The New More Friendly

Division of Structural Design

Bridge Design Basics

Things about bridges you could care less about but occasionally need to know.

Functions of Div. of Structural Design

- Design/Detail
  - New Structures
    - Bridges, Culverts, Sign Supports
  - Bridge Rehabilitation/Bridge Widening
- Consultant Review
- Geotechnical Branch

Common KY Structure Types

- Culverts
- Non-composite side by side box beams
- Composite side by side box beams
- Composite spread box beams
- Composite spread “I” beams
- Composite spread steel beams
  - Plate Girder and W-Beam
- Cast in Place – Slab Bridges

Other Bridge Types

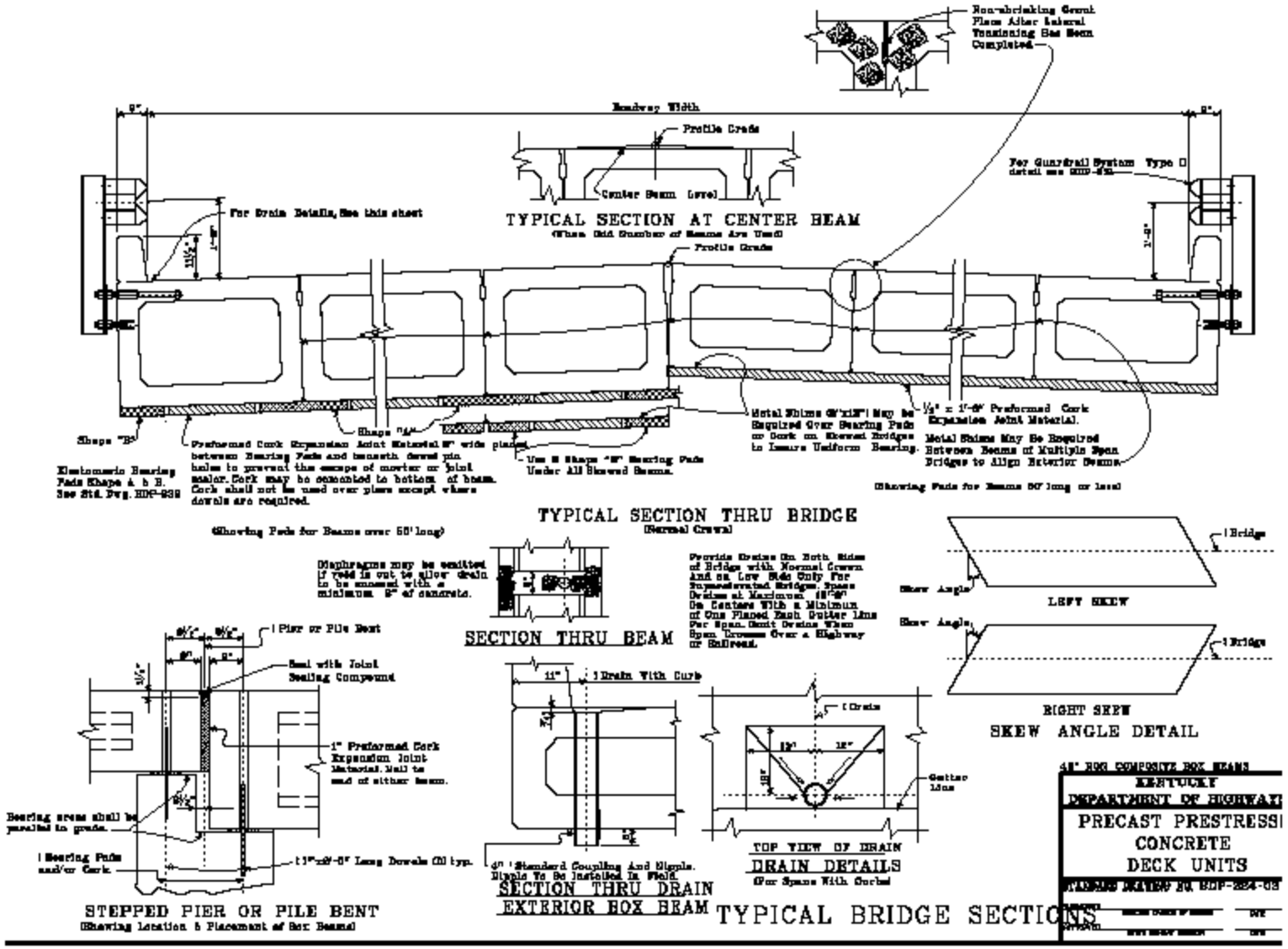
- Toy trusses
- Real Trusses
- Cable stayed
- Steel and concrete box girders
- Through Girders
- Post Tension Concrete

Culverts

- Culverts are economical for spans to about 24 feet.
- Can be single, double. Avoid triples
- Can be “three sided” although we quit using them for good reason. You have to be real careful what you put them on, i.e. non-scourable material. Check with Geotech before using them.
- Try to keep culverts straight so we can use our culvert program.
- “Not all culverts are created equal” Because of design assumptions, construction techniques, product details, etc., we do not recommend precast culverts/con-span. You are on your own with these.

