Designing & Specifying Cost Effective Concrete Pavements

NWPMA 2017 CONFERENCE

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What Affects PCCP Costs

- Thickness
- Design Details
- Materials Requirements
- Equipment Requirements
- Geometrics
- Staging

PCCP Thickness Design

- Use appropriate design procedures
  - Empirical (AASHTO 93)
    - Typically very conservative, especially at high levels of reliability
    - Ensure that appropriate inputs are used – LOS, Drainage, Strength
    - Use appropriate load equivalency factors
  - Mechanistic/Empirical
    - AASHTO Pavement ME – StreetPave/Pavementdesigner.org
      - More reasonable/accurate designs
      - Use best available load data
      - Use appropriate reliability
      - Use appropriate strength

Design Details

- Dowels
- Tie bars
- Joint layout
- Curb

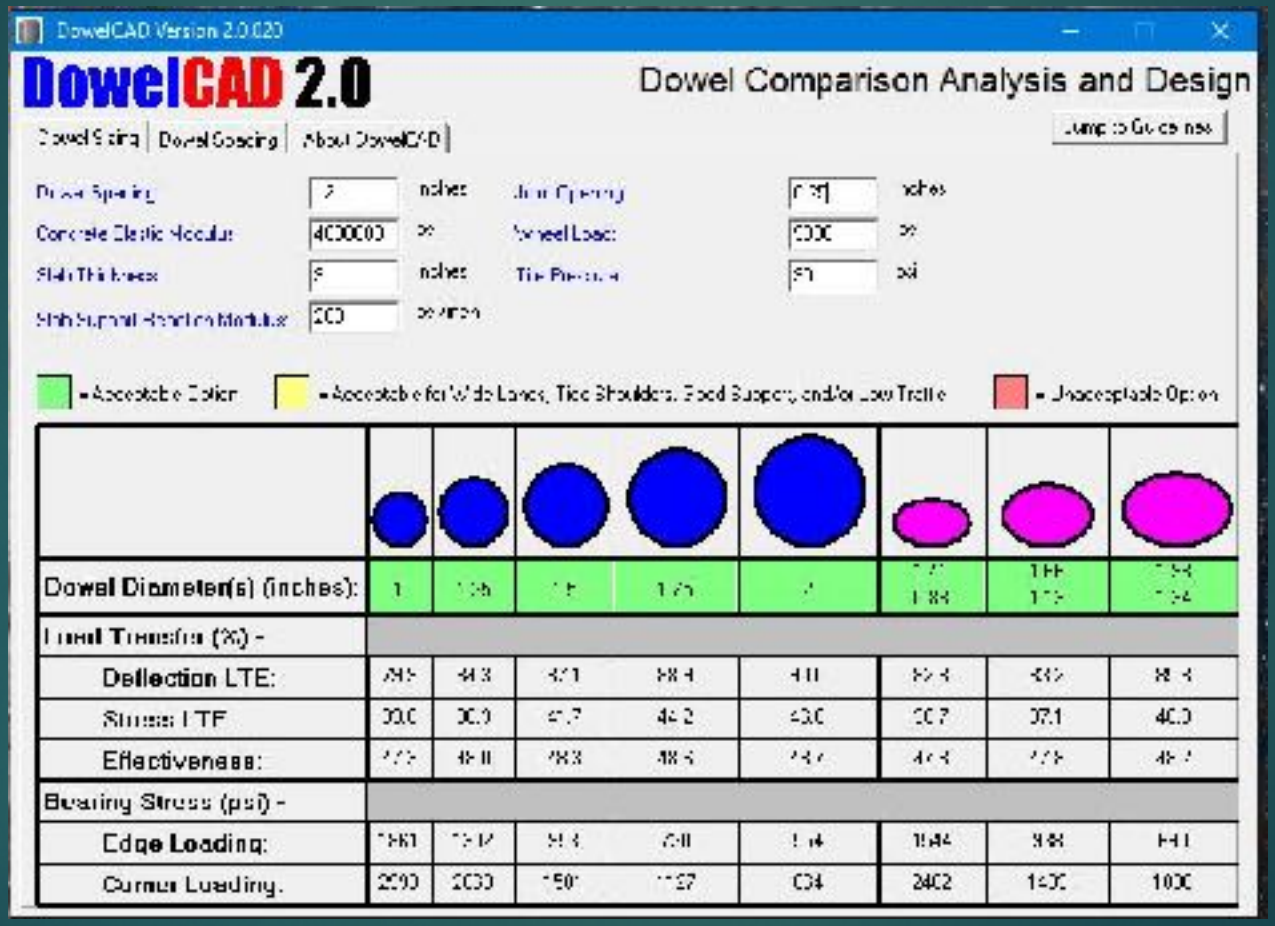
Dowel Bars

- Are dowels necessary
  - Based on predicted failure mode
    - Run design with and without dowels
    - If predicted failure mode is cracking, dowels may not be necessary
  - Traffic level
    - If more than 100 heavy trucks/busses per day. Consider dowels
  - Reduce need for dowels
    - Shorter joint spacing
    - Stabilized base

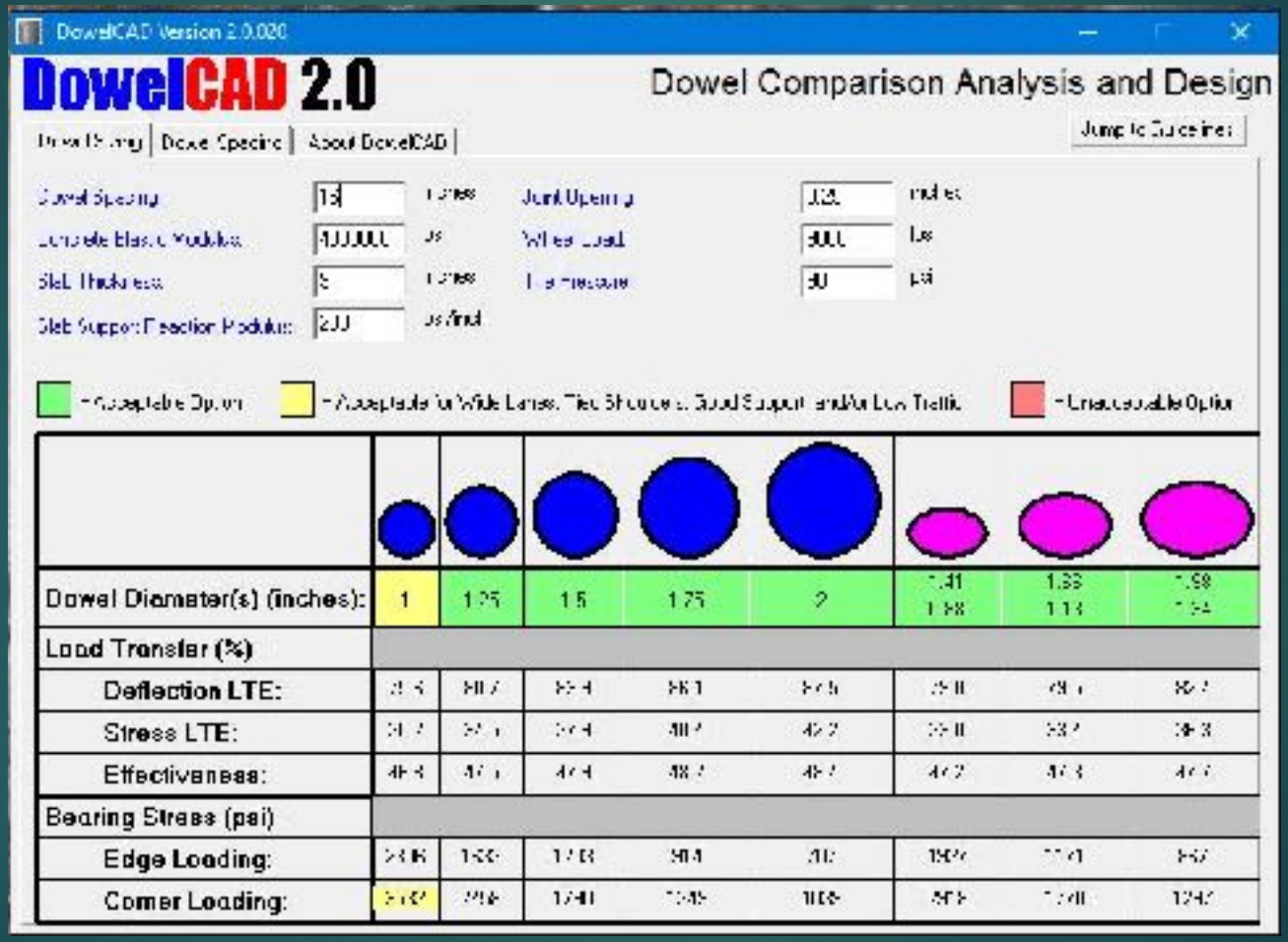
Dowel Bars

- Optimize dowel bar design
  - Dowel CAD 2.0
    - Check dowel size
    - Check dowel Spacing
    - Check number of dowels
    - Available at http://apps.acpa.org/applibrary/ can also be reached through pavement.com

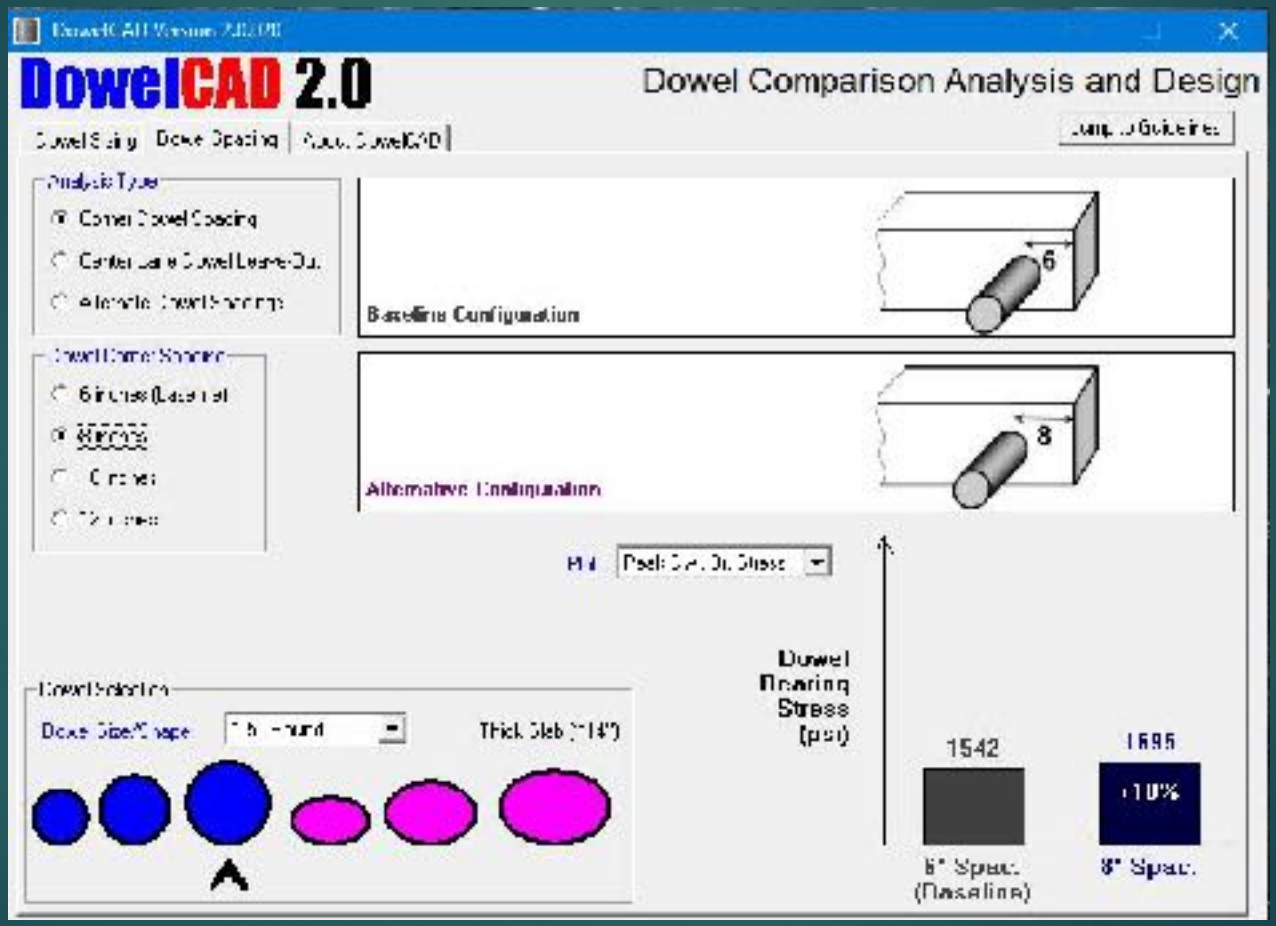
Dowel Bars


DowelCAD Version 2.0.020
DowelCAD 2.0
Dowel Comparison Analysis and Design
Dowel Sizing
Dowel Spacing
About DowelCAD
Concrete Elastic Modulus:
4000000
psi
Slab Thickness:
8
inches
Slab Support Modulus:
200
psi/in
= Acceptable Option
= Acceptable for Wide Lanes, Tied Shoulders, Good Support, and/or Low Traffic
= Unacceptable Option
Dowel Diameter(s) (inches):
Load Transfer (%) -
Deflection LTE:
Stress LTE:
Effectiveness:
Bearing Stress (psi) -
Edge Loading:
Corner Loading:

