Precast Innovation in Washington State

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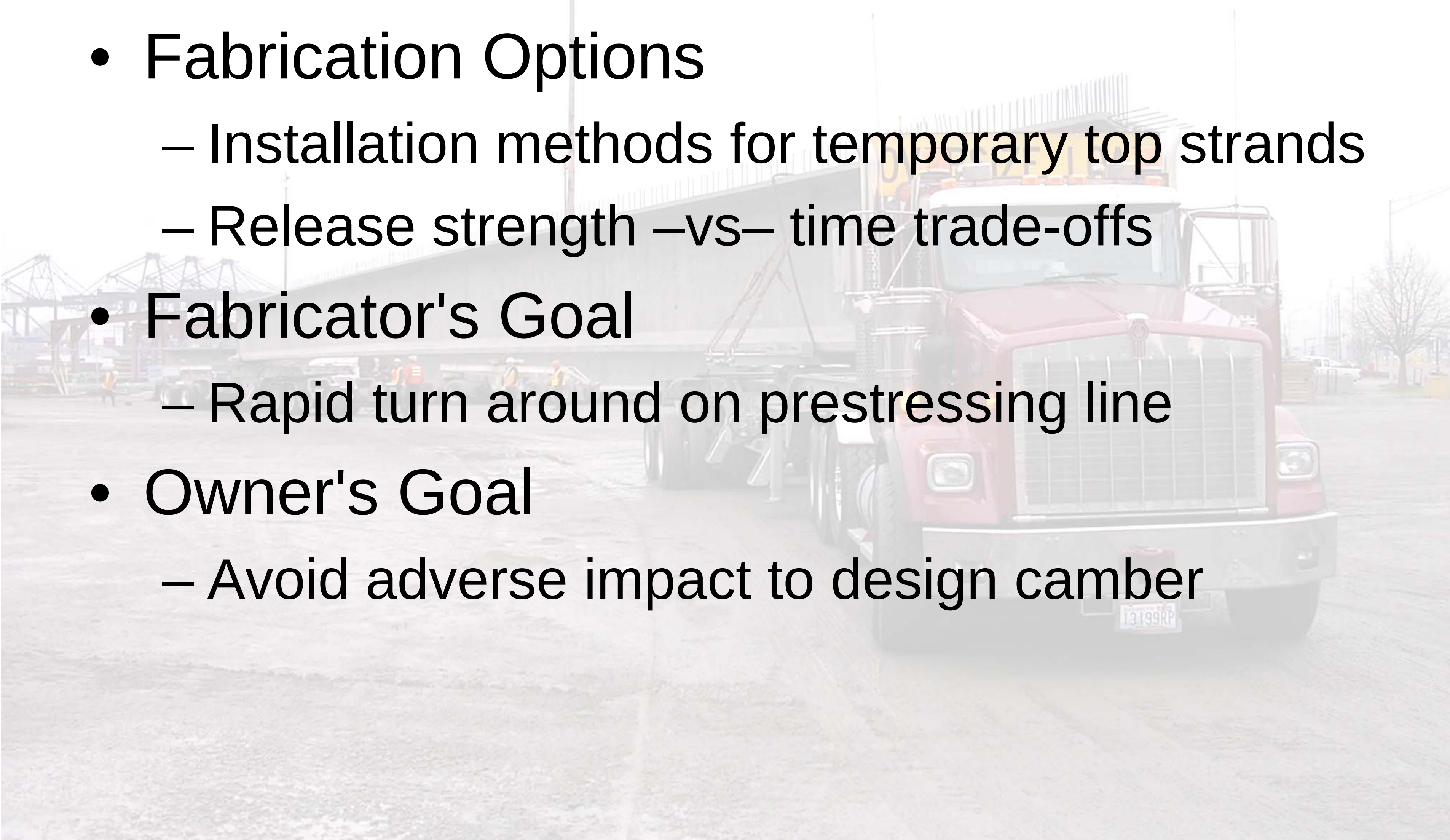
Overview