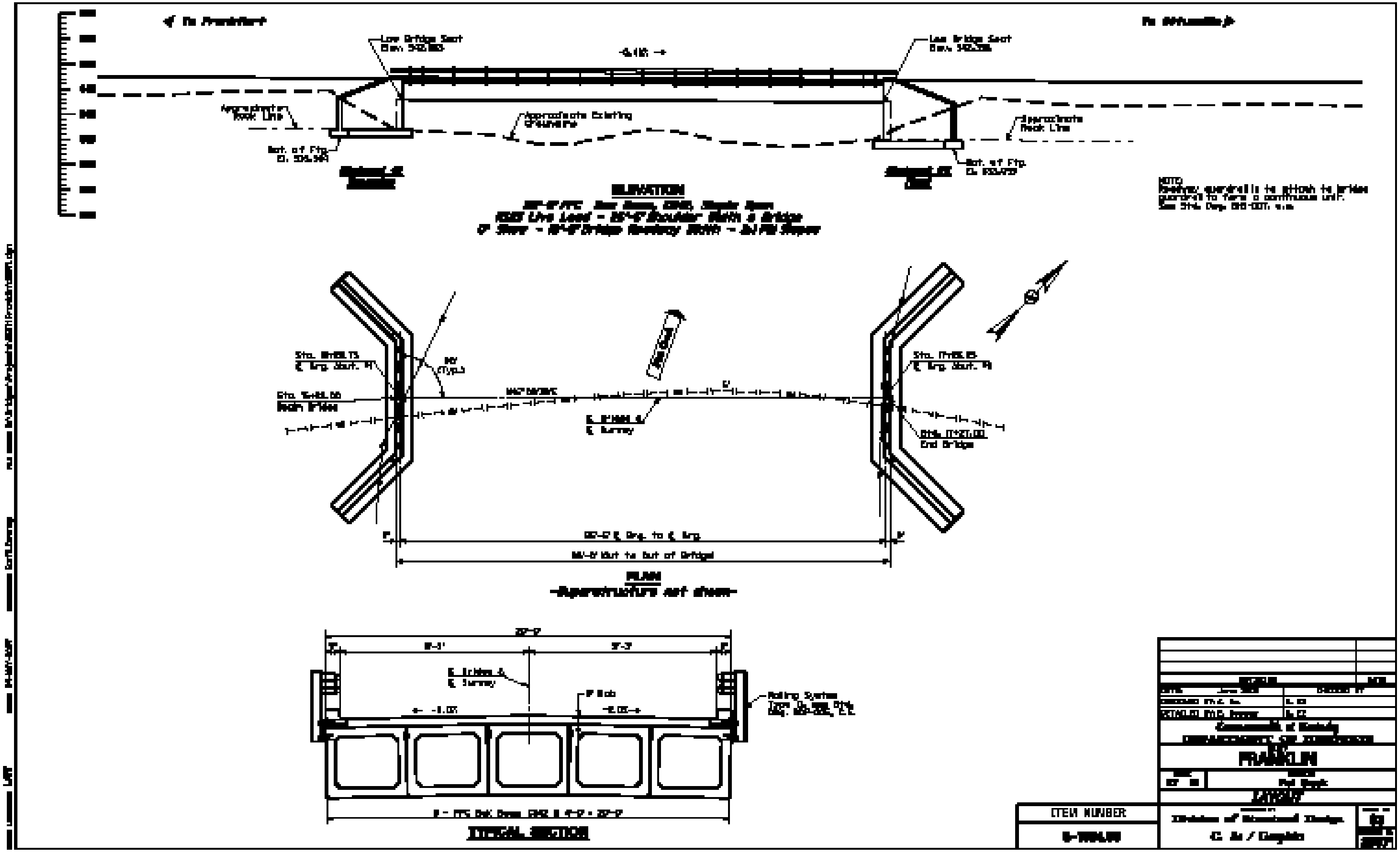
Side by side box beams

- Two types, with and without composite slab.
- We do not recommend non-composite although there are applications on very low volume roads with little or no truck traffic and a need to minimize structure depth. “Think Dead End Road.”
- Heavy truck traffic causes shear keys/grout to break leading to beam overload and failure.


Roadway Width
Profile Grade
Center Beam Level
TYPICAL SECTION AT CENTER BEAM
For Drain Details, See this sheet
For Guardrail System Type D detail see
Profile Grade
Shape "B"
Shape "A"
Elastomeric Bearing Pads Shape A & B. See Std. Dwg. HDP-838
Preformed Cork Expansion Joint Material 8" wide placed between Bearing Pads and beneath dowel pin holes to prevent the escape of mortar or joint sealer. Cork may be cemented to bottom of beam. Cork shall not be used over plane except where dowels are required.
Metal Shims 6"x12" May be Required Over Bearing Pads or Cork on Skewed Bridges to Insure Uniform Bearing.
½" x 1'-6" Preformed Cork Expansion Joint Material.
Metal Shims May Be Required Between Beams of Multiple Span Bridges to Align Exterior Beams.
Use H Shape "B" Bearing Pads Under All Skewed Beams.
(Showing Pads for Beams 50' long or less)
(Showing Pads for Beams over 50' long)
TYPICAL SECTION THRU BRIDGE
(Normal Crown)
Diaphragms may be omitted if void is cut to allow drain to be screened with a minimum 2" of concrete.
SECTION THRU BEAM
Provide Drains On Both Sides of Bridge with Normal Crown And on Low Side Only For Superelevated Bridges. Space Drains at Maximum 15'-0" On Centers With a Minimum of One Placed Each Gutter Line Per Span. Omit Drains When Span Crosses Over a Highway or Railroad.
Bridge
Skew Angle
LEFT SKEW
RIGHT SKEW
SKEW ANGLE DETAIL
Pier or Pile Bent
Seal with Joint Sealing Compound
1" Preformed Cork Expansion Joint Material. Nail to end of either Beam.
Bearing areas shall be parallel to grade.
Bearing Pads and/or Cork.
1"x20"-0" Long Dowels (2) typ.
STEPPED PIER OR PILE BENT
(Showing Location & Placement of Box Beams)
Drain With Curb
4" Standard Coupling And Nipple. Nipple To Be Installed In Field.
SECTION THRU DRAIN EXTERIOR BOX BEAM
Drain
Gutter Line
TOP VIEW OF DRAIN
DRAIN DETAILS
(For Spans With Curbs)
48" BOX COMPOSITE BOX BEAMS
KENTUCKY
DEPARTMENT OF HIGHWAYS
PRECAST PRESTRESSED CONCRETE DECK UNITS
STANDARD DRAWING NO. BDP-224-08
TYPICAL BRIDGE SECTIONS

Side by side box beams

- The composite side by side box beams cost a little more but perform much better and have a smoother riding surface.
- For both types see standard drawings for types and span length.



To Frankfort
Low Bridge Seat
Low Bridge Seat
Approximate Existing Groundline
Approximate Rock Line
Approximate Rock Line
Bott. of Ftg.
Bott. of Ftg.
ELEVATION
TYPICAL SECTION
Railing System
ITEM NUMBER
FRANKLIN

