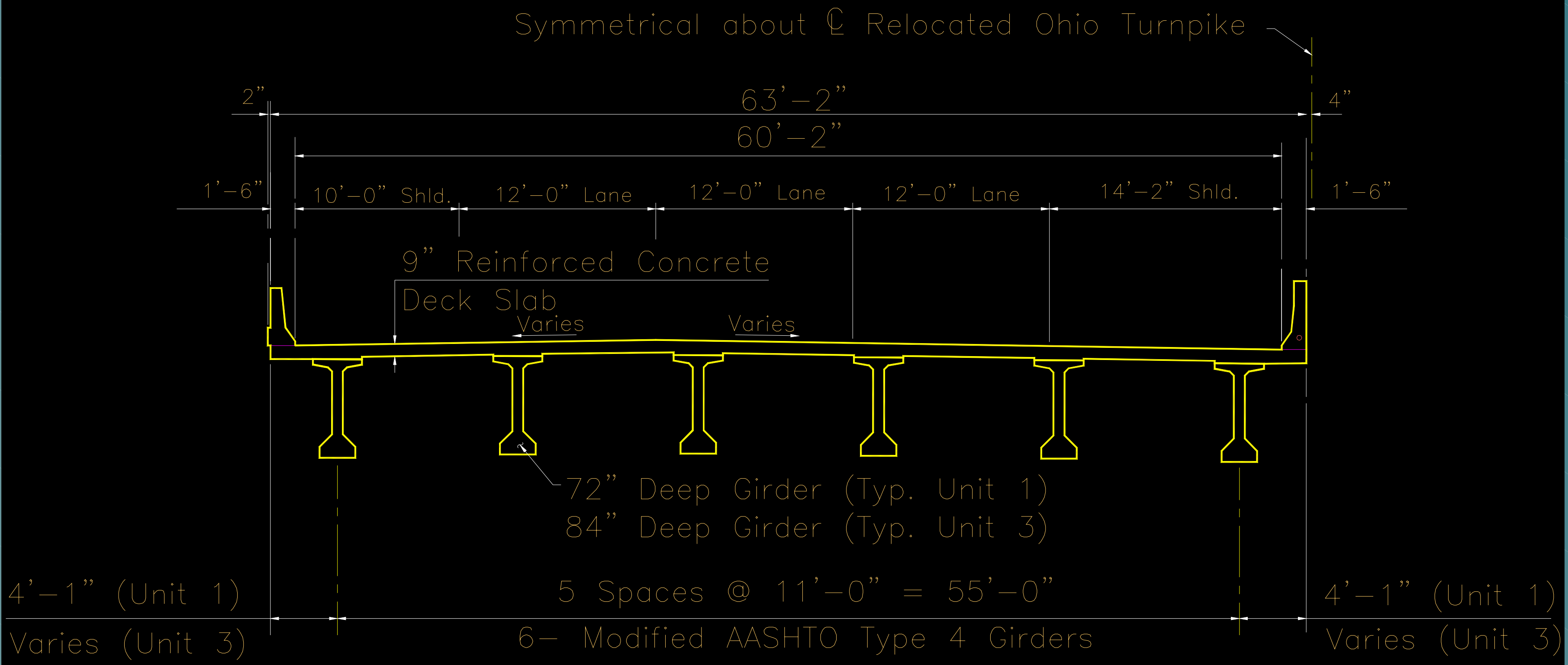
Bridge Type Study: Alternatives

- Concrete Alternate Units 1 and 3
  - Most Economical Superstructure
    - 9” reinforced concrete deck slab
    - 6 girders @ 11’-0” spacing
    - Conventional prestressed girders
      - 7,500 psi concrete
    - ~140’ span length

Bridge Type Study: Alternatives

- Based on site constraints and optimum span length
  - Concrete Alternate Unit 1
    - 115’, 126’, 116’
  - Concrete Alternate Unit 3
    - 132’, 8@142’, 132’