- Designing for Fabrication Options
- Software Technology
- New Girder Sections

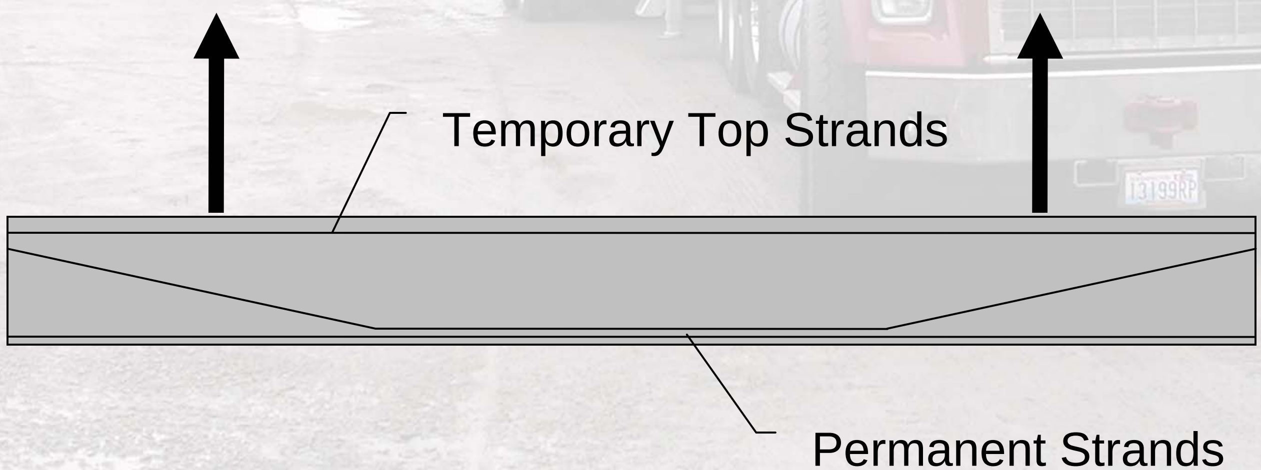
Designing for Fabrication Options

- Fabrication Options
  - Installation methods for temporary top strands
  - Release strength –vs– time trade-offs
- Fabricator's Goal
  - Rapid turn around on prestressing line
- Owner's Goal
  - Avoid adverse impact to design camber



Designing for Fabrication Options

- Why Temporary Top Strands (TTS)?
  - Long girder stability is improved during lifting and transportation when support points are moved towards center of girder
  - TTS control tensile stresses in top of girder



Camber

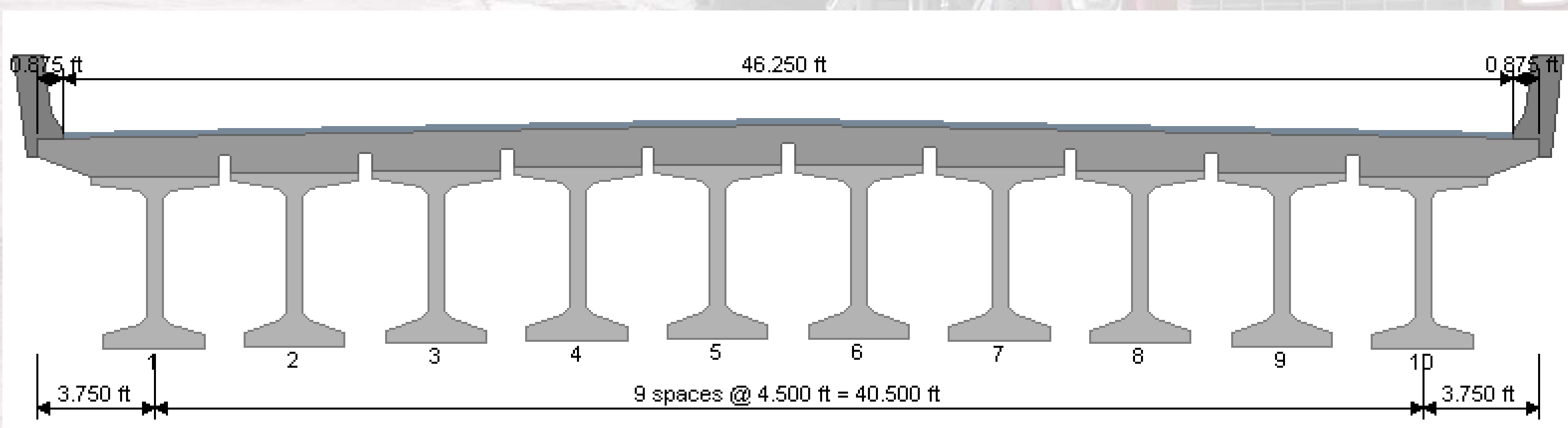
- Consequence of altering design camber
  - Material Quantities
  - Bearing Seat Elevations
  - Roadway Profile
- Changes that affecting Camber
  - Re-configuring Harped Strands
  - Adding Temporary Top Strands when not considered in design