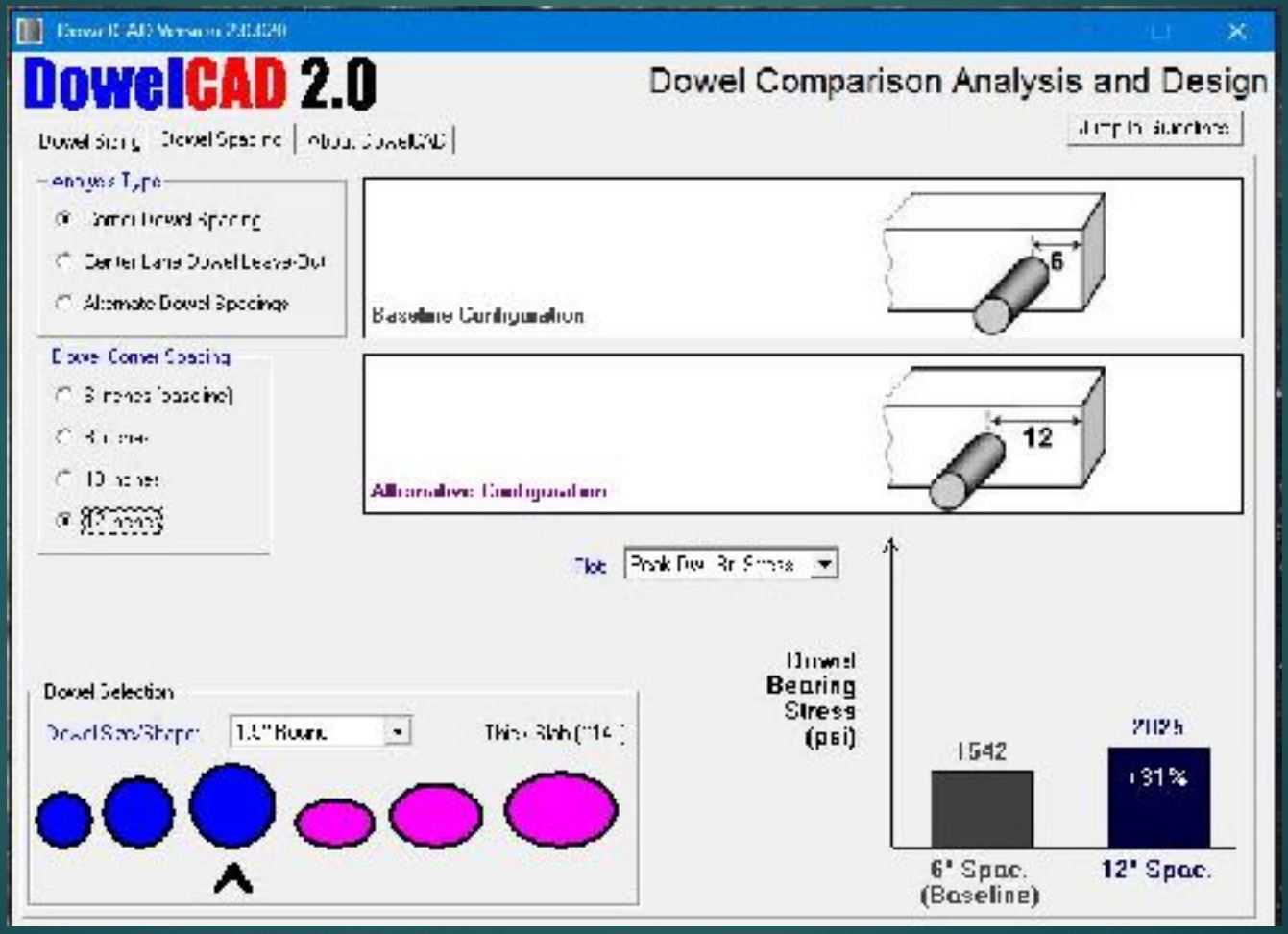
Dowel Bars


DowelCAD Version 2.0.020
DowelCAD 2.0
Dowel Comparison Analysis and Design
About DowelCAD
Dowel Diameter(s) (inches):
1
1.25
1.5
1.75
2
Load Transfer (%)
Deflection LTE:
Stress LTE:
Effectiveness:
Bearing Stress (psi)
Edge Loading:
Corner Loading:

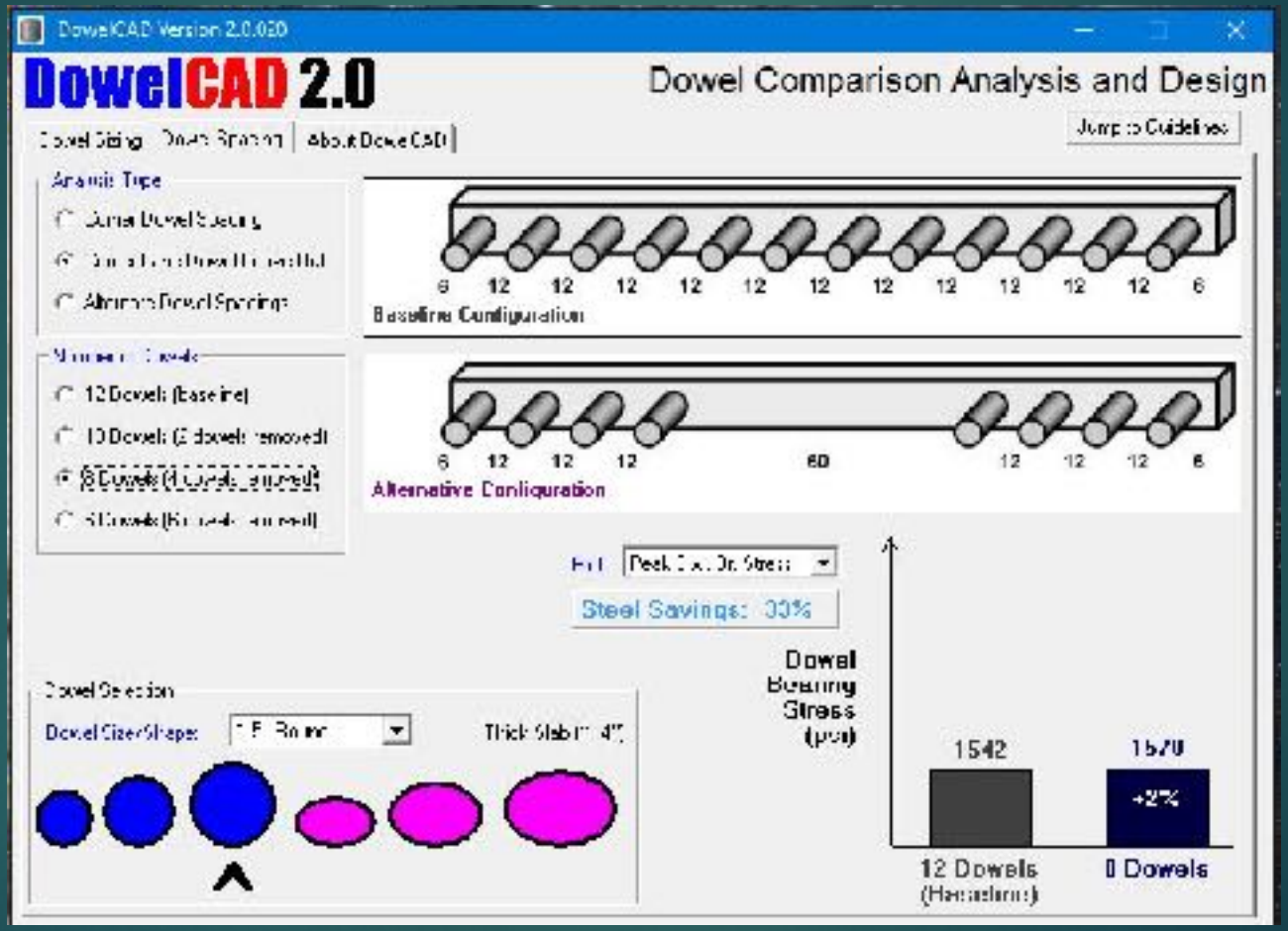
Dowel Bars


DowelCAD 2.0
Dowel Comparison Analysis and Design
Baseline Configuration
6
Alternative Configuration
8
Dowel Bearing Stress (psi)
1542
1695
+10%
6" Spac. (Baseline)
8" Spac.

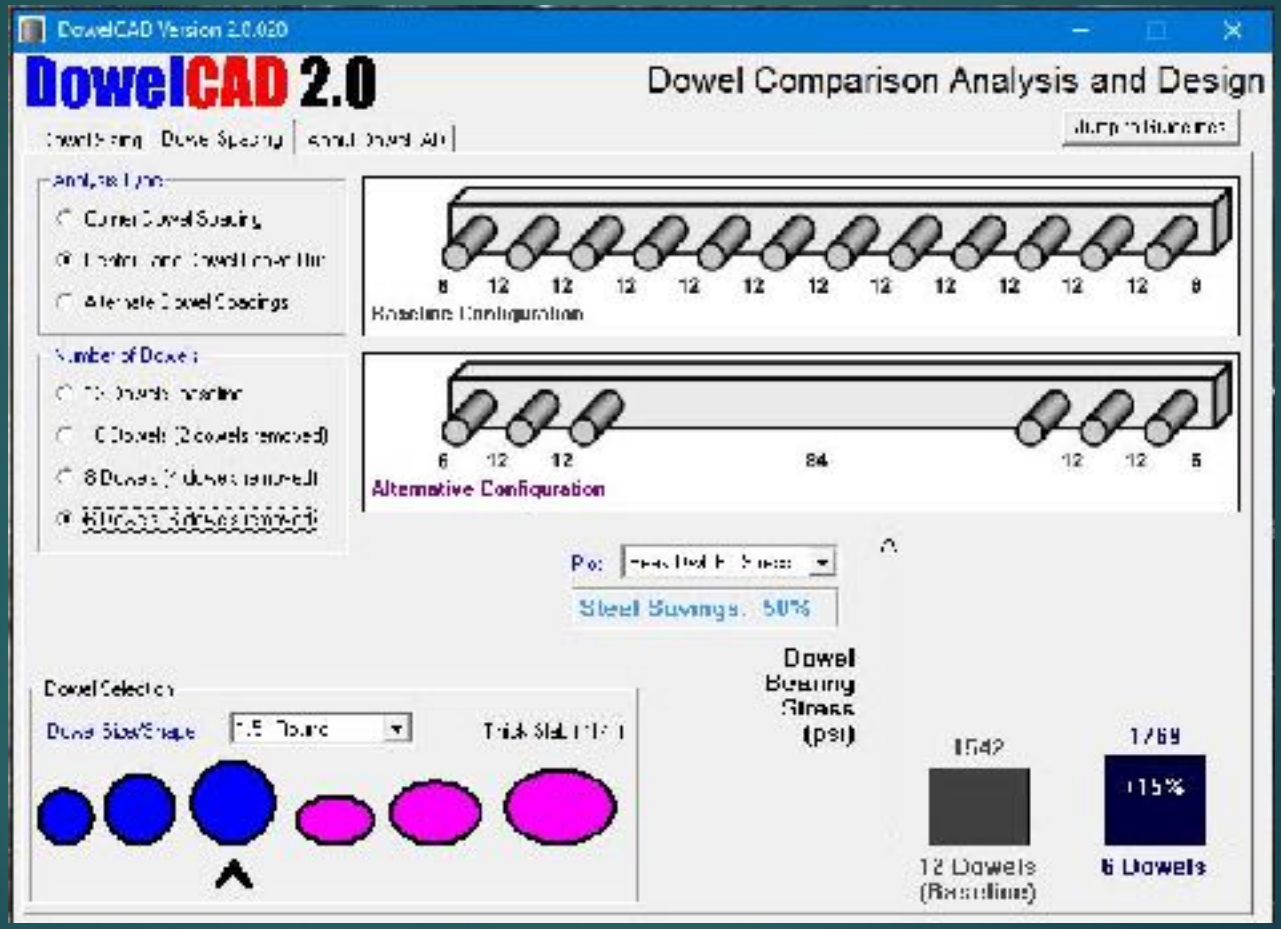
Dowel Bars


DowelCAD 2.0
Dowel Comparison Analysis and Design
Dowel Sizing
Dowel Spacing
About DowelCAD
Jump to Summary
Baseline Configuration
6
Alternative Configuration
12
Plot
Dowel Selection
Dowel Size/Shape:
1.5" Round
Thick Slab (14")
Dowel Bearing Stress (psi)
1542
2029
+31%
6" Spac. (Baseline)
12" Spac.