Bridge Type Study: Alternatives

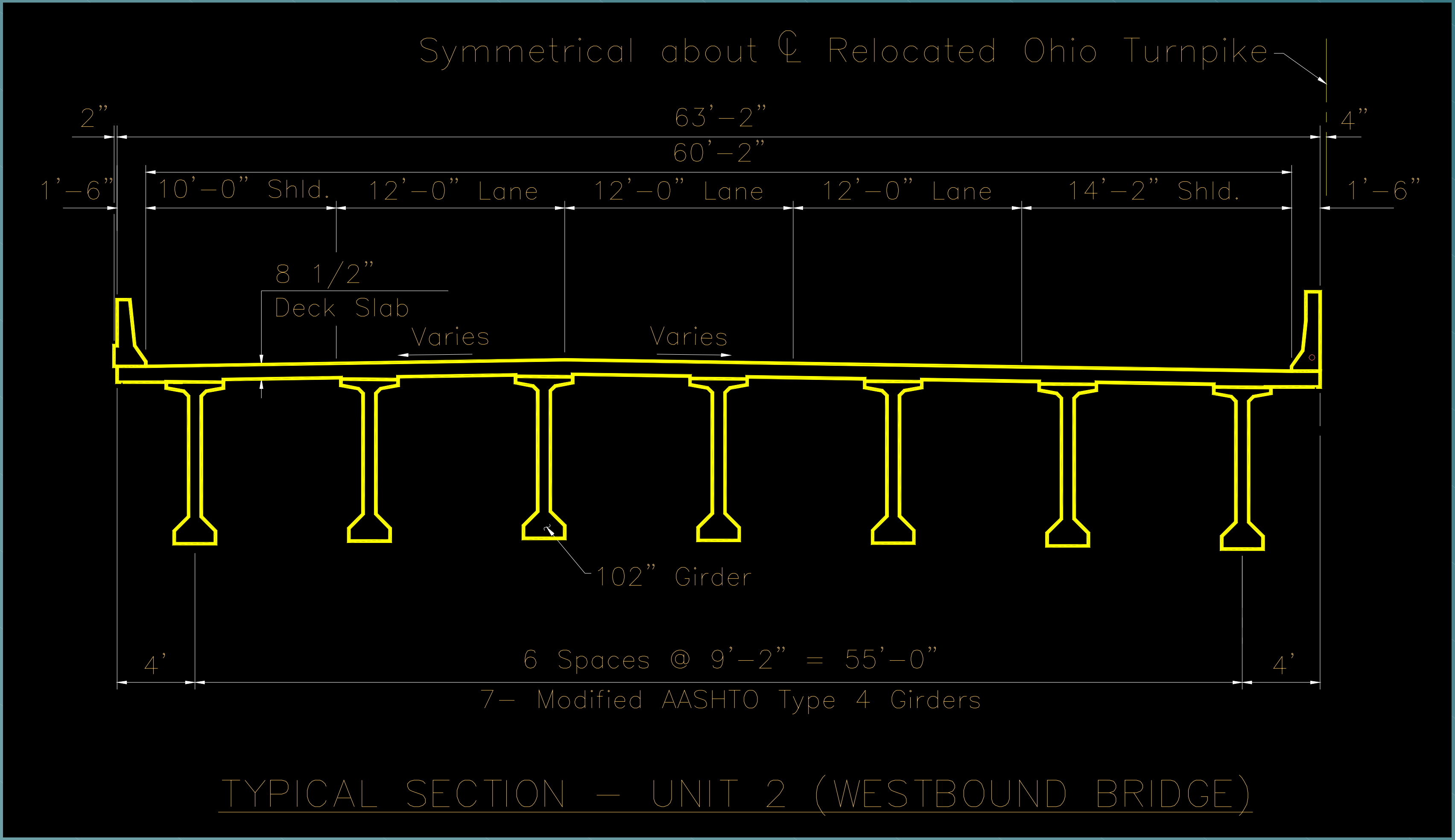


TYPICAL SECTION – UNIT 1 AND UNIT 3 (WESTBOUND BRIDGE)