PRECAST SIDE BY SIDE BOX BEAM BRIDGE

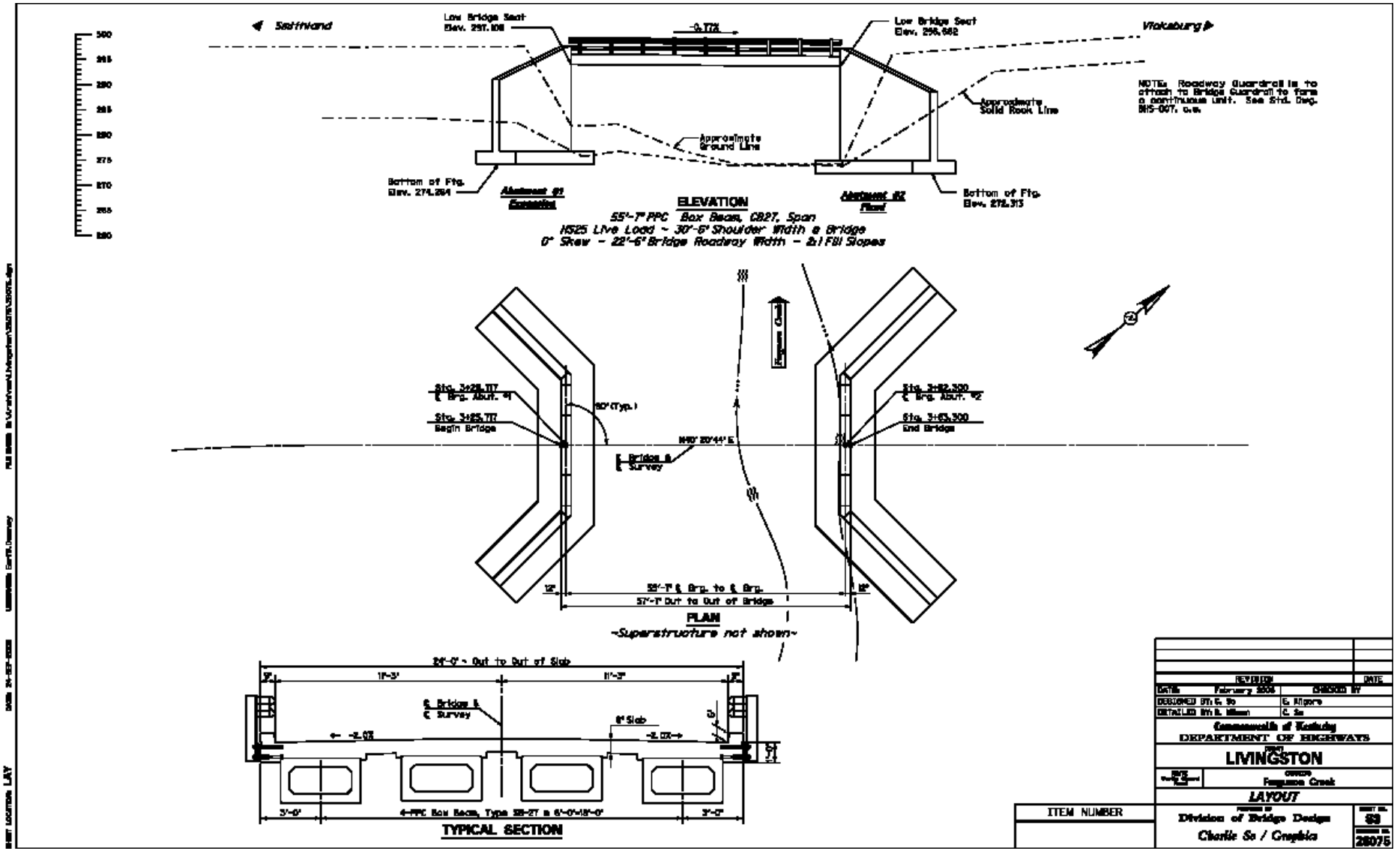
FRANKLIN COUNTY

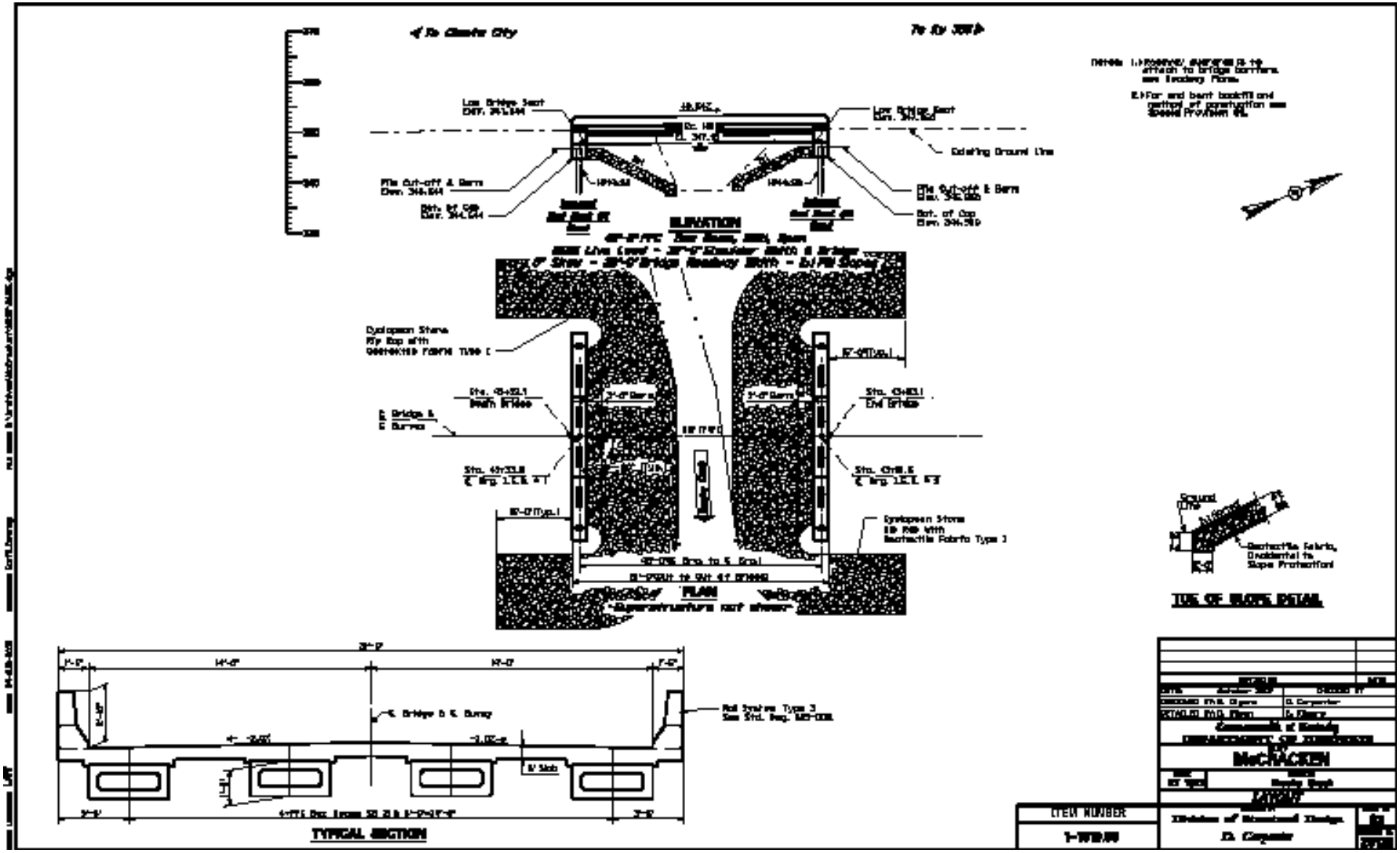
PRECAST SIDE BY SIDE BOX BEAM BRIDGE

FRANKLIN COUNTY

Spread Box Beams

- It turns out that if you are going to use precast boxes with a slab, it is usually cheaper to make the deck a little thicker and "remove" every other beam. We do a lot of these since they have a good combination of minimal depth, good riding surface and cost.
- The standard drawing for the "CB" series gives a good approximate span ranges.


Saltfriand
Low Bridge Seat Elev. 297.108
Low Bridge Seat Elev. 296.682
Vicksburg
NOTE: Roadway Guardrail is to attach to Bridge Guardrail to form a continuous unit. See Std. Dwg. BHS-007, etc.
Approximate Solid Rock Line
Approximate Ground Line
Bottom of Ftg. Elev. 274.264
Abutment #1 Concrete
Abutment #2 Piles
Bottom of Ftg. Elev. 272.313
ELEVATION
55'-7" PPC Box Beam, CB27, Span
HS25 Live Load - 30'-6" Shoulder Width @ Bridge
0° Skew - 22'-6" Bridge Roadway Width - 2:1 Fill Slopes
Ferguson Creek
Sta. 3+28.777 ℄ Brg. Abut. #1
Sta. 3+85.777 Begin Bridge
60° (Typ.)
N40° 20' 44" E
℄ Bridge & ℄ Survey
Sta. 3+82.300 ℄ Brg. Abut. #2
Sta. 3+63.300 End Bridge
12"
55'-7" ℄ Brg. to ℄ Brg.
57'-1" Out to Out of Bridge
12"
PLAN
~Superstructure not shown~
24'-0" - Out to Out of Slab
1'-3"
11'-3"
1'-3"
℄ Bridge & ℄ Survey
8" Slab
-2.0%
-2.0%
3'-0"
4-PPC Box Beam, Type SB-27 x 6'-0"x18'-0"
3'-0"
TYPICAL SECTION
REVISION
DATE
DATE February 2008
CHECKED BY
DESIGNED BY: C. Su
E. Rigore
DETAILED BY: B. Wilson
C. Su
Commonwealth of Kentucky
DEPARTMENT OF HIGHWAYS
DIST. LIVINGSTON
COUNTY Ferguson Creek
LAYOUT
ITEM NUMBER
Division of Bridge Design
Charlie Su / Graphics
SHEET NO. 69
DRAWING NO. 28075