Dowel Bars


DowelCAD Version 2.0.020
DowelCAD 2.0
Dowel Comparison Analysis and Design
Jump to Guidelines
6 12 12 12 12 12 12 12 12 12 12 12 6
Baseline Configuration
6 12 12 12 60 12 12 12 6
Alternative Configuration
Steel Savings: 33%
Dowel Bearing Stress (psi)
1542
1570
+2%
12 Dowels
0 Dowels
Dowel Selection
Thick Slab: 4"

Dowel Bars

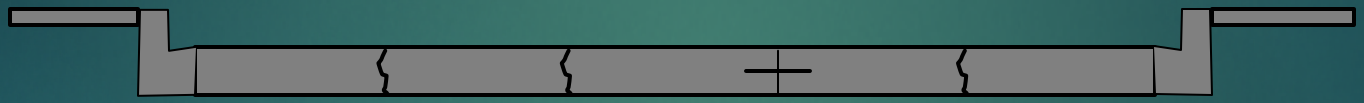

DowelCAD Version 2.0.020
DowelCAD 2.0
Dowel Comparison Analysis and Design
6 12 12 12 12 12 12 12 12 12 12 12 6
Alternative Configuration
6 12 12 84 12 12 6
Steel Savings: 50%
Dowel Bearing Stress (psi)
1542
1769
15%
12 Dowels (Baseline)
6 Dowels

Tie Bars

- Are tie bars necessary
  - Tie bars are not typically designed for load transfer
  - Tie bars are used to stop progressive joint opening and maintain aggregate interlock on longitudinal joints

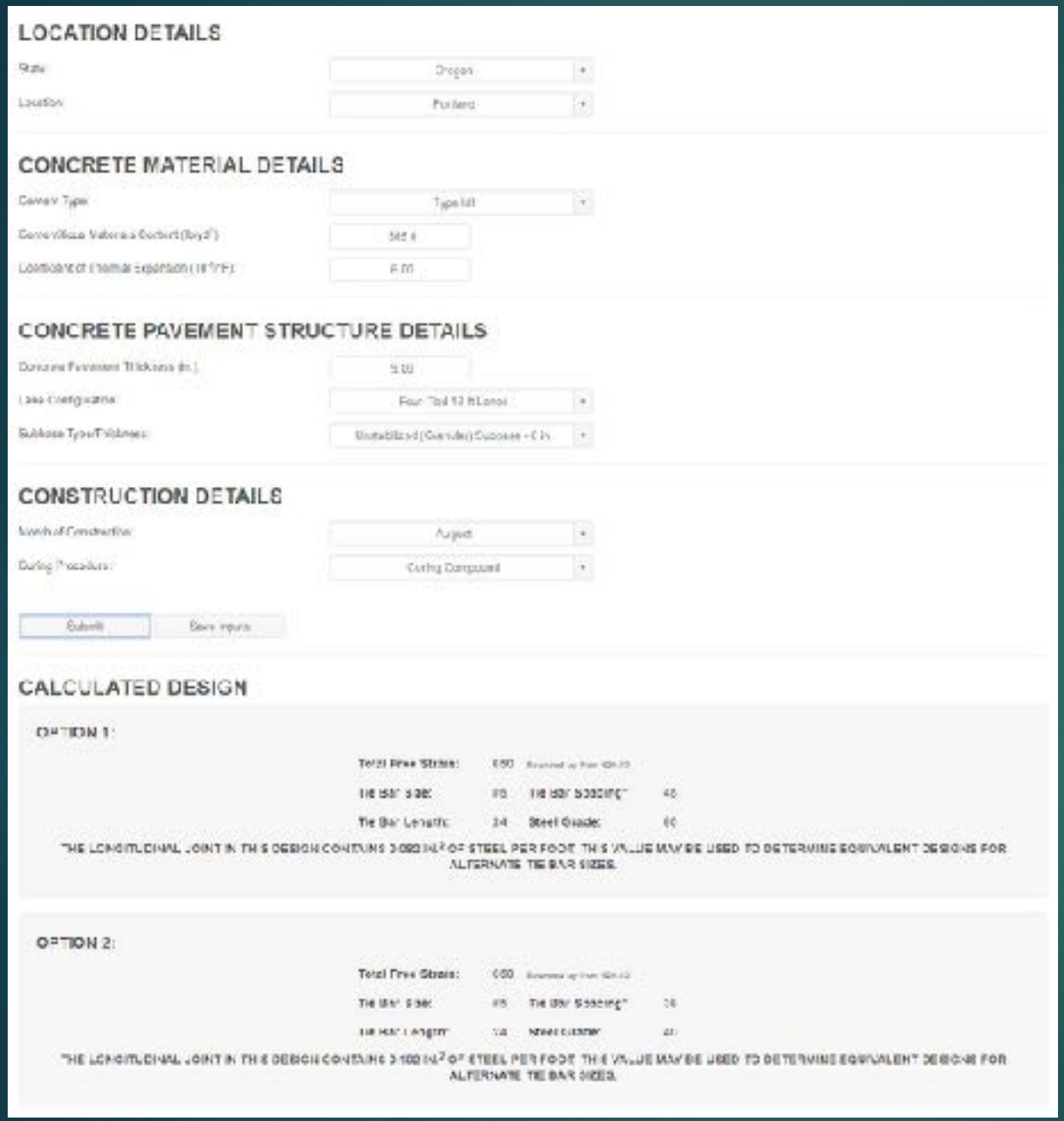
Tie Bars

- With lateral restraint, tie bars are not necessary on contraction joints



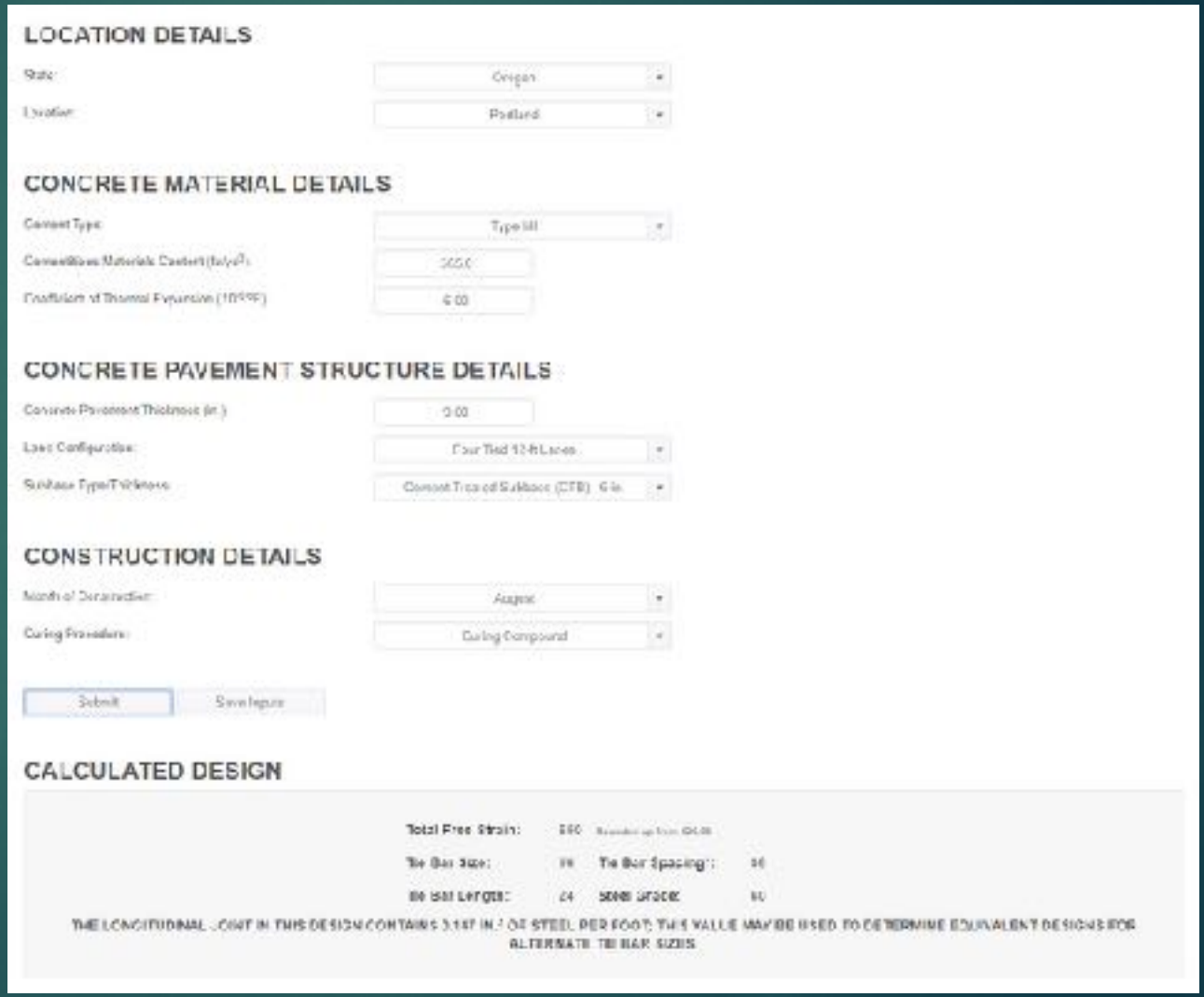
Tie Bar Design

- ME Tie Bar Designer
  - Developed from ME analysis
  - Based on "A Mechanistic-Empirical Tie Bar Design Approach for Concrete Pavements"
  - Available at http://apps.acpa.org/applibrary can also be reached through pavement.com



Tie Bar Design

Tie Bar Design



Joint Layout

- Try to layout joints in logical paving lanes
- Allow contractor proposed changes provided they meet your general criteria for spacing, etc.

Joint Layout

Curb

- Vertical curb placed prior to paving can require extensive labor and intrusive measures.

Curb

- Without a gutter for equipment to ride on, rails must be placed, and then dug out and finished over.