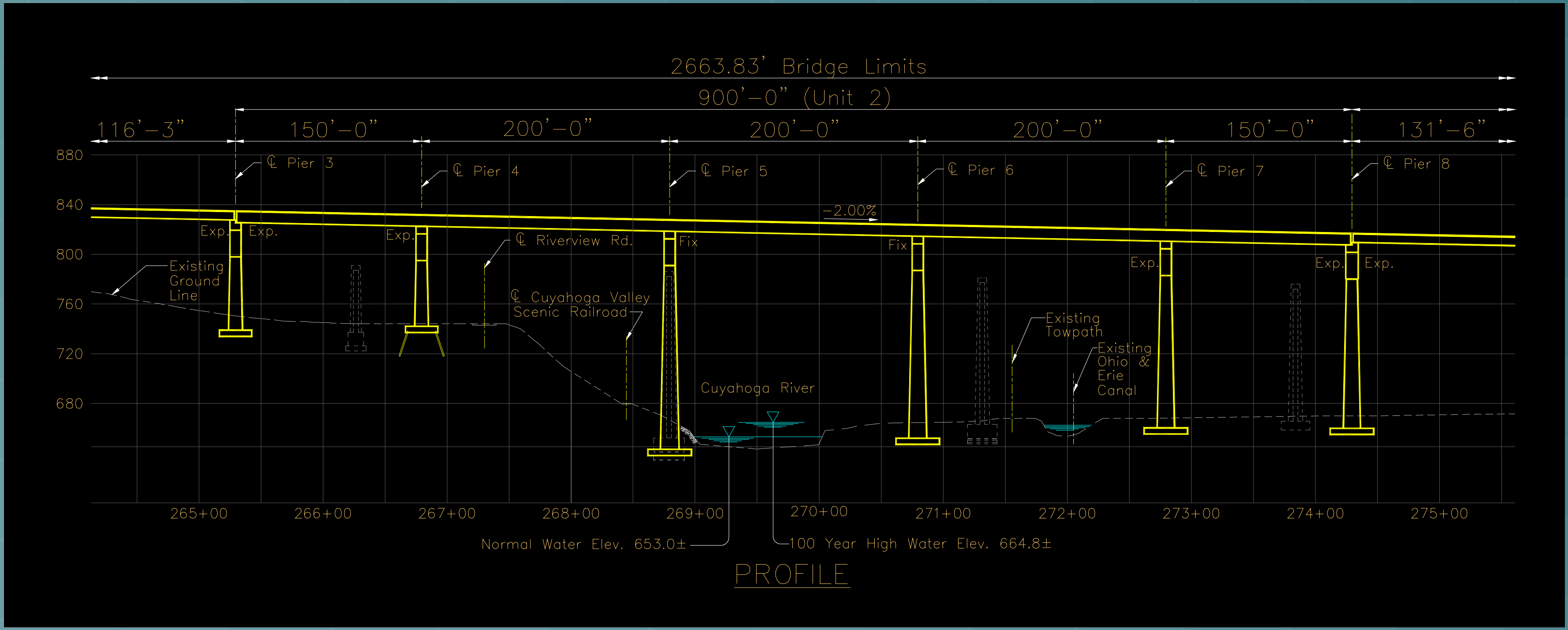
Bridge Type Study: Alternatives

- **Concrete Alternate Unit 2**
  - **Based on site constraints**
    - **150’, 3@200’, 150’**
  - **Most Economical Superstructure**
    - **8 1/2” reinforced concrete deck slab**
    - **7 girders @ 9’-2” spacing**
    - **Post-tensioned spliced girders**
      - **7,500 psi concrete**