ELEVATION
PLAN
TYPICAL SECTION
TOE OF SLOPE DETAIL
McCRACKEN

PRECAST SPREAD BOX BEAM BRIDGE

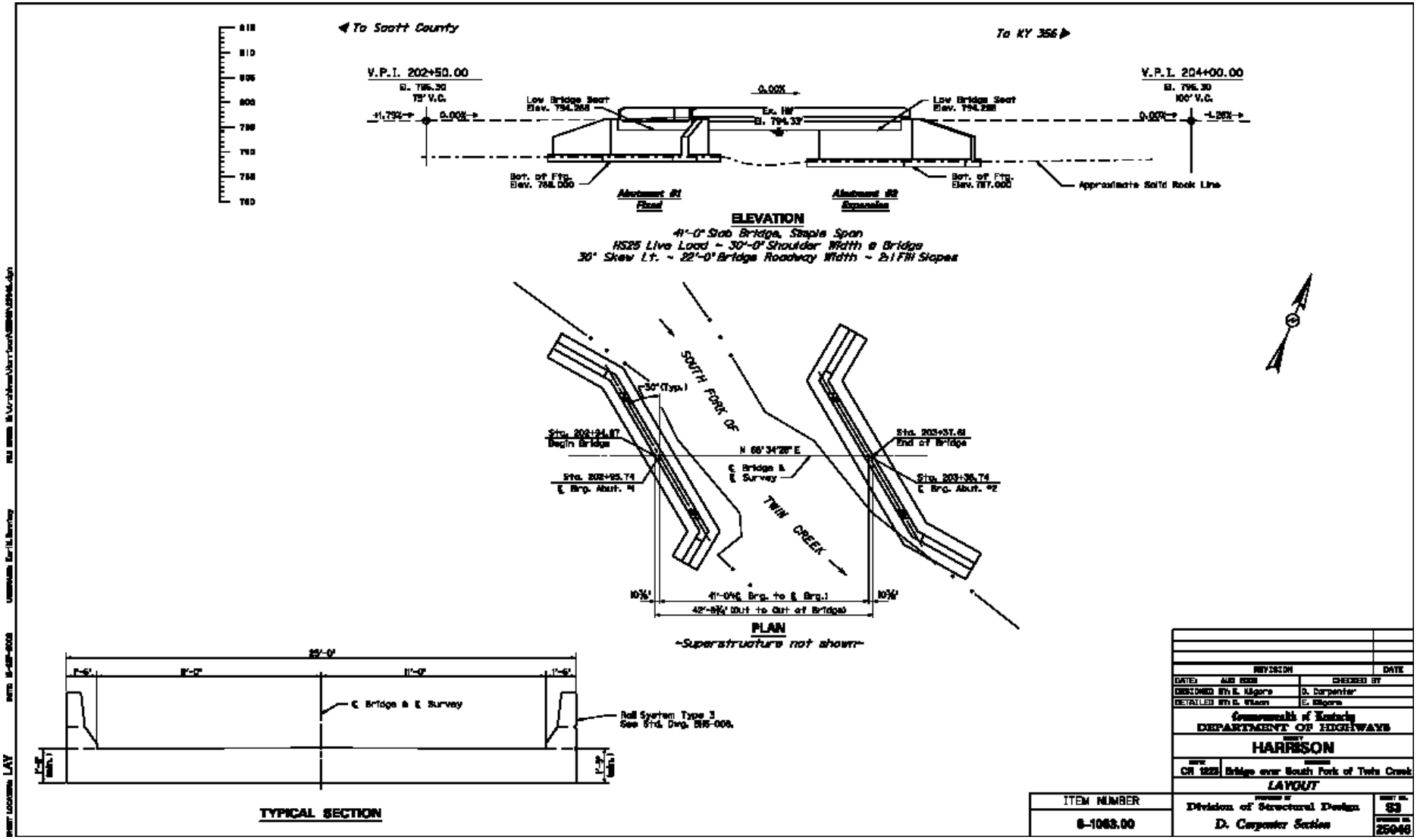
ADAIR COUNTY

PRECAST SPREAD BOX BEAM BRIDGE

ADAIR COUNTY

Slab Bridges

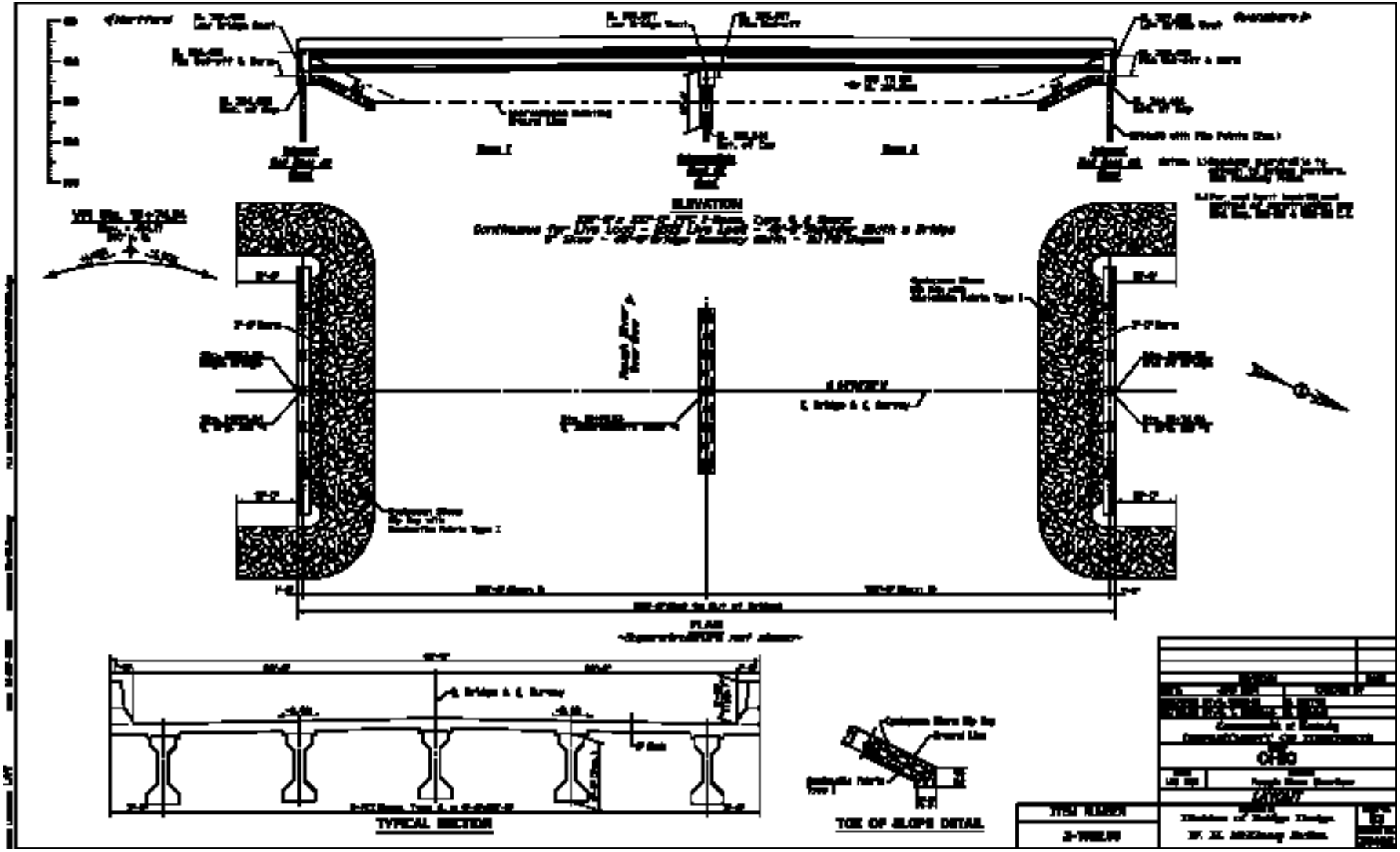
Are a competitive choice for 12”-17” box beam bridges.