Curb

- Vertical curb can also further restrict the width of the placing equipment

Materials Requirements

- Maximum aggregate size
- Aggregate gradations
- Cement content
- Strength

Maximum Aggregate Size

- Large maximum aggregate size affects placibility
- Large maximum aggregate size affects aggregate interlock load transfer and durability
- Very large aggregates can be difficult or expensive to obtain
- Maximum aggregate size of 1" to 1 ½" is typically best

Aggregate Gradations

- Typical specifications for coarse and fine aggregates frequently result in gap graded mixes
- Gap gradation affects workability and cement requirements
- Requiring a well graded aggregate will improve workability and strength
- Well graded aggregates can also reduce the minimum required cement content

Cement Content

- As the most expensive constituent of a mix, cement content can significantly affect material costs
- Higher early strength requirements may increase required cement contents

Strength Requirements

- Requiring more strength than necessary may increase costs
- All design procedures are based on average strengths, not minimum strengths
- Designing for a given strength, then specifying that as the minimum will result in a conservative section, and increase costs

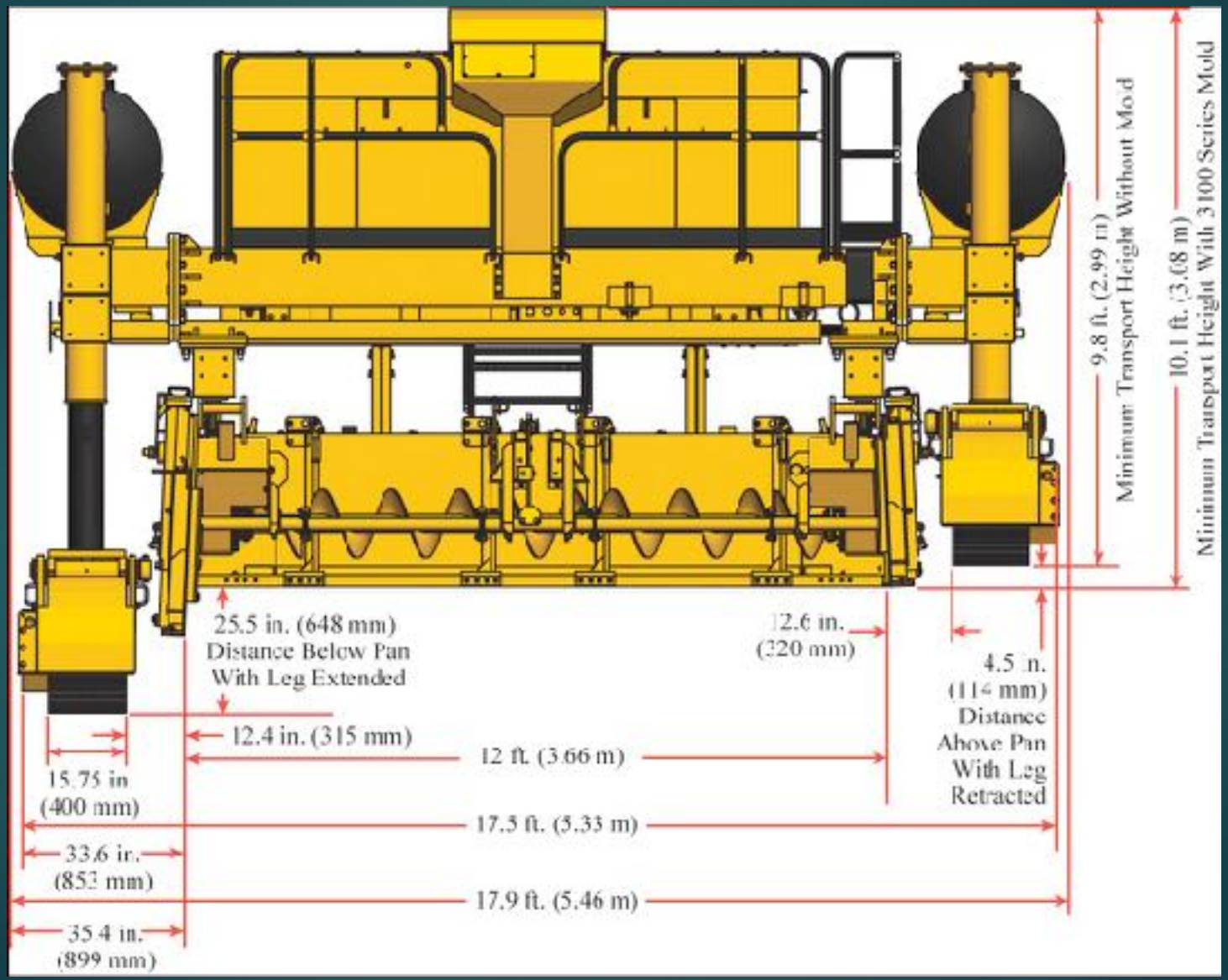
Equipment Requirements

- Concrete pavement can be placed with either slipform pavers or stationary side form equipment.
- As a general rule, large quantities placed with slipform equipment have a lower unit cost due to labor requirements

Slipform Pavers

- Slipform pavers use multiple vibrators to fluidize a stiff mix, and extrude it out the back of the paver.
- Slipform paving significantly reduces labor costs, and increases production rates.

Slipform Paver



Slipform Paver

Slipform Paver

Slipform Paver

Slipform Paver

Slipforming Integral Curb

Form Riding Screeds

- Roller screeds
  - Single tube
  - Multi tube ride on
- Truss screeds
- Roller pavers

Single Tube Roller Screed

- Flexible
- Can be used in tight quarters

Single Tube Roller Screed

Single Tube Roller Screed

Multi Tube Ride On Screed

- Larger than single tube
- Less labor required
- Adjustable width **Within Limits**
- Heavy

Multi Tube Screed

Multi Tube Screed

Multi Tube Screed

Multi Tube Screed

Truss Screeds

- Can be vibratory, but only effective a few inches down
- Lighter than multi tube roller screed
- Require cabling to move
- Adjustable width **Within Limits**

Truss Screed

Truss Screed

Truss Screed

Roller Paver “Bidwell”

- Heavier than roller screeds or truss screeds
- Require rails

Roller Paver

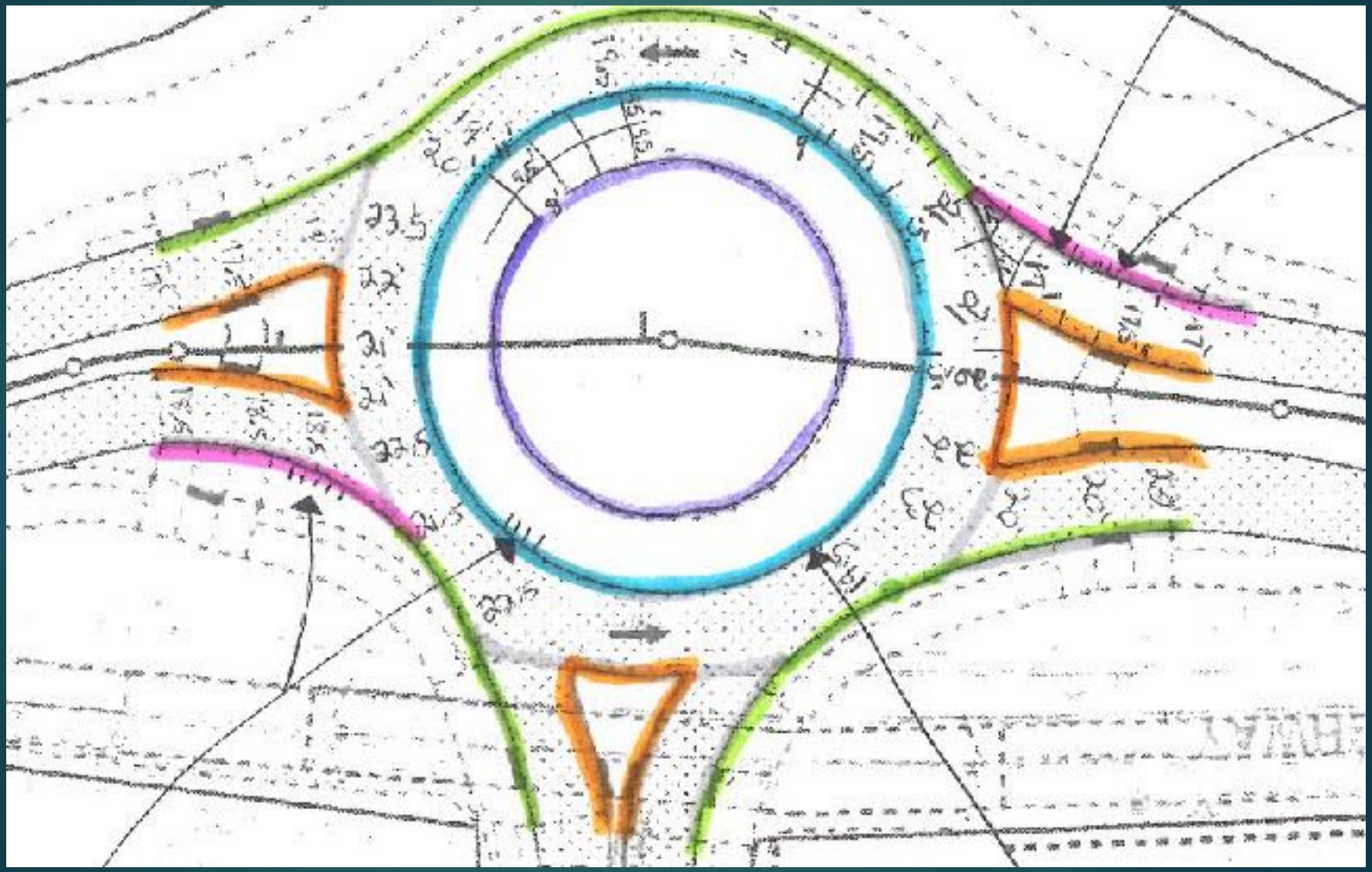
Which is Best?

- Each has it's own advantages and disadvantages
- All can produce quality concrete when run properly
- Depends on the application

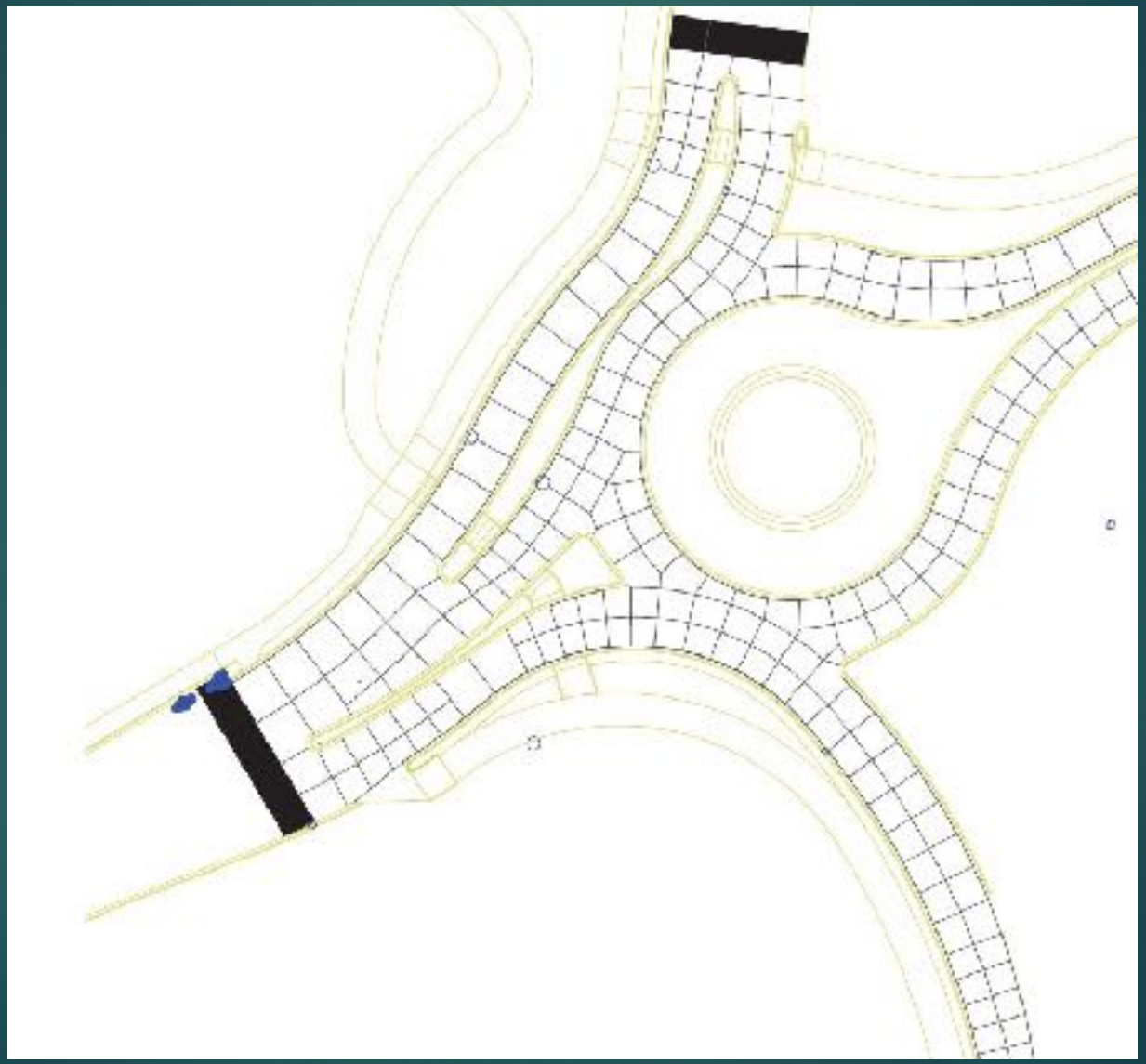
Geometrics

- Geometrics can affect what equipment can be used
- Slipform pavers, ride on roller screeds, truss screeds, and roller pavers can be difficult or impossible to use with variable widths.