Bridge Type Study: Alternatives

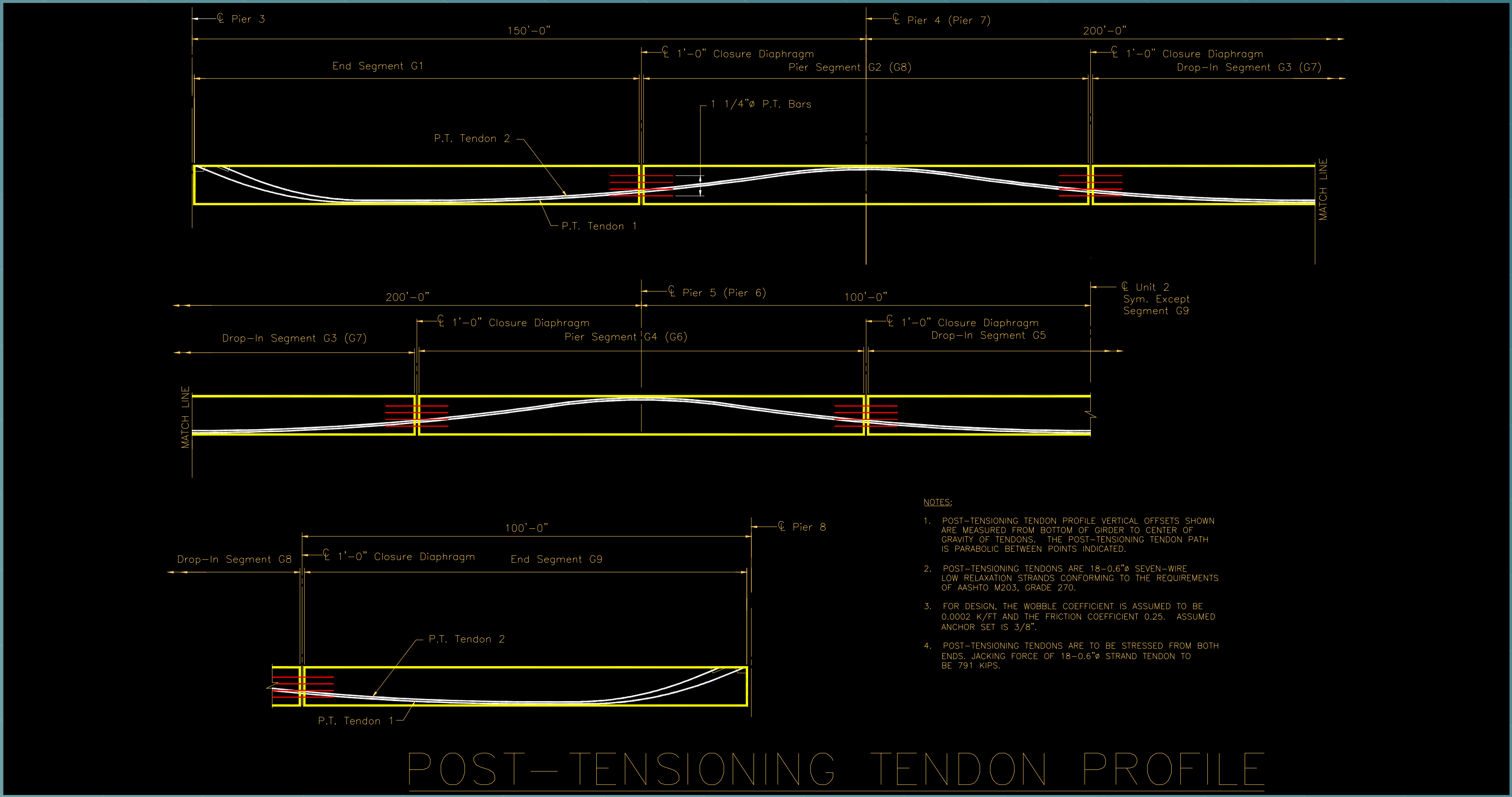


Concrete Alternative: Precast Spliced Girder Design



Unit 2 (Concrete Alternate)

Concrete Alternative:
Precast Spliced Girder Design

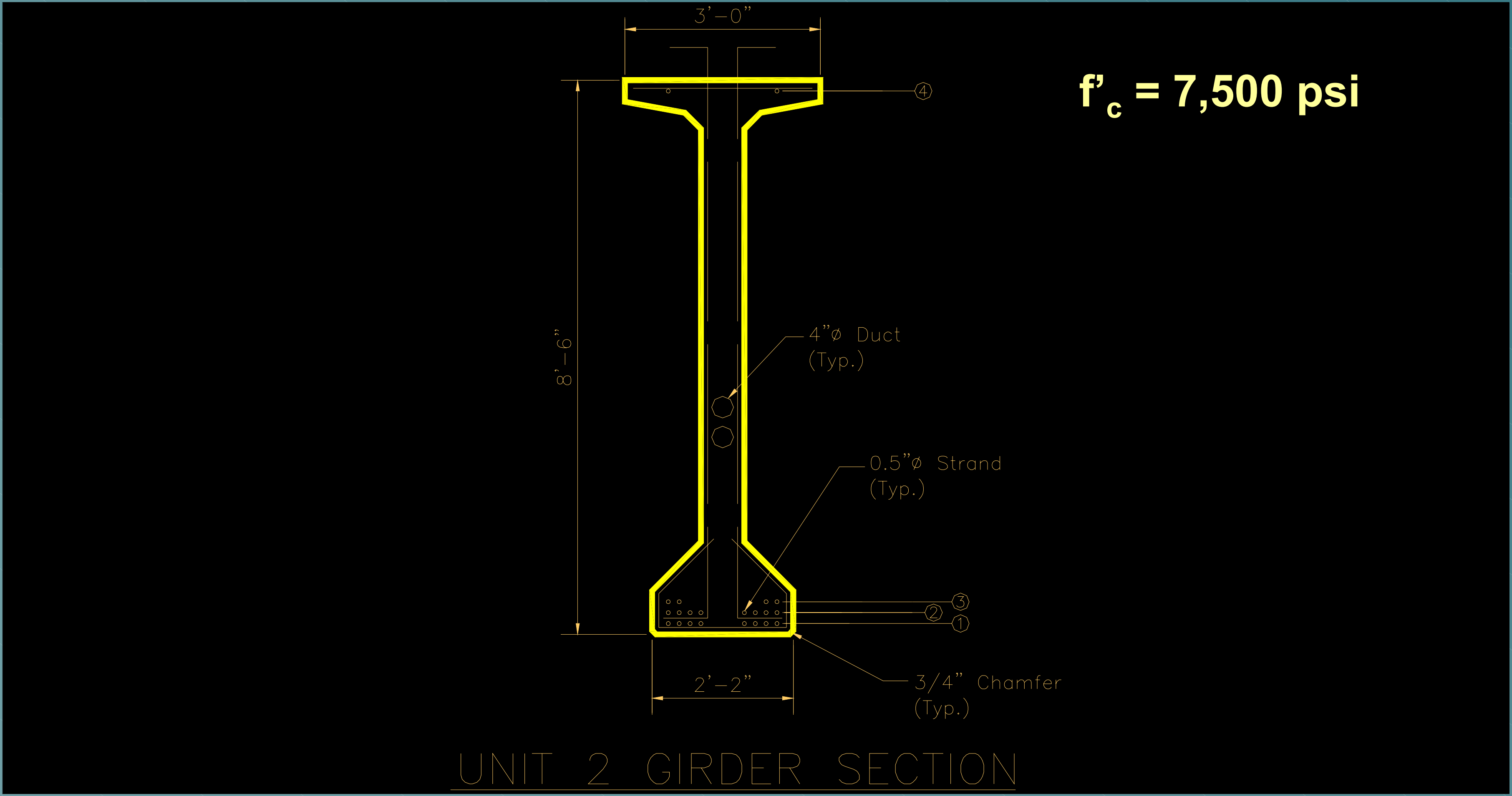


NOTES:

1. POST–TENSIONING TENDON PROFILE VERTICAL OFFSETS SHOWN ARE MEASURED FROM BOTTOM OF GIRDER TO CENTER OF GRAVITY OF TENDONS. THE POST–TENSIONING TENDON PATH IS PARABOLIC BETWEEN POINTS INDICATED.
2. POST–TENSIONING TENDONS ARE 18–0.6"ø SEVEN–WIRE LOW RELAXATION STRANDS CONFORMING TO THE REQUIREMENTS OF AASHTO M203, GRADE 270.
3. FOR DESIGN, THE WOBBLE COEFFICIENT IS ASSUMED TO BE 0.0002 K/FT AND THE FRICTION COEFFICIENT 0.25. ASSUMED ANCHOR SET IS 3/8".
4. POST–TENSIONING TENDONS ARE TO BE STRESSED FROM BOTH ENDS. JACKING FORCE OF 18–0.6"ø STRAND TENDON TO BE 791 KIPS.

POST–TENSIONING TENDON PROFILE

Concrete Alternative: Precast Spliced Girder Design



f'_c = 7,500 psi

UNIT 2 GIRDER SECTION

Concrete Alternative: Precast Spliced Girder Design

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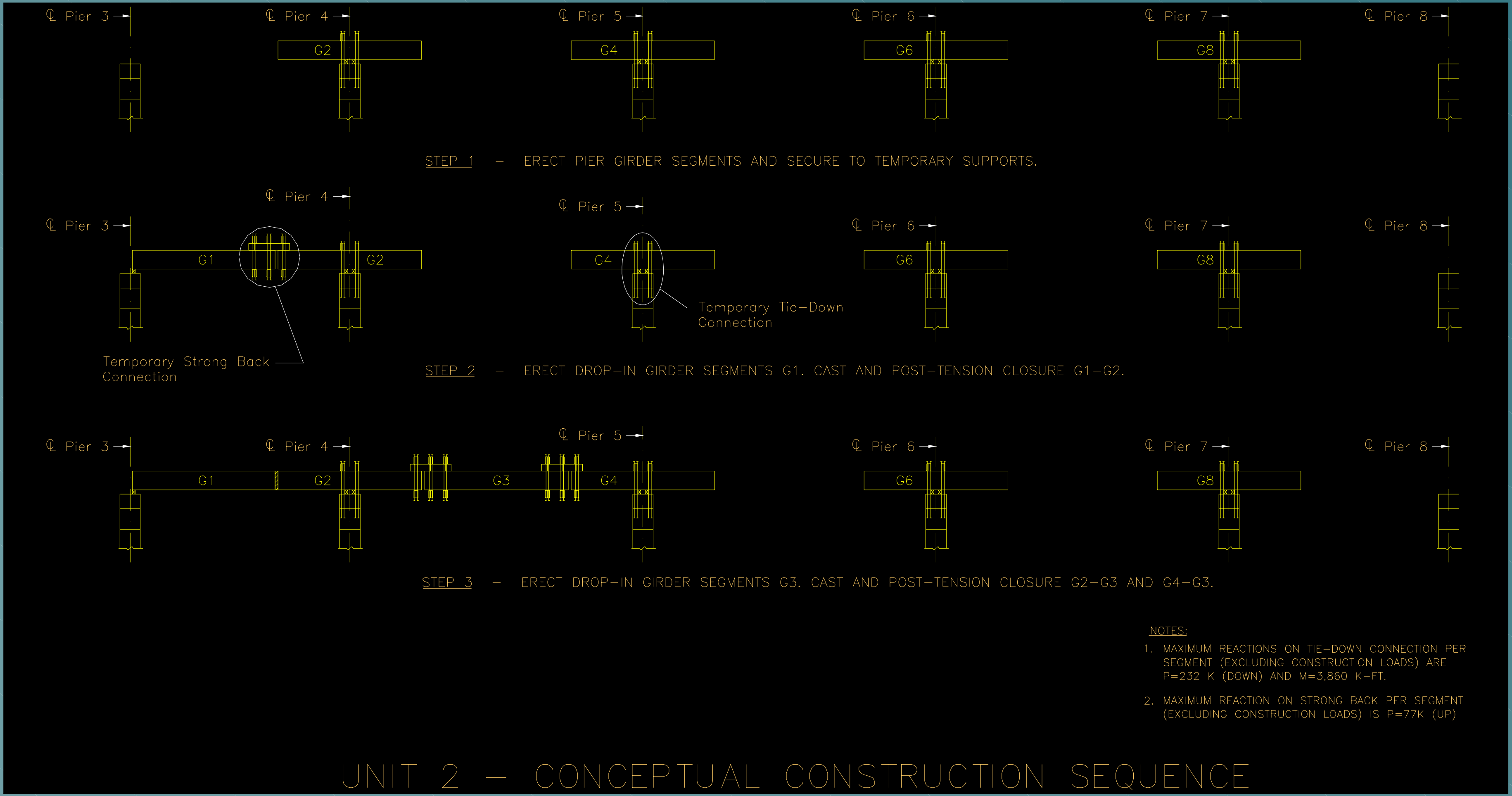