Camber

$$\left(\frac{4\,ft\ \text{top flange}}{girder}\right)\left(1in\,\frac{1\,ft}{12in}\,\text{camber change}\right)\left(\frac{100\,ft}{span}\right)\left(\frac{1cy}{27\,ft^3}\right)=1.25\frac{cy}{girder\cdot span}$$

$$\left(1.25\frac{cy}{girder\cdot span}\right)(10\,girders)(3\,spans)=37cy$$

$$9\frac{cy}{truck}\Rightarrow 4\,trucks$$



Designing for Fabrication Options

Driving Factors

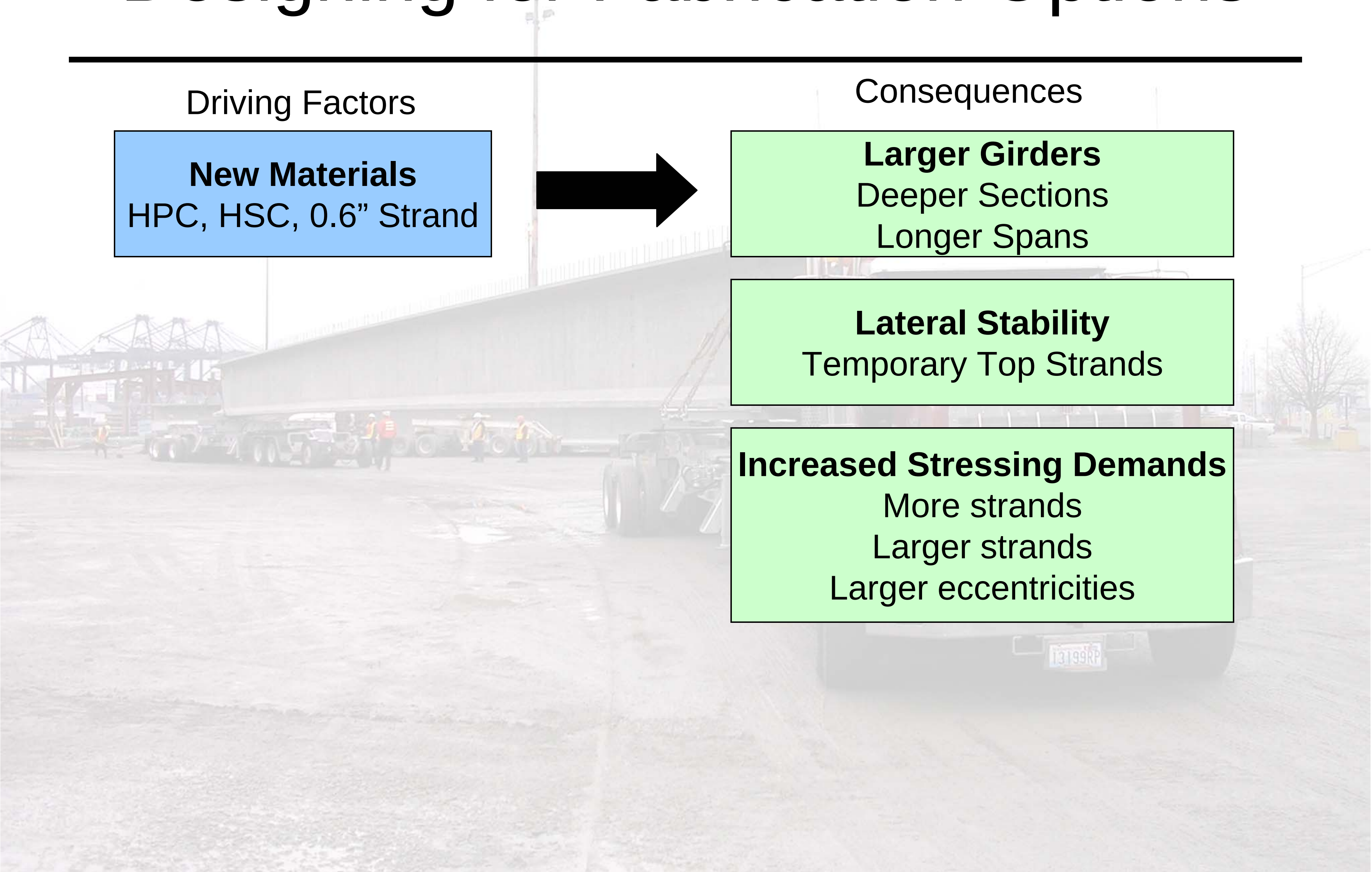
New Materials
HPC, HSC, 0.6” Strand

Consequences