Geometrics



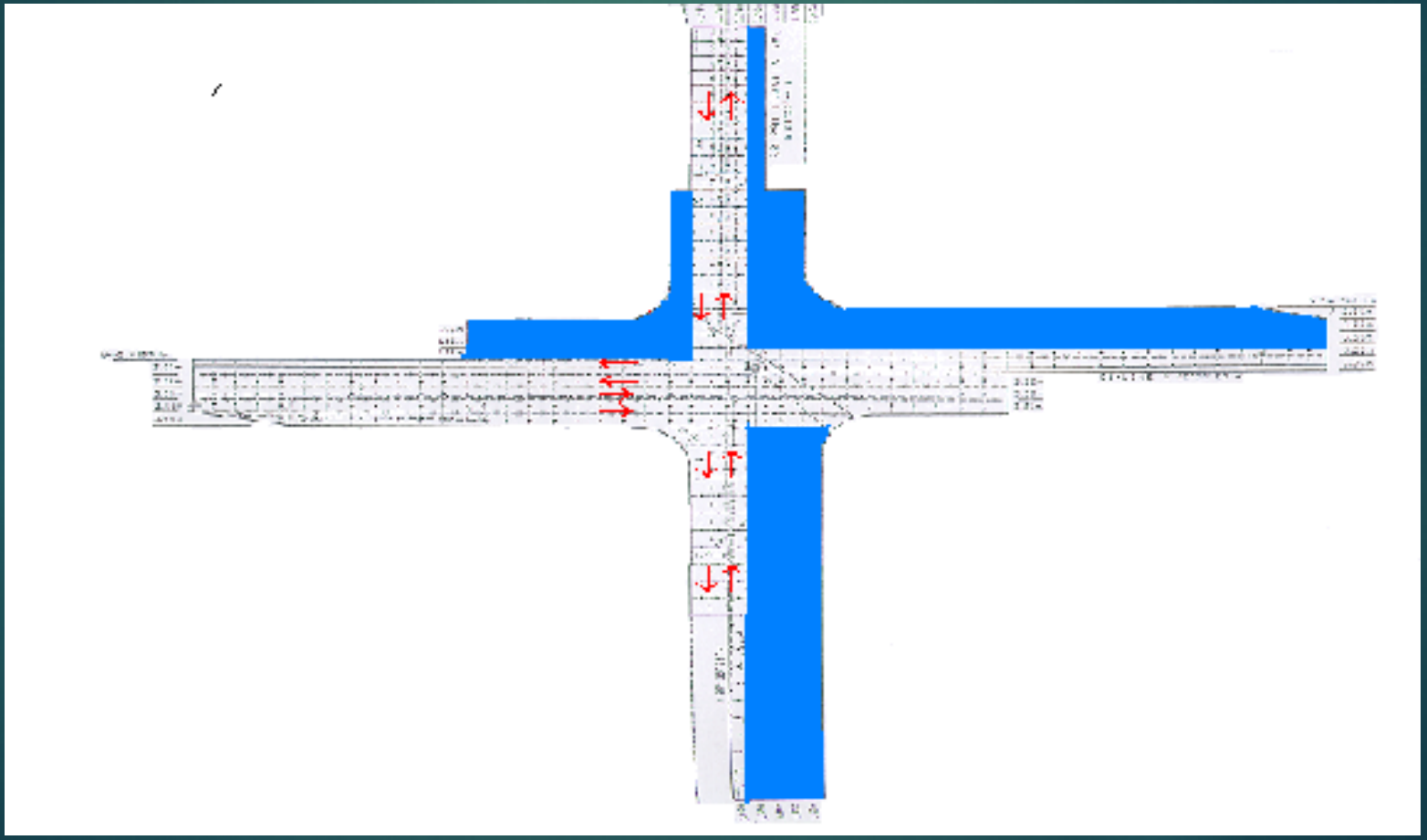
Geometrics



Staging

- Staging affects what equipment can be used
- Leave outs for driveways, skipping intersections, etc. can change a project from slipform to form paving. This can increase the unit price by 60% or more.
- Short work windows limit production rates, which significantly increases prices.
- Placing curb and gutter prior to paving can limit equipment

Staging



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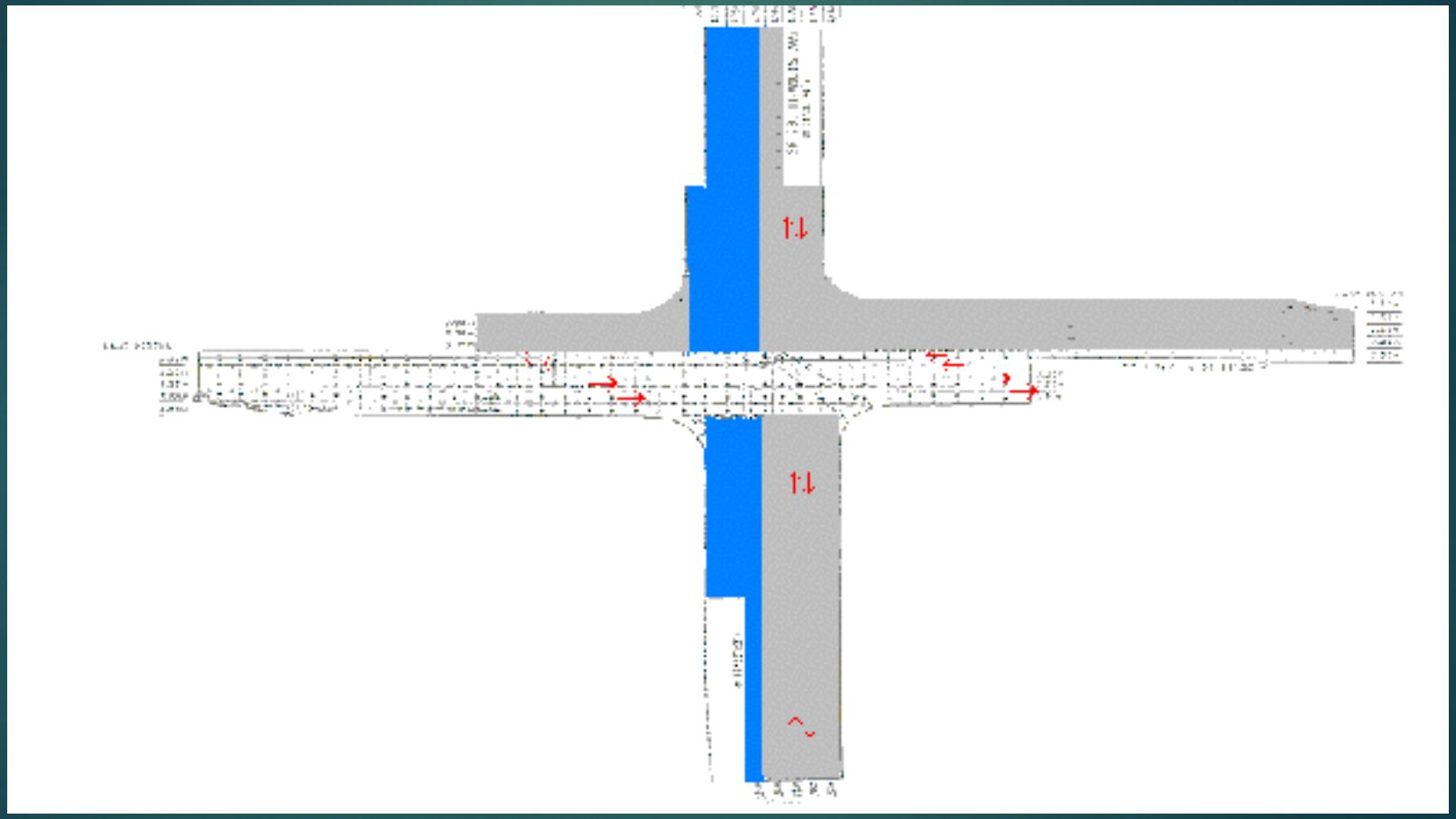

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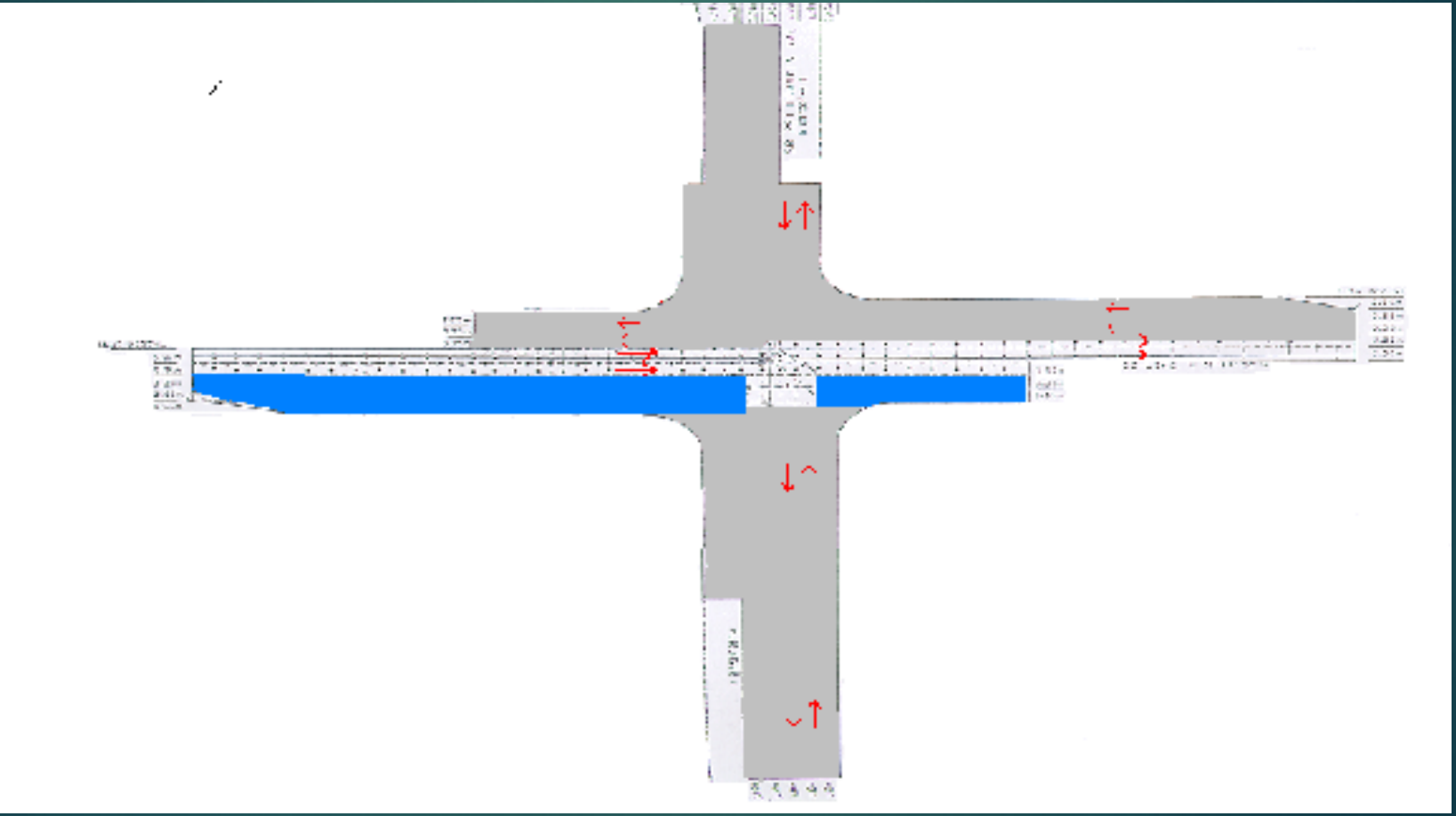