STEP 1 – ERECT PIER GIRDER SEGMENTS AND SECURE TO TEMPORARY SUPPORTS.

STEP 2 – ERECT DROP–IN GIRDER SEGMENTS G1. CAST AND POST–TENSION CLOSURE G1–G2.

STEP 3 – ERECT DROP–IN GIRDER SEGMENTS G3. CAST AND POST–TENSION CLOSURE G2–G3 AND G4–G3.

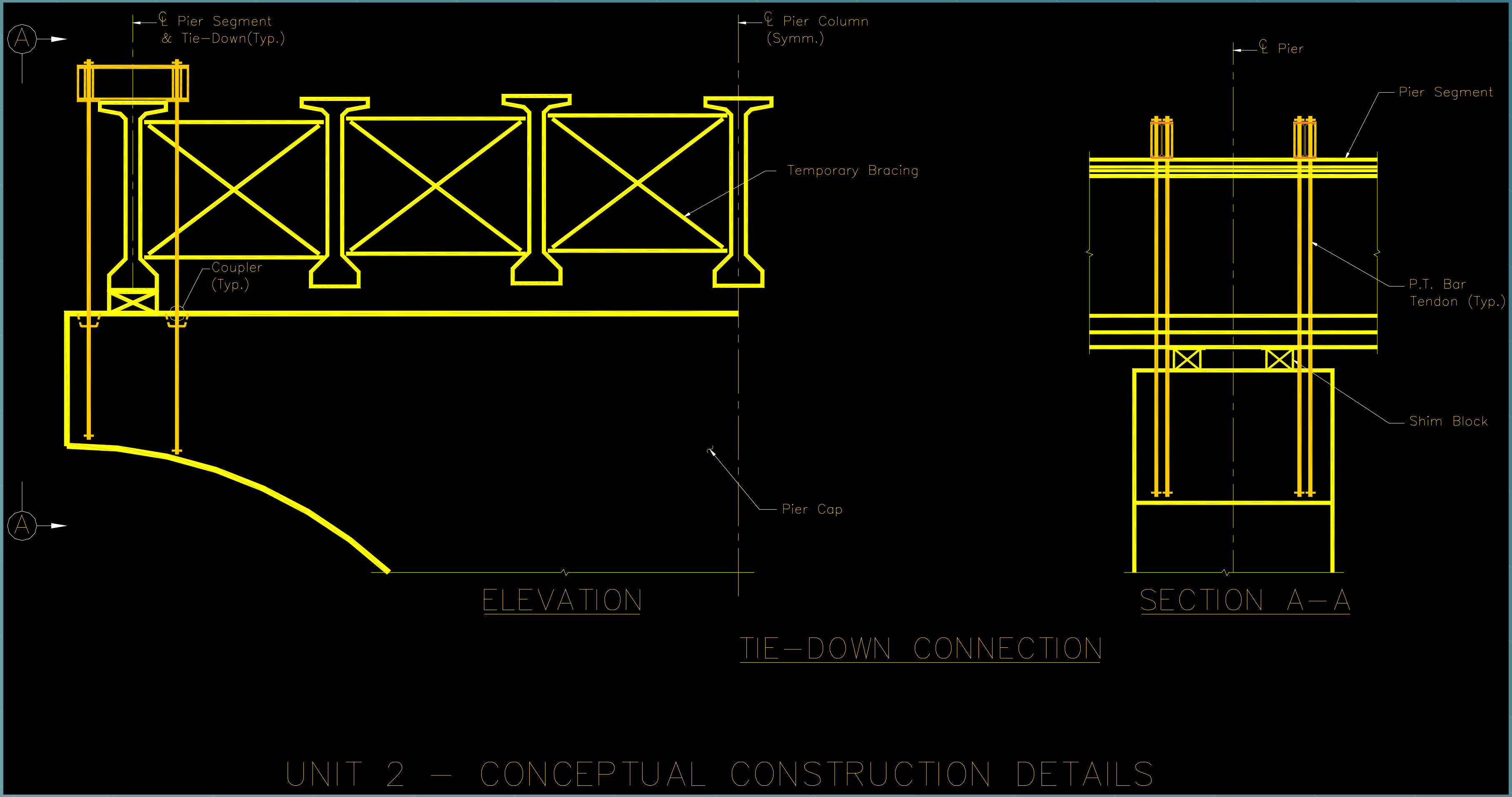
NOTES:

1. MAXIMUM REACTIONS ON TIE–DOWN CONNECTION PER SEGMENT (EXCLUDING CONSTRUCTION LOADS) ARE P=232 K (DOWN) AND M=3,860 K–FT.
2. MAXIMUM REACTION ON STRONG BACK PER SEGMENT (EXCLUDING CONSTRUCTION LOADS) IS P=77K (UP)

UNIT 2 – CONCEPTUAL CONSTRUCTION SEQUENCE

Concrete Alternative: Precast Spliced Girder Design

Concrete Alternative: Precast Spliced Girder Design



Concrete Alternative: Precast Spliced Girder Design

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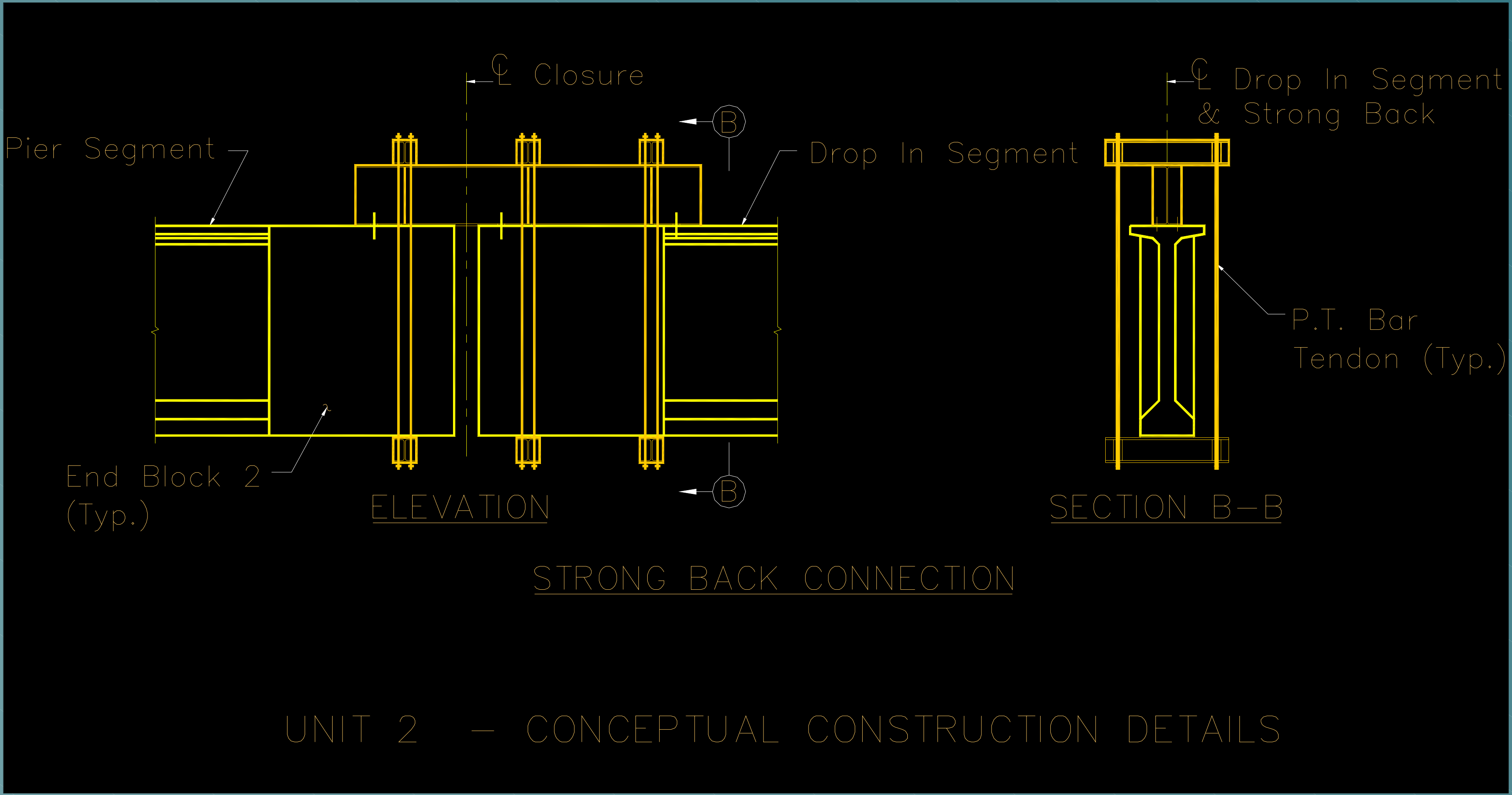