Larger Girders
Deeper Sections
Longer Spans

Lateral Stability
Temporary Top Strands

Increased Stressing Demands
More strands
Larger strands
Larger eccentricities



Designing for Fabrication Options

Consequences

Larger Girders
Deeper Sections
Longer Spans

Lateral Stability
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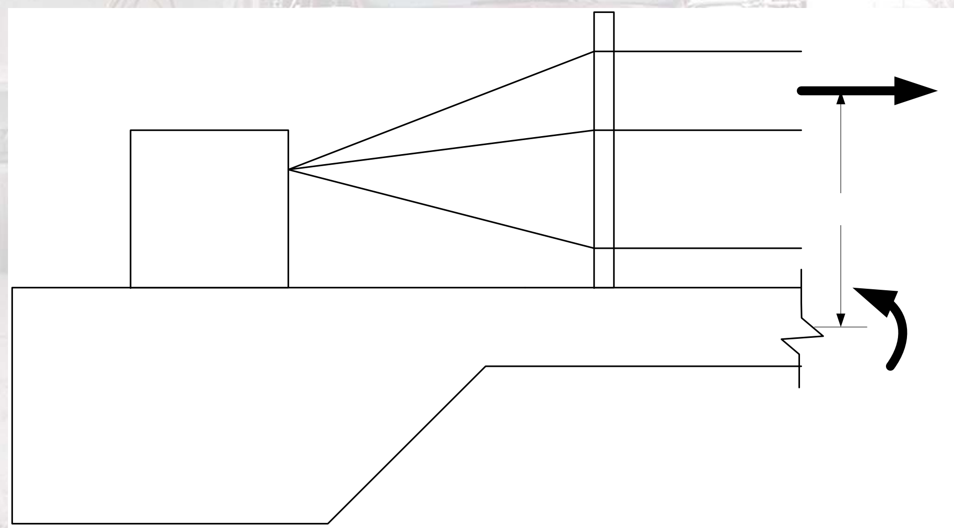
Constraints

Capacity of Existing Prestressing Lines
Limited by total prestress force
and overturning moment