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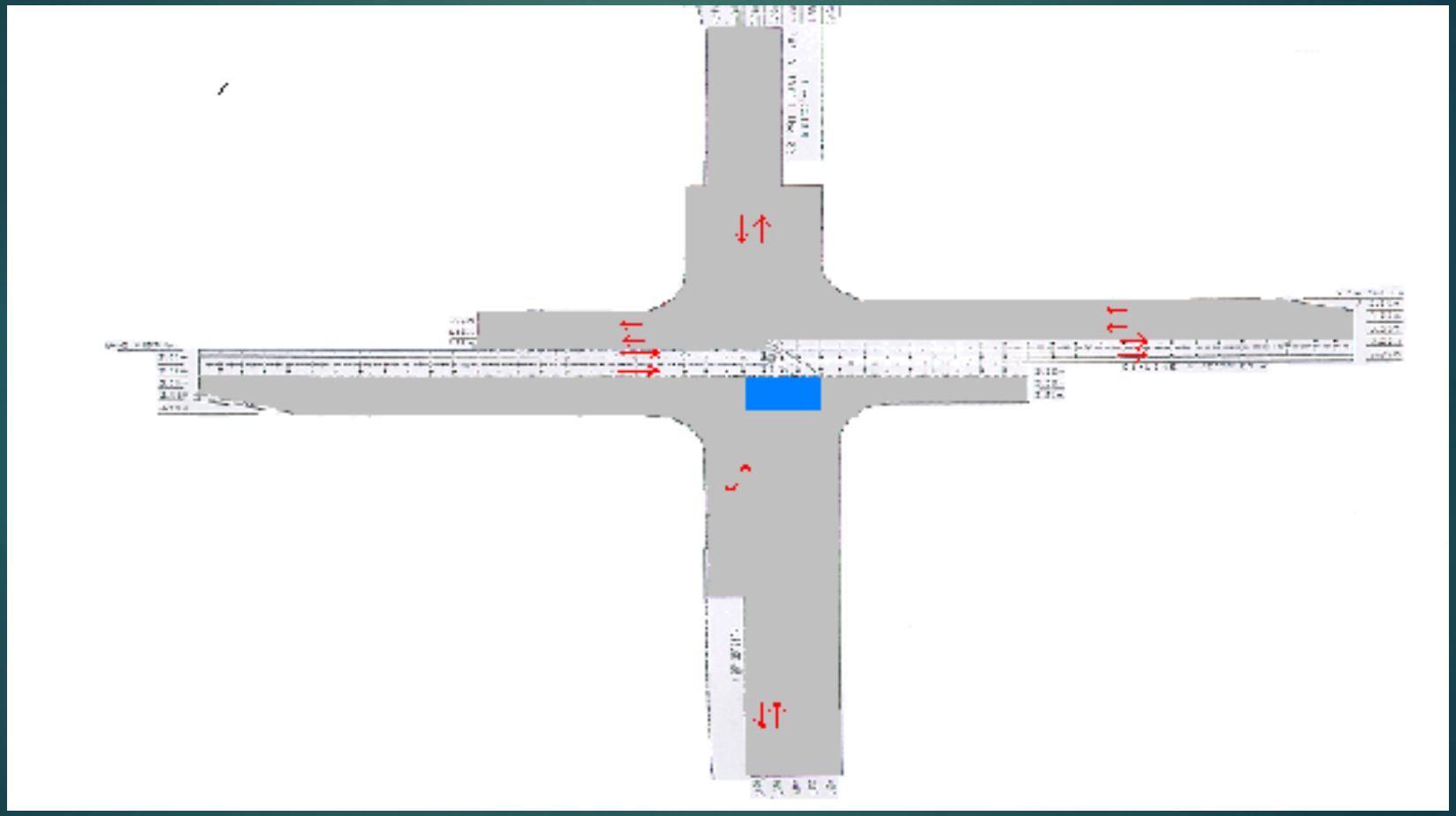

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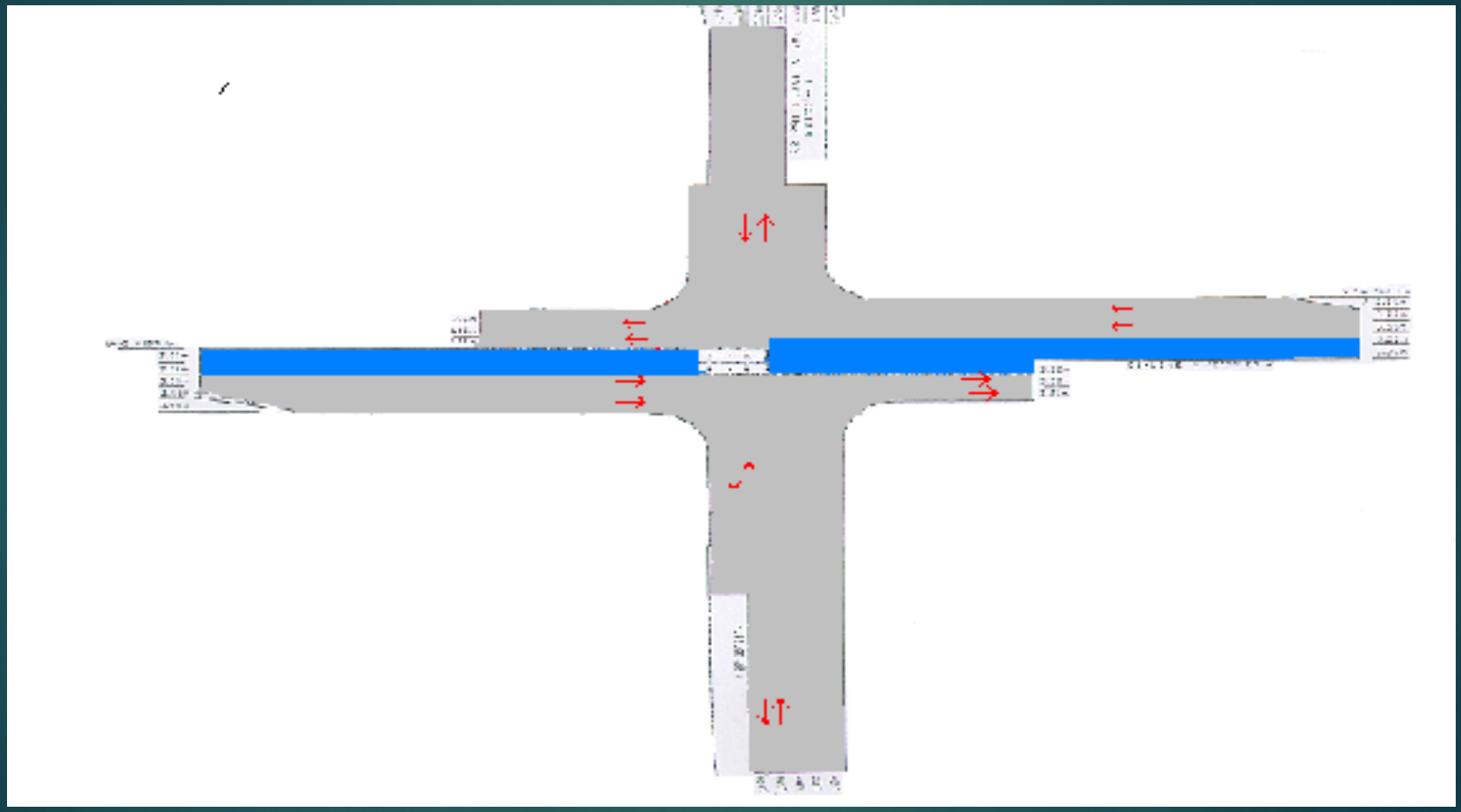

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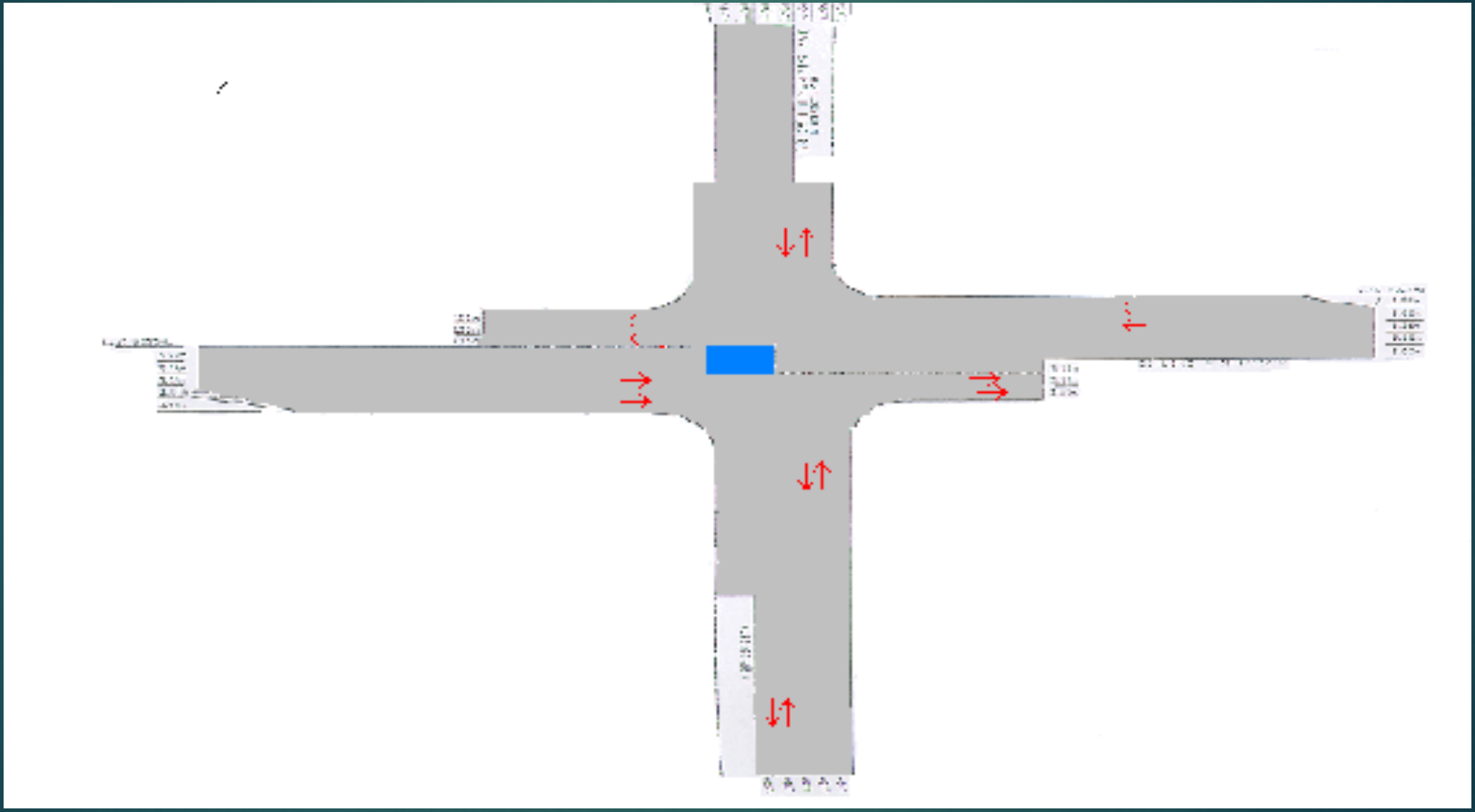

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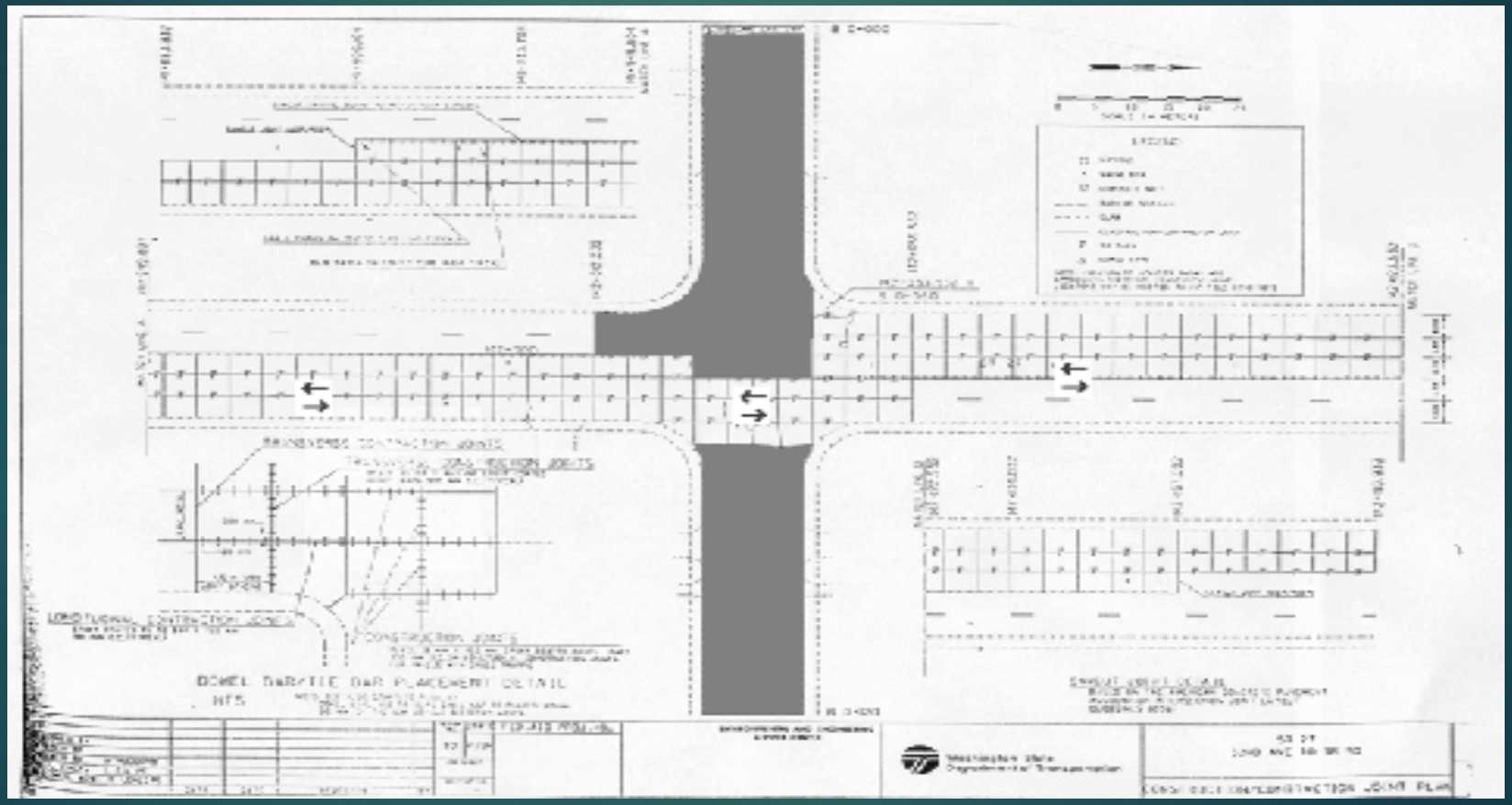