To Scott County
To KY 356
V.P.I. 202+50.00
El. 786.30
75' V.C.
V.P.I. 204+00.00
El. 795.30
100' V.C.
Low Bridge Seat Elev. 794.268
Low Bridge Seat Elev. 794.288
Ex. HW El. 794.33'
Bot. of Ftg. Elev. 788.050
Bot. of Ftg. Elev. 787.000
Approximate Solid Rock Line
Abutment #1 Fixed
Abutment #2 Expansion
ELEVATION
41'-0" Slab Bridge, Simple Span
HS25 Live Load - 30'-0" Shoulder Width @ Bridge
30° Skew Lt. - 22'-0" Bridge Roadway Width - 2:1 Fill Slopes
SOUTH FORK OF TWIN CREEK
30° (Typ.)
Sta. 202+24.87 Begin Bridge
Sta. 202+65.74 ℄ Brg. Abut. #1
N 65° 34' 28" E
℄ Bridge & ℄ Survey
Sta. 203+37.61 End of Bridge
Sta. 203+38.74 ℄ Brg. Abut. #2
10½'
41'-0½" Brg. to ℄ Brg.
42'-8½" Out to Out of Bridge
PLAN
~Superstructure not shown~
25'-0"
1'-6"
11'-0"
℄ Bridge & ℄ Survey
Rail System Type 3 See Std. Dwg. RMS-006
TYPICAL SECTION
ITEM NUMBER
6-1063.00
Commonwealth of Kentucky
DEPARTMENT OF HIGHWAYS
HARRISON
CR 1823 Bridge over South Fork of Twin Creek
LAYOUT
Division of Structural Design
D. Carpenter Section
33
25046

Spread Concrete I Beams

- Spread concrete I beams are the most economical bridges that you can build.
- Do pay a penalty in depth.
- Type 1 28” deep Spans to 45’(don’t use)
- Type 2 36” deep Spans to 60’
- Type 3 45” deep Spans to 80’
- Type 4 54” deep Spans to 100’
- Type 5 60” deep Spans to 120’
- Type 6 66” deep Spans to 130’
- Type 7 72” deep Spans to 140’
- Type 8 78” deep Spans to 150’
- These are approximations and can be adjusted some.

Or you can call us


ELEVATION
PLAN
TYPICAL SECTION
TOE OF SLOPE DETAIL

WILLOW SLOUGH PCIB BRIDGE

BALLARD COUNTY

Spread Steel I Beams

- Steel is a step up in cost from concrete.
- 150’ to 550’ spans
- Approximate depth.
  - Simple spans 1/25 x span length
  - Tail spans of multi-span 1/25 x span length x 0.8
  - Interior span of multi-span 1/25 x span x 0.7

Or you can call us

Other Types - Toy Trusses

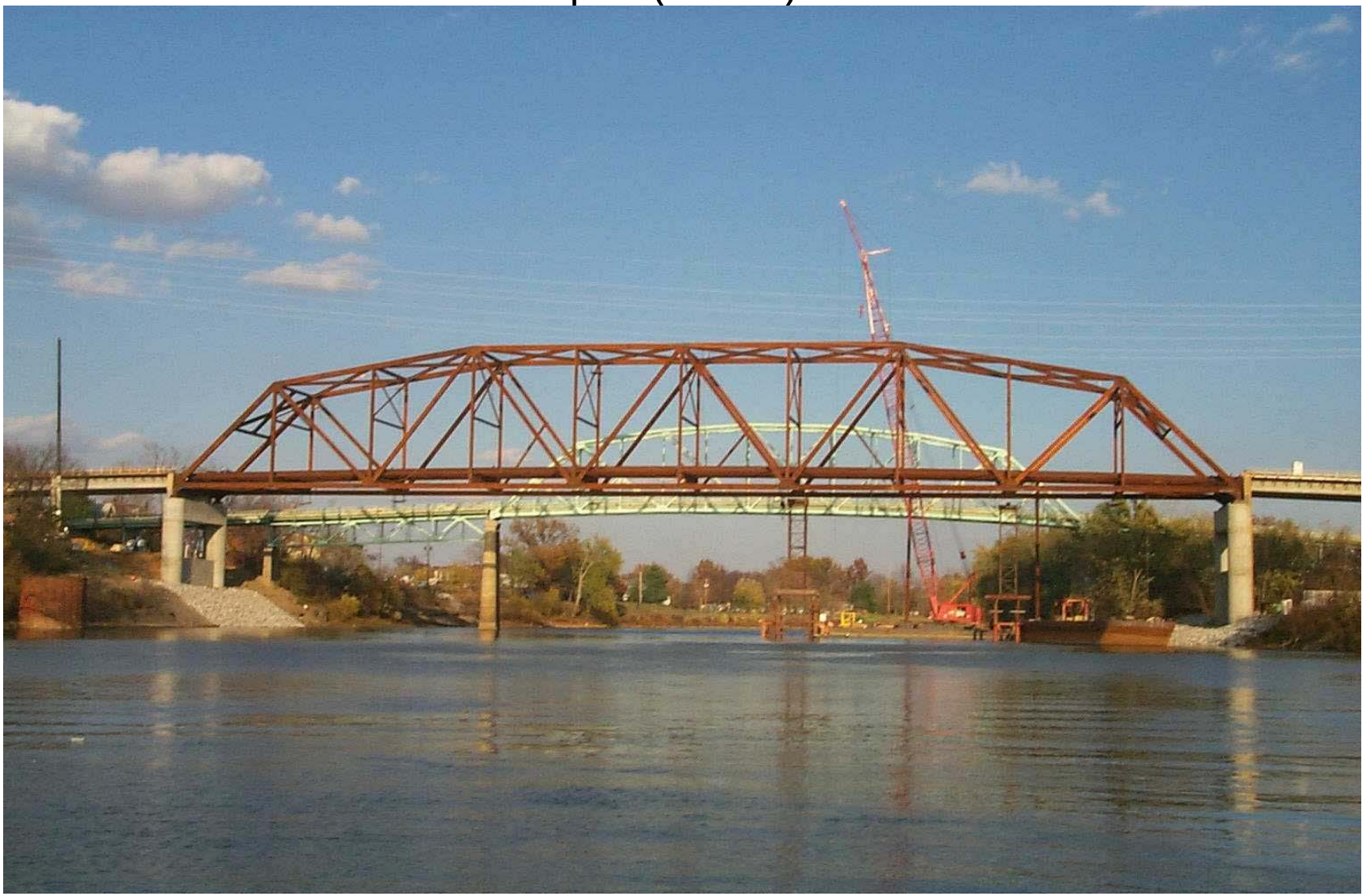
- These are not cost effective but are being used more and more for “mitigation” reason.