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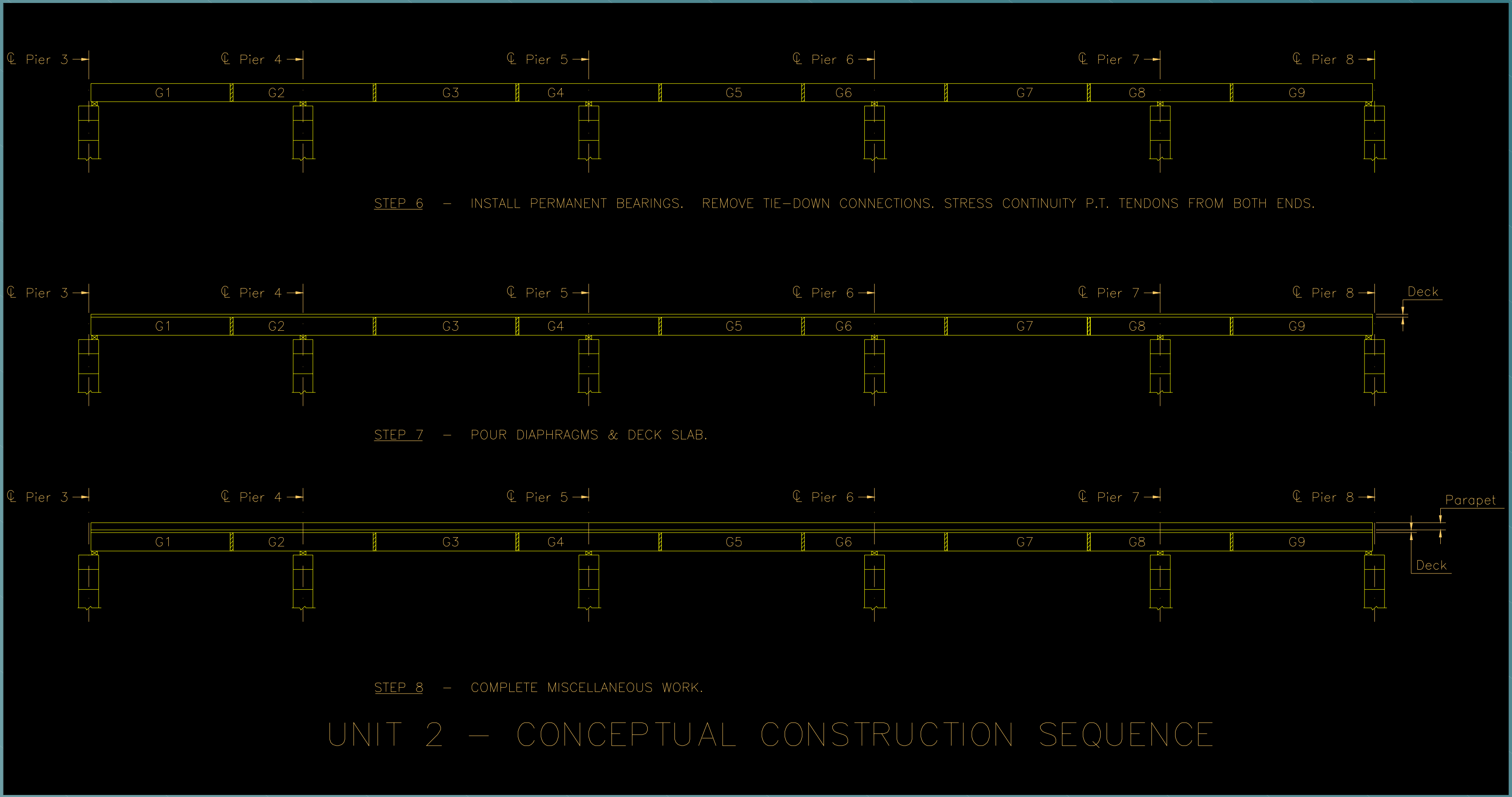

STEP 6 – INSTALL PERMANENT BEARINGS. REMOVE TIE–DOWN CONNECTIONS. STRESS CONTINUITY P.T. TENDONS FROM BOTH ENDS.

STEP 7 – POUR DIAPHRAGMS & DECK SLAB.

STEP 8 – COMPLETE MISCELLANEOUS WORK.

UNIT 2 – CONCEPTUAL CONSTRUCTION SEQUENCE

Concrete Alternative: Precast Spliced Girder Design

- Summary
  - Advantages
    - Structural Efficiency
    - Fast Track Construction
    - Long Term Durability
    - Low Maintenance Cost
  - Wide Range of Options
    - Span Arrangement (up to 280 foot span lengths)
    - Prestressing
    - Temporary Supports
    - Splice Types
    - Construction Sequence