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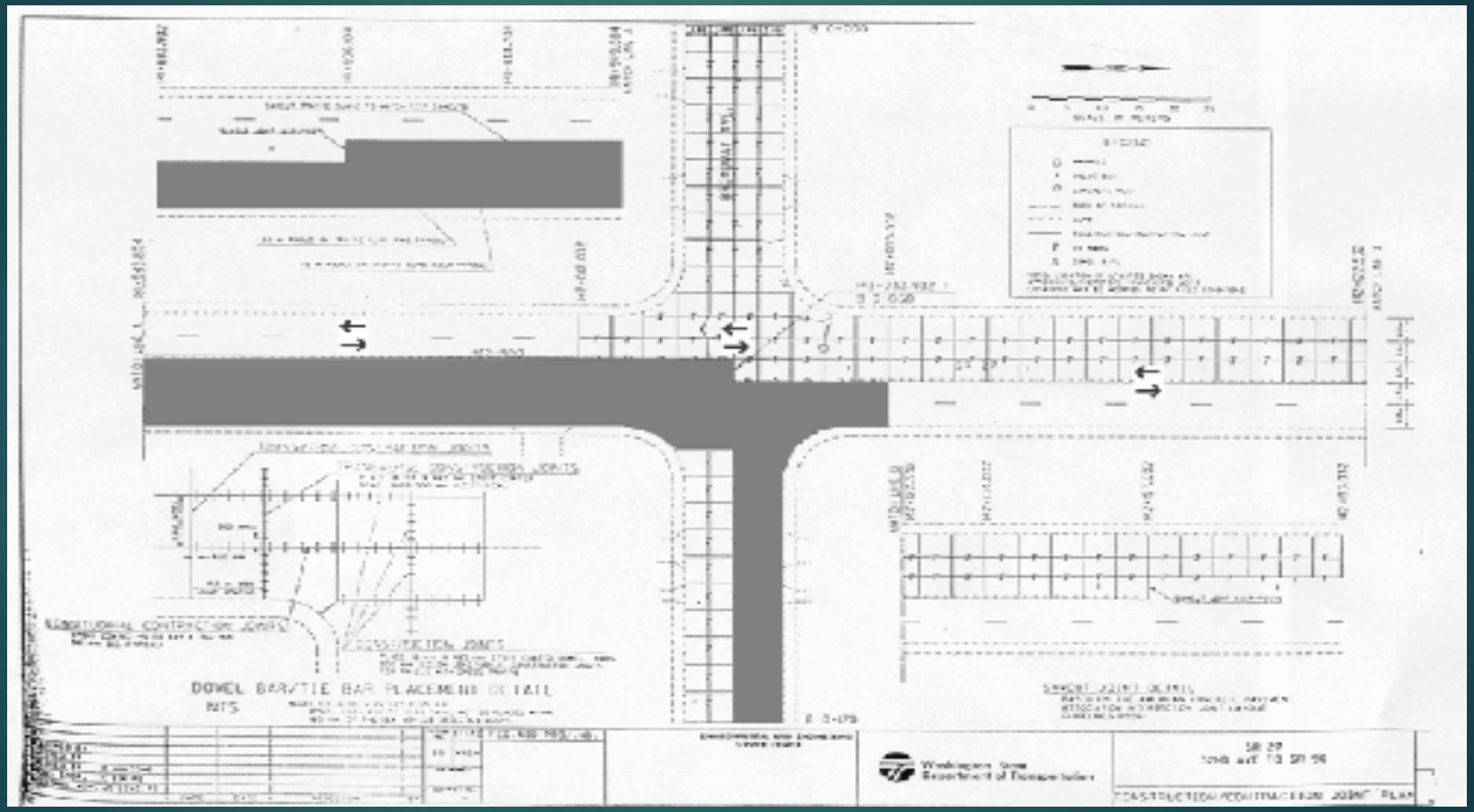

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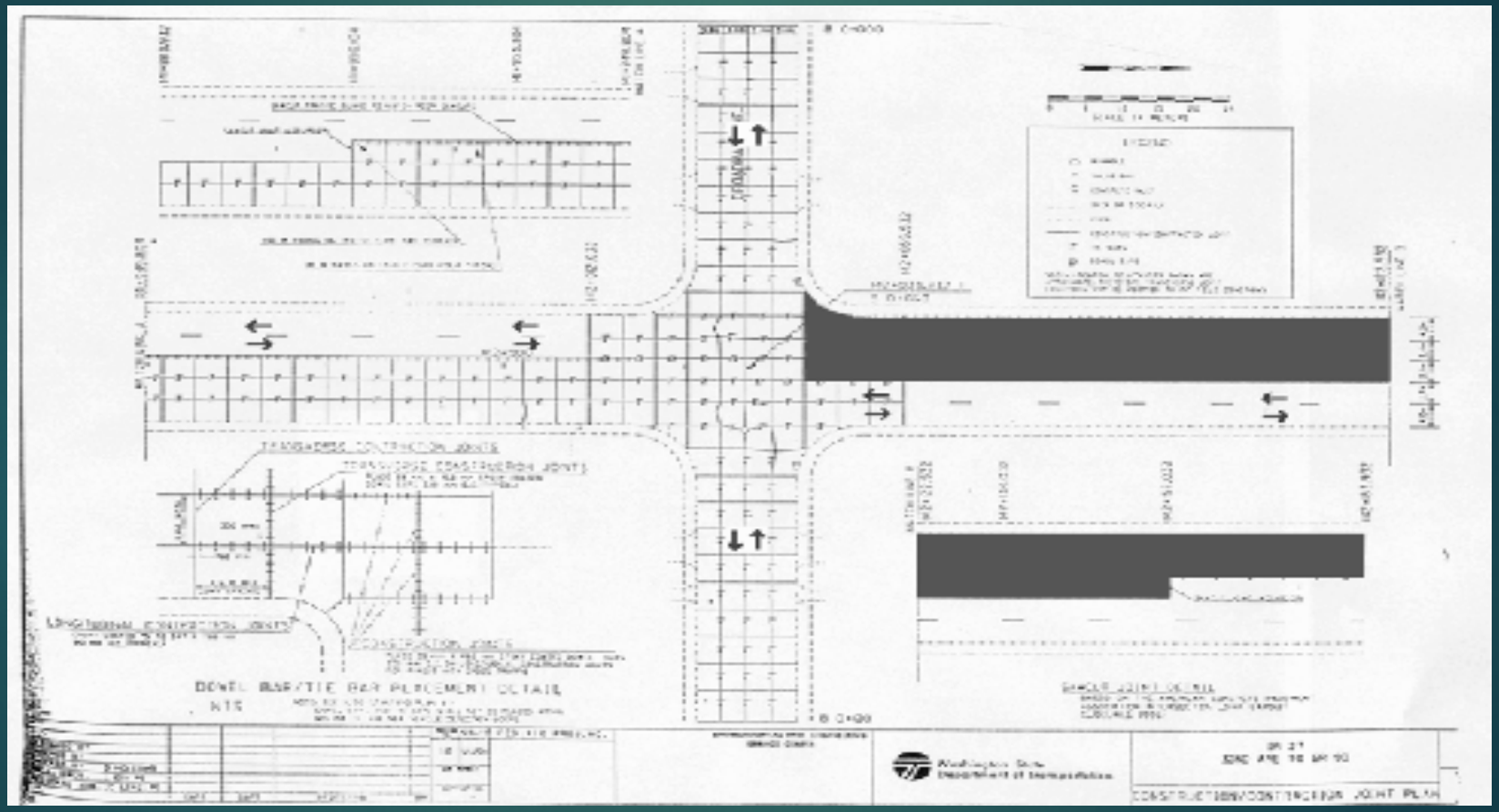