WEIGHT
LIMIT
12
TONS
6/8/2001

Other Types – Real Trusses

- These are cost effective for long spans (600’ – 1000’).
- The are not favored these days because they are not consider pretty. They have a track record of more than 100 years but you have to watch your welds.

Medium Span (150 M) Steel Truss



Long Span (786') "Draconian" Steel Truss

Other Types – Cable Stayed

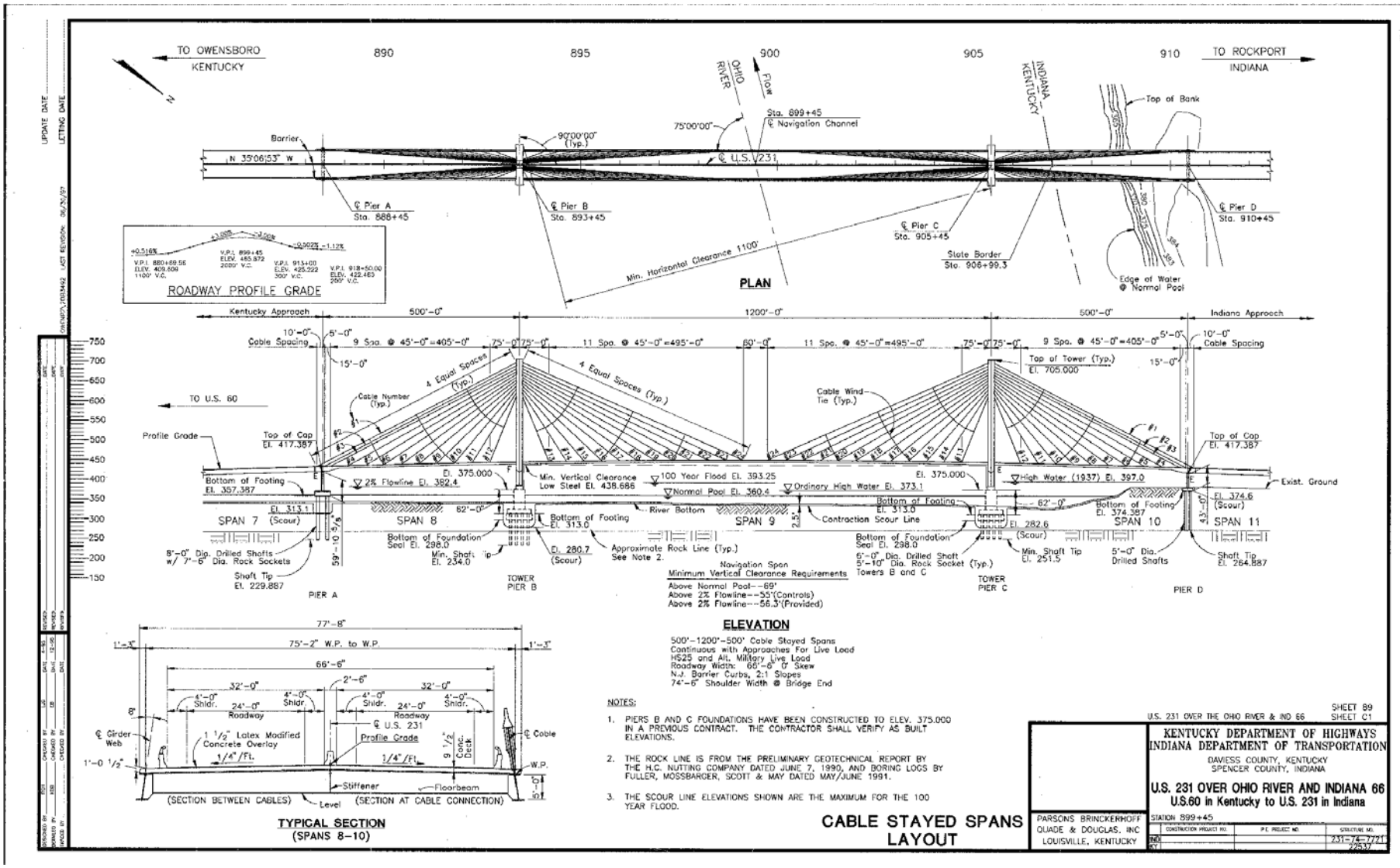
- Not generally cost effective under 1000’ but very pretty. Considered “signature” structures. All communities want a signature structure, especially if someone else is paying for it.

Maysville Bridge

WINNER OF THE A.C.E.C. 2001 GRAND CONCEPTOR AWARD
FOR ENGINEERING EXCELLENCE (WHATEVER THAT IS).
A truss would have been a lot cheaper but you don't get awards for that.

Owensboro Bridge which is not anywhere near Owensboro

1200’ span with 4 lanes probably needed to be a cable stayed


TO OWENSBORO
KENTUCKY
TO ROCKPORT
INDIANA
OHIO RIVER FLOW
INDIANA - KENTUCKY
Top of Bank
Barrier
N 35°06'53" W
℄ Pier A
Sta. 888+45
℄ Pier B
Sta. 893+45
℄ Pier C
Sta. 905+45
℄ Pier D
Sta. 910+45
Sta. 899+45
℄ Navigation Channel
℄ U.S. 231
State Border
Sta. 908+99.3
Min. Horizontal Clearance 1100'
Edge of Water
@ Normal Pool
PLAN
ROADWAY PROFILE GRADE
Kentucky Approach
500'-0"
1200'-0"
500'-0"
Indiana Approach
Cable Spacing
9 Spa. @ 45'-0" = 405'-0"
11 Spa. @ 45'-0" = 495'-0"
4 Equal Spaces (Typ.)
Top of Tower (Typ.)
El. 705.000
TO U.S. 60
Cable Number (Typ.)
Cable Wind-Tie (Typ.)
Profile Grade
Top of Cap
El. 417.387
Bottom of Footing
El. 357.387
El. 313.1
(Scour)
SPAN 7
SPAN 8
SPAN 9
SPAN 10
SPAN 11
El. 375.000
2% Flowline El. 382.4
Min. Vertical Clearance
Low Steel El. 438.686
100 Year Flood El. 393.25
Normal Pool El. 360.4
Ordinary High Water El. 373.1
High Water (1937) El. 397.0
Exist. Ground
El. 374.6
(Scour)
River Bottom
Bottom of Footing
El. 313.0
Contraction Scour Line
Bottom of Footing
El. 374.387
Bottom of Foundation
Seal El. 298.0
Min. Shaft Tip
El. 234.0
El. 280.7
(Scour)
Approximate Rock Line (Typ.)
See Note 2.
El. 282.6
(Scour)
6'-0" Dia. Drilled Shaft
5'-10" Dia. Rock Socket (Typ.)
Towers B and C
Min. Shaft Tip
El. 251.5
5'-0" Dia.
Drilled Shafts
Shaft Tip
El. 264.887
8'-0" Dia. Drilled Shafts
w/ 7'-6" Dia. Rock Sockets
Shaft Tip
El. 229.887
59'-10 5/8"
62'-0"
43'-0"
PIER A
TOWER PIER B
TOWER PIER C
PIER D
Navigation Span
Minimum Vertical Clearance Requirements
Above Normal Pool--69'
Above 2% Flowline--55'(Controls)
Above 2% Flowline--56.3'(Provided)
ELEVATION
500'-1200'-500' Cable Stayed Spans
Continuous with Approaches For Live Load
HS25 and Alt. Military Live Load
Roadway Width: 66'-6" Skew
N.J. Barrier Curbs, 2:1 Slopes
74'-6" Shoulder Width @ Bridge End
77'-8"
75'-2" W.P. to W.P.
66'-6"
32'-0"
24'-0"
Roadway
4'-0" Shldr.
2'-6"
1'-3"
1'-3"
8"
℄ Girder Web
1 1/2" Latex Modified Concrete Overlay
1/4"/Ft.
℄ U.S. 231
Profile Grade
9 1/2" Conc. Deck
℄ Cable
W.P.
Stiffener
Floorbeam
(SECTION BETWEEN CABLES)
Level
(SECTION AT CABLE CONNECTION)
TYPICAL SECTION
(SPANS 8-10)
NOTES:
1. PIERS B AND C FOUNDATIONS HAVE BEEN CONSTRUCTED TO ELEV. 375.000 IN A PREVIOUS CONTRACT. THE CONTRACTOR SHALL VERIFY AS BUILT ELEVATIONS.
2. THE ROCK LINE IS FROM THE PRELIMINARY GEOTECHNICAL REPORT BY THE H.C. NUTTING COMPANY DATED JUNE 7, 1990, AND BORING LOGS BY FULLER, MOSSBARGER, SCOTT & MAY DATED MAY/JUNE 1991.
3. THE SCOUR LINE ELEVATIONS SHOWN ARE THE MAXIMUM FOR THE 100 YEAR FLOOD.
CABLE STAYED SPANS LAYOUT
U.S. 231 OVER THE OHIO RIVER & IND 66
SHEET 89
SHEET C1
KENTUCKY DEPARTMENT OF HIGHWAYS
INDIANA DEPARTMENT OF TRANSPORTATION
DAVIESS COUNTY, KENTUCKY
SPENCER COUNTY, INDIANA
U.S. 231 OVER OHIO RIVER AND INDIANA 66
U.S.60 in Kentucky to U.S. 231 in Indiana
STATION 899+45
PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC
LOUISVILLE, KENTUCKY
231-74-7721
22537