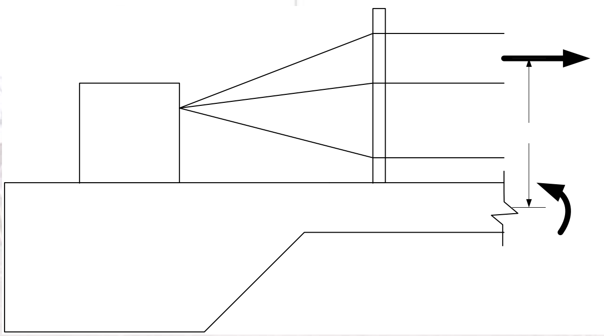


Free Body Diagram of Stressing Abutment

Designing for Fabrication Options

Constraints

Capacity of Existing Prestressing Lines



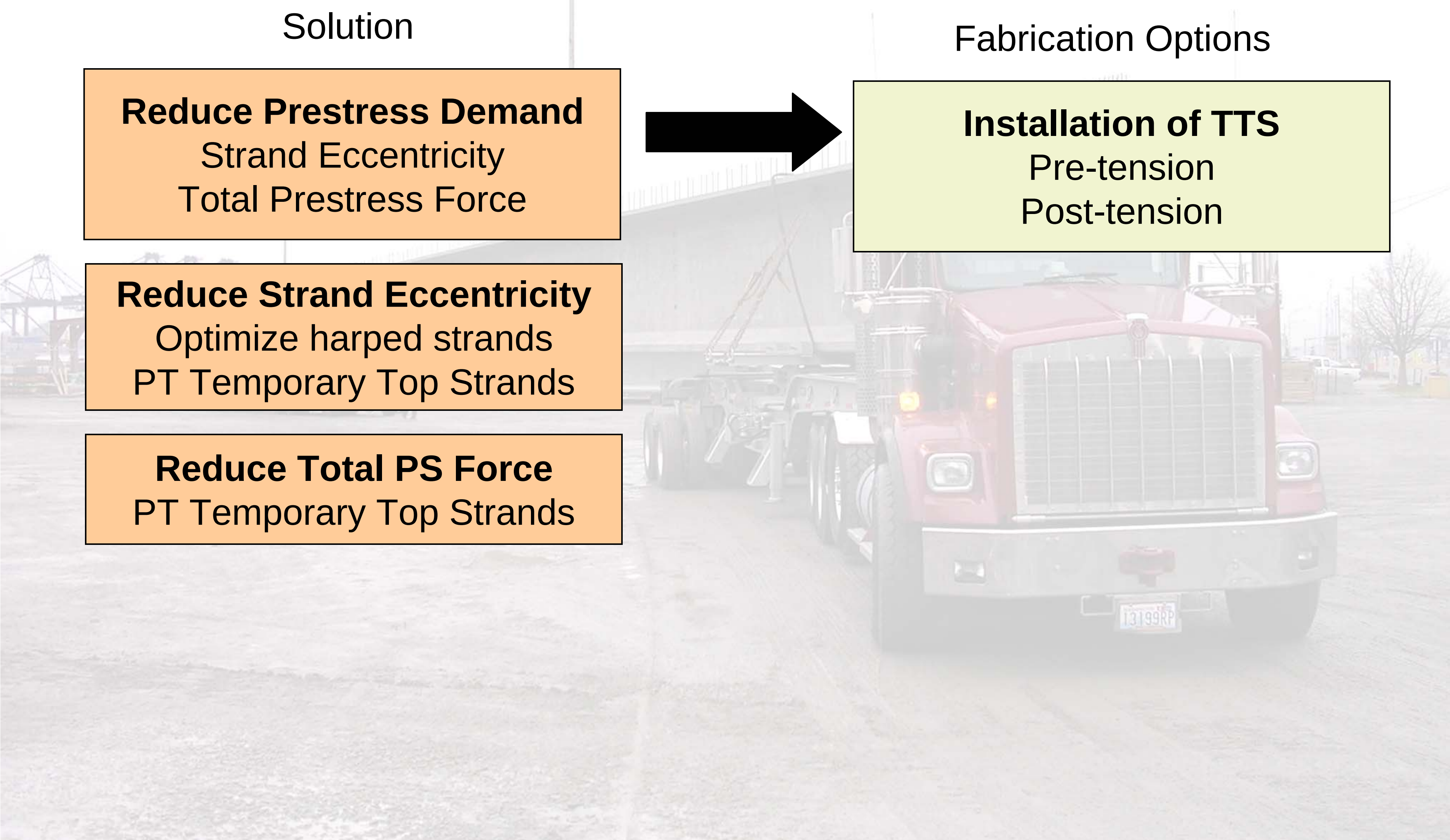
Solution

Reduce Prestress Demand
Strand Eccentricity
Total Prestress Force

Reduce Strand Eccentricity
Optimize harped strands
PT Temporary Top Strands

Reduce Total PS Force
PT Temporary Top Strands

Designing for Fabrication Options



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→

Fabrication Options

Installation of TTS
Pre-tension
Post-tension

Designing for Fabrication Options

Fabrication Options

Installation of TTS
Pre-tension
Post-tension

Constraints

Camber
Do not alter the design camber

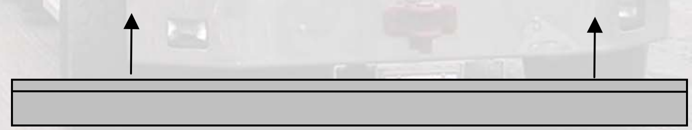
Considerations

Release Strength

$$f'_{ci} = f(time)$$

$$time = \$$$

Lifting without temporary top strands
Greatest f'_{ci} required
Least demand on stressing bed



Lifting with temporary top strands
Least f'_{ci} required
Greatest demand on stressing bed
Stressing line might not be able to handle this case