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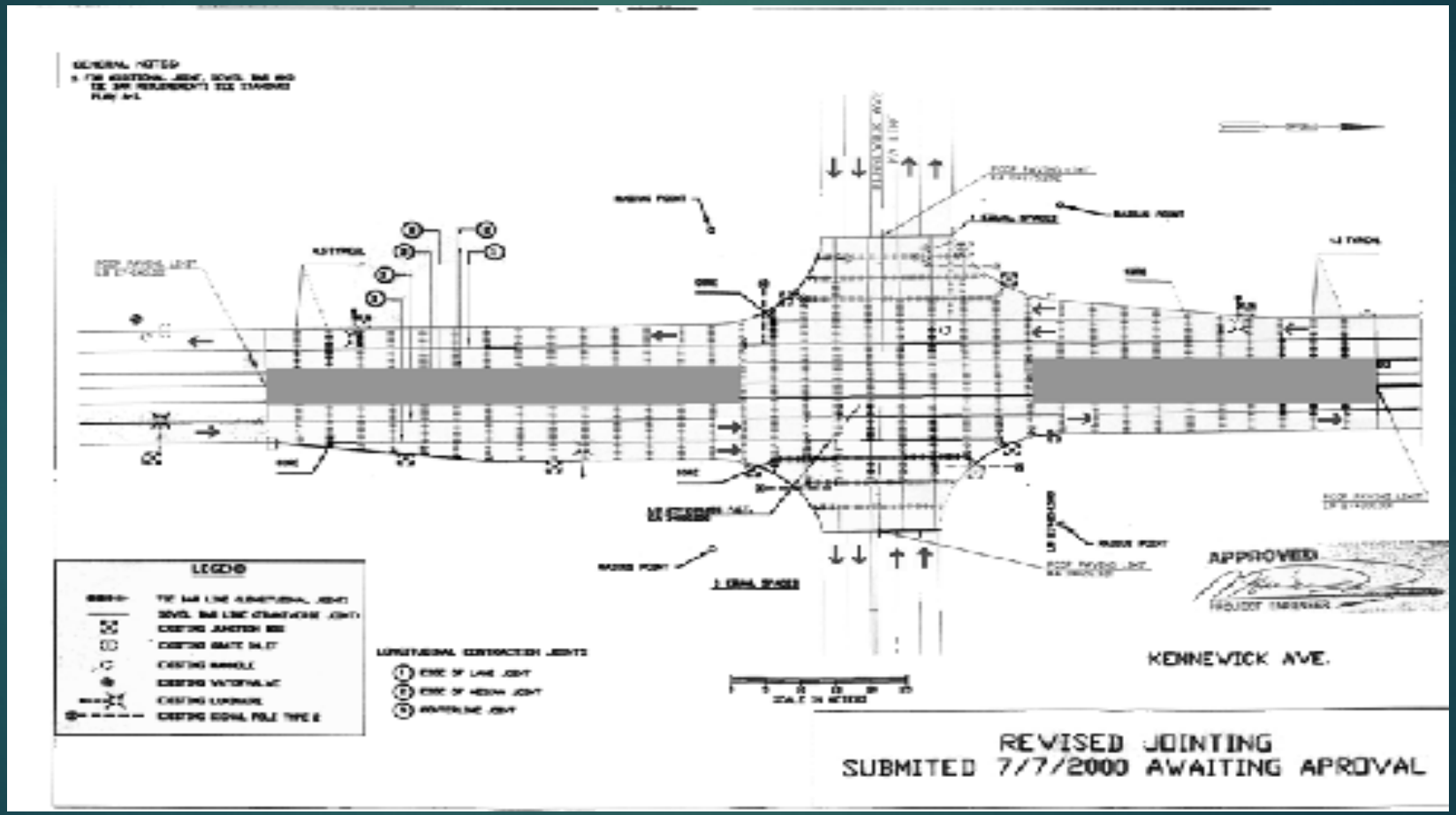
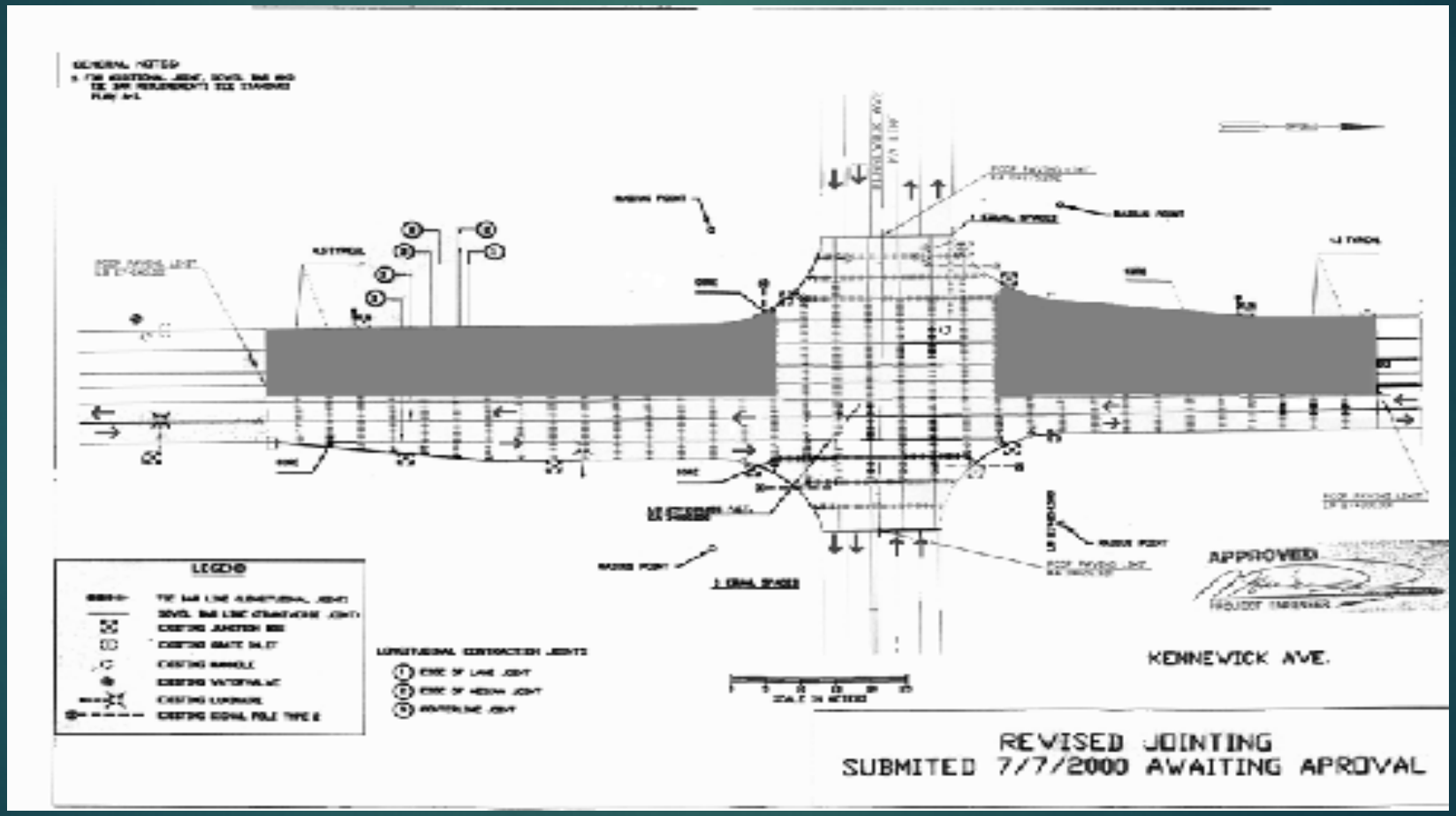

LEGEND
KENNEWICK AVE.
APPROVED
REVISED JOINTING
SUBMITED 7/7/2000 AWAITING APROVAL

Staging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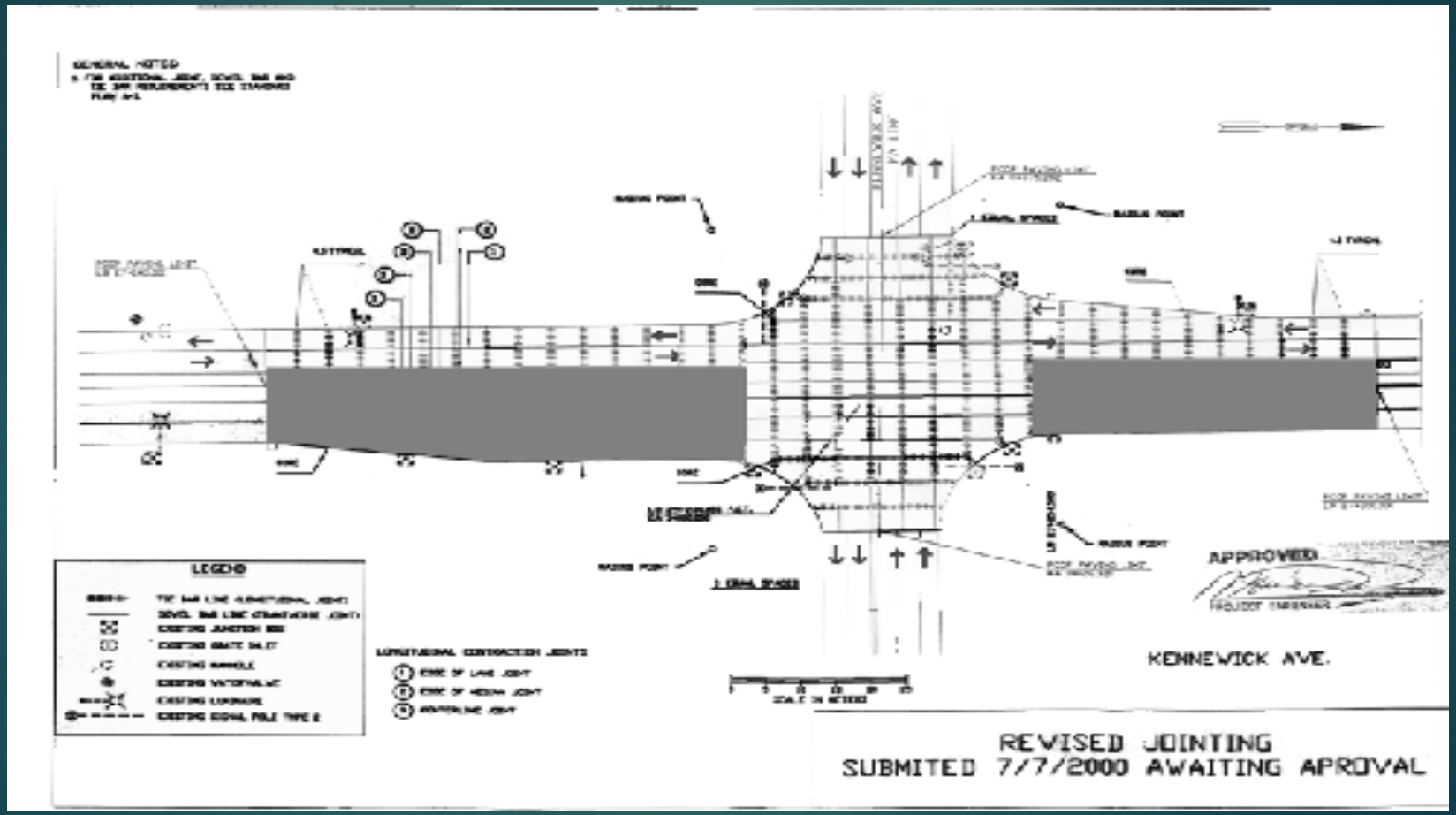
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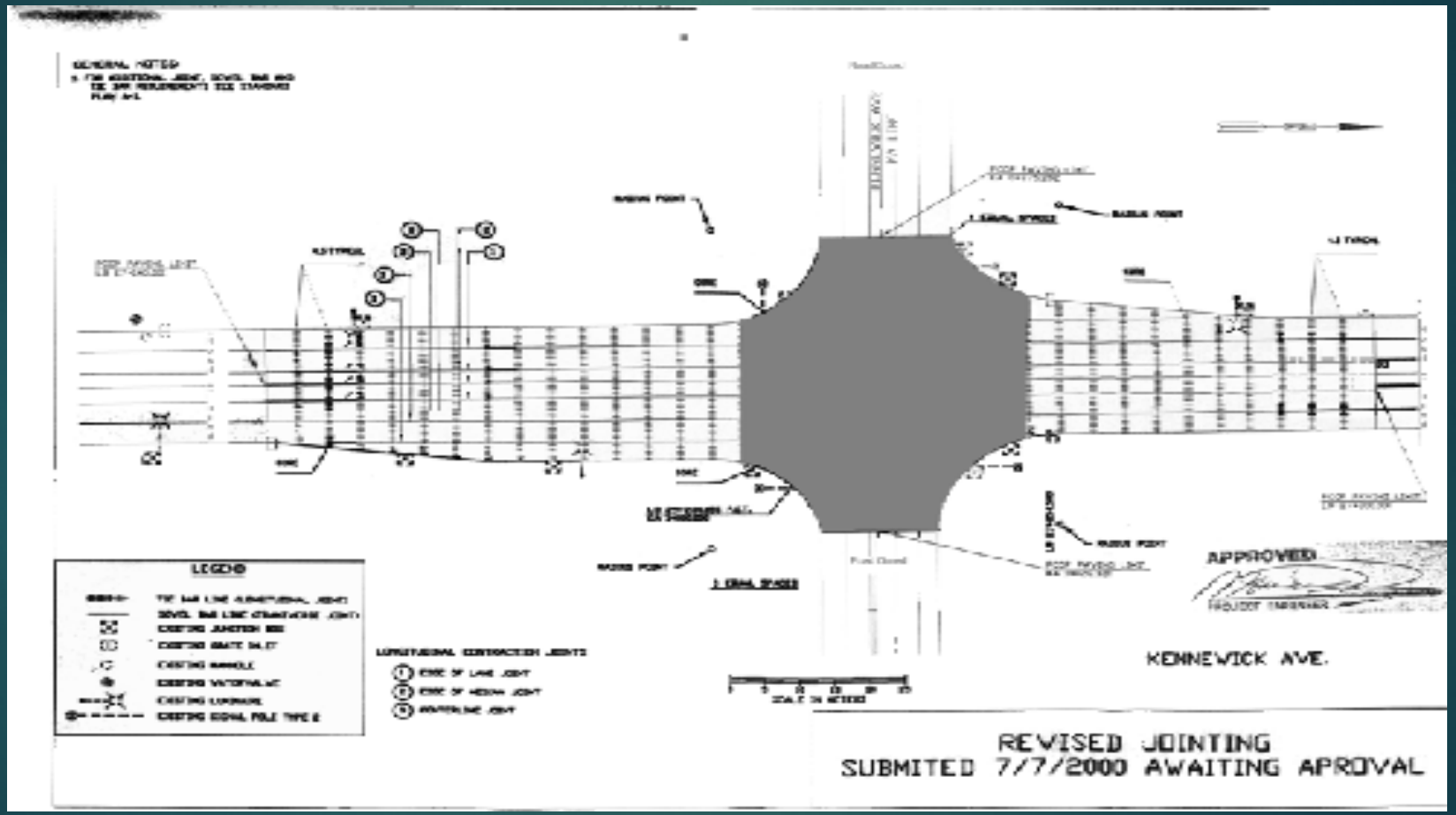
APPROVED
KENNEWICK AVE.
REVISED JOINTING
SUBMITED 7/7/2000 AWAITING APROVAL

Staging

Location	Days	Cubic Yards
Francis & Division	35	3050
Broadway & Pines	19	1681
Kennewick, Clearwater & SR-395	15	3384

Cost Effective Concrete Pavements

- PCCP cost effectiveness can be improved by
  - Optimizing thickness
  - Optimizing steel design
  - Simplifying geometrics
  - Simplifying staging