Other Types – box girders

- These are almost never economical.
  - Post-Tension Concrete
  - Steel Box

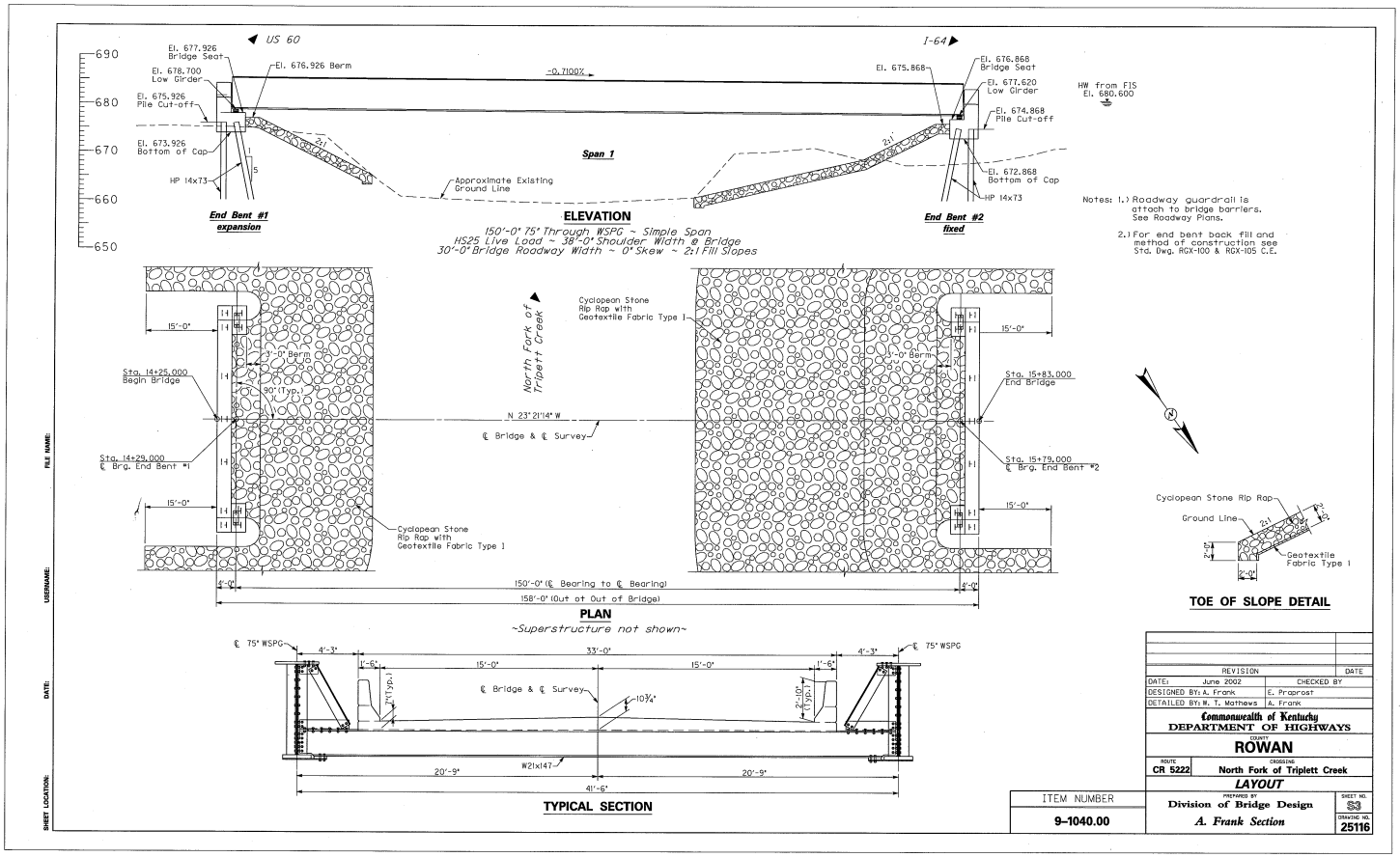
Steel Box Girder

(Expensive but you get to go on the lecture circuit)

Other Types - Through Girders

- If the span is long and the available depth is not.
- PG to low steel controlled by cross girder depth which is controlled by roadway width.

Rowan County



Abutment Types

- Wall
- Spill-through slopes.
- MSE Walls

Wall Type Abutments

- Economical when the distance from rock to bridge seat is < 15 - 20’
- Over 20’ they get kind of pricy and it becomes cheaper to lengthen the bridge and use spill-through slopes even if you have to add spans.

Wing Wall Abutment

Spill-through slopes

- These are the most economical but you need about 15’ minimum to rock.

Spill-Through Slopes

MSE Walls

- Some designers use MSE walls as a means to shorten the bridge.
- When you do the numbers correctly, there is little of no savings and we do not favor them because the critical element, the straps, cannot be inspected.
- We do use them for retaining walls since the consequences of failure are not as great.

Basic Calculations – Structure Depth

Four components

Cross slope to exterior girder

- Assume exterior girder is 3.5’ from outside face of parapet wall.

Slab

- Assume 8” for typical concrete bridge.
- Assume 5” for composite side by side.
- Assume 9” for steel girders.

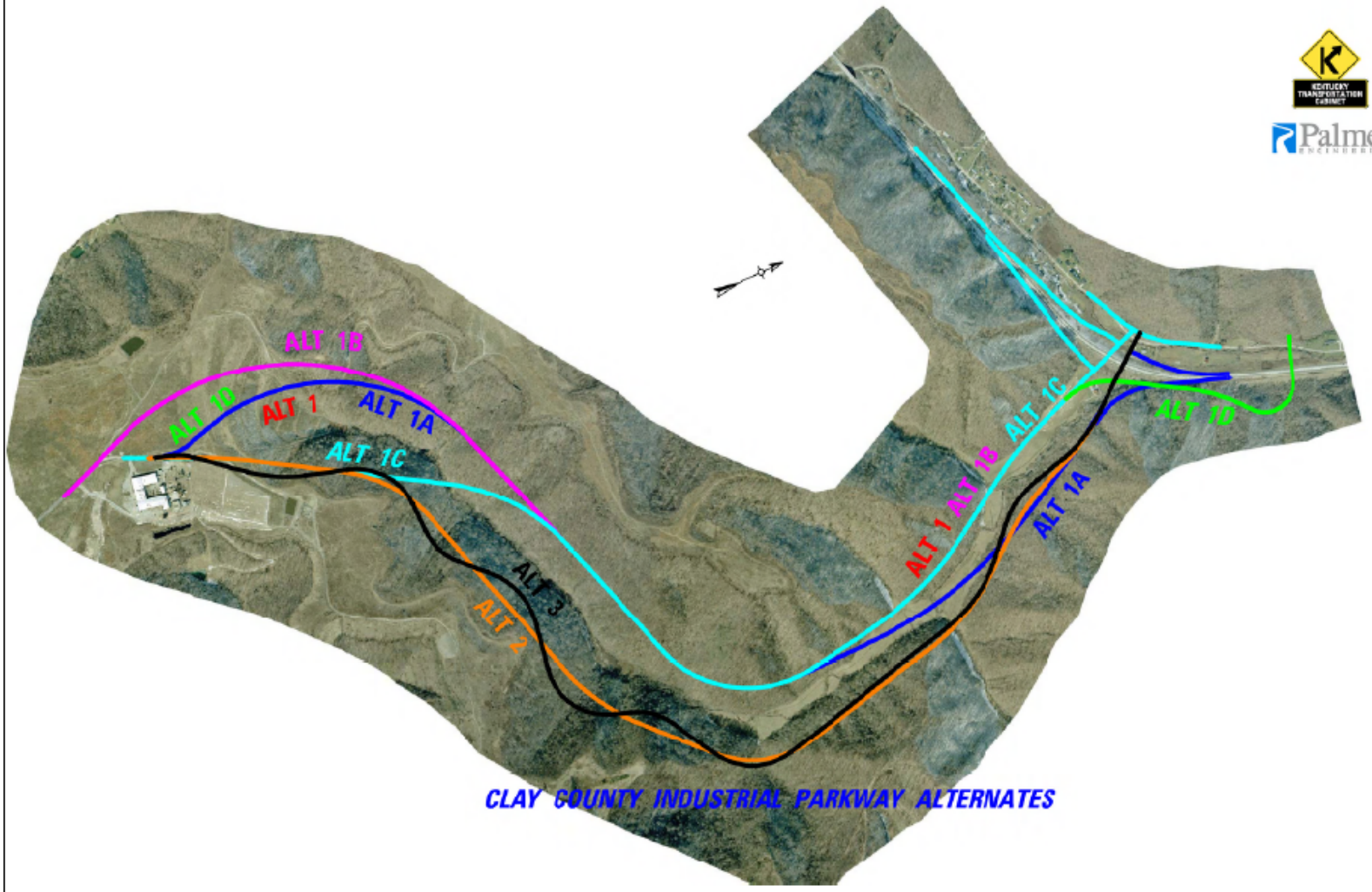
Haunch

- Assume 2” for typical concrete bridge.
- Assume 1” for composite side by side box beams.
- Assume 3” for steel girders.

Beam Depth (see previous slides)

Basic Calculations – Bridge Length

- Use clear distance between faces of abutments. We will determine the beginning and end bridge stations based on skew, beam type , expansion joint requirements, etc.
- Put piers anywhere you want to.
  - Single span with spill through slopes most economical
  - Stay in concrete beam range if possible
  - Looks bad when you put pier in middle of creek.
- When using spill through slopes assume 1’ berm for dry structures and 3’ for wet structures.


ALT 1B
ALT 1D
ALT 1
ALT 1A
ALT 1C
ALT 3
ALT 2
ALT 1
ALT 1B
ALT 1C
ALT 1D
ALT 1A
CLAY COUNTY INDUSTRIAL PARKWAY ALTERNATES

Things to avoid if possible

- Curved bridges. They are frequently necessary (and we do a lot of them) but they are more expensive than straight bridges.
- Super elevation transition on bridge. We can draw it up easier than it can be built.
- >40 degree skews

Things to do if possible

- Raise grade. More vertical clearance will generally allow for a more economical structure so on projects where right of way and embankment cost are not controlling, raise the grade a bit.
- Spill through slopes with Type 2, 3 or 4 PCI-beams generally produce the most economical structure.

Geotechnical

- Request soundings as early as possible, i.e. preliminary line and grade
- Speeds up project. If we wait to ADF submittal, project may take 6 months longer
- Some project decisions are geotechnical dependent.
- Three sided culverts and abutment type.
- Needed for scour calculation.

Railroads

- Get with RR early in the project to determine their requirements. Some want provision for future double tracking.
- Provide about 28’ from the centerline of the nearest track (or future track) to the centerline of piers.
- Be prepared for longer project development since RR approvals can take a while.
- Railroads over highways are a special situation and really take a long time.

Coast Guard Involvement

- Bridges over navigable streams obviously require Coast Guard Permits but bridges over creeks and rivers near where they enter navigable streams also require Coast Guard Permits. Applying for and getting a Coast Guard Permit requires a significant amount of additional effort and takes forever.

Buzz Words

Context Sensitive Design

Signature Structure

Type Study

Public Involvement

Historic Structure SHPO

Practical Solutions

CITATION BOULEVARD - FAYETTE COUNTY

GLADIE CREEK - MENIFEE COUNTY

This bridge is destined to be more famous than the nearby natural bridges

PARIS PIKE - FAYETTE COUNTY
When the budget is not the context

BLUE LICKS STATE PARK PEDESTRIAN BRIDGE

LINCOLN HOMESTEAD STATE PARK

This is not a good example since the form liners and timber fascia did not add much to the cost of a project in a park setting.

Cemetery Road

What if you spend a bunch of money and nobody notices?

Overall project success is still the main goal.

- This seems redundant but we in Structural Design realize that overall project success is the goal.
- Things that make a bridge the most economical may not make the overall project the most economical or meet project goals.
- Believe it or not, at the end of the day we prefer to design complicated and expensive bridges because they are usually the most professionally rewarding.
- And when necessary we are even willing co-conspirators in sacrificing public money to the aesthetic gods at the alter of context sensitive design.
- Last but not least, call us if you need to but do not submit the ADF in until all bridge issues are settled. We can start the final design **after** ADF and Geotech report are **finalized;** any changes after that have cost and scheduling consequences.

Division of Structural Design

"We were Practical when Practical wasn't Cool."