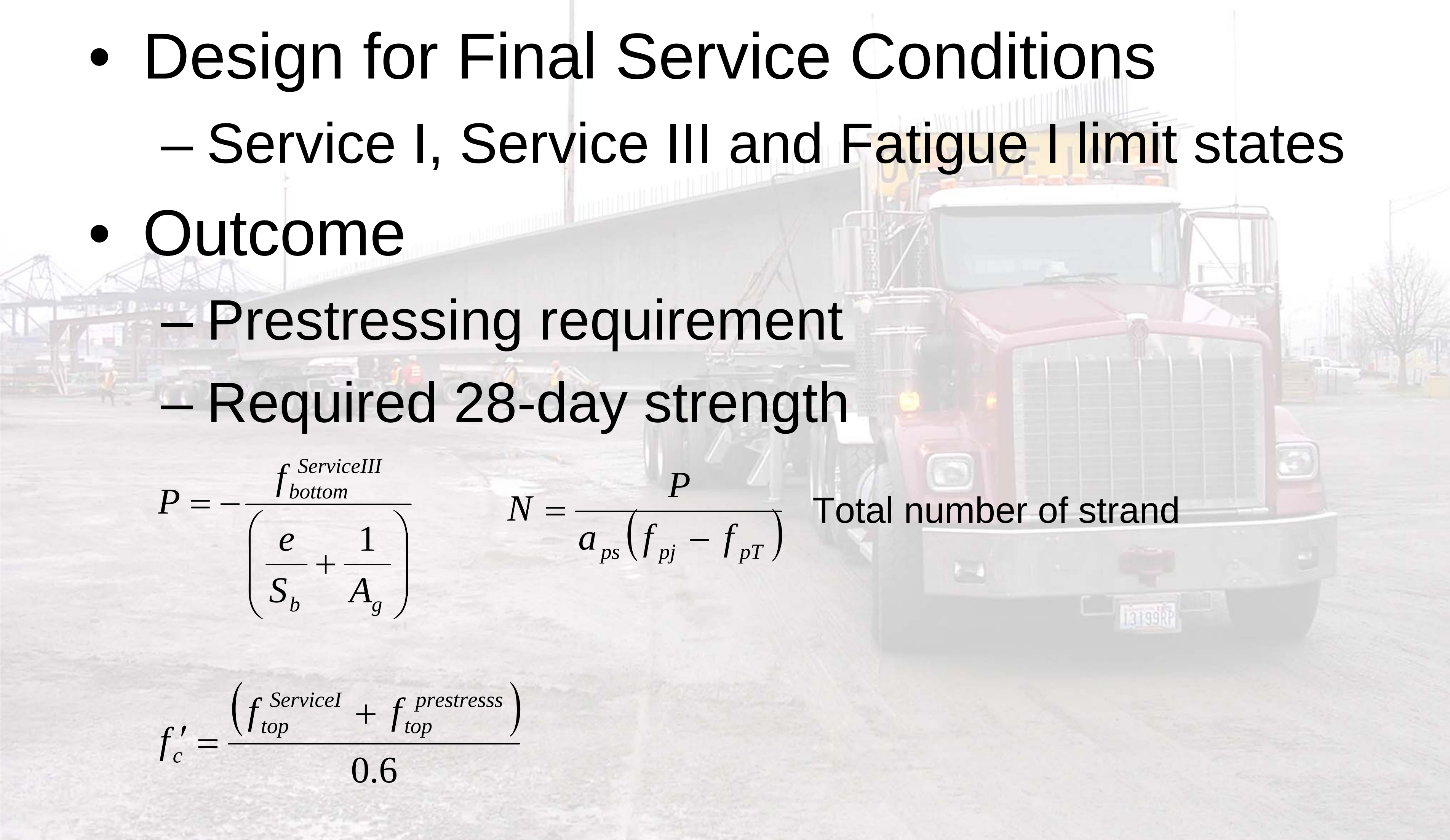
Step 1

- Design for Final Service Conditions
  - Service I, Service III and Fatigue I limit states
- Outcome
  - Prestressing requirement
  - Required 28-day strength

$$P = -\frac{f_{bottom}^{ServiceIII}}{\left(\frac{e}{S_b} + \frac{1}{A_g}\right)}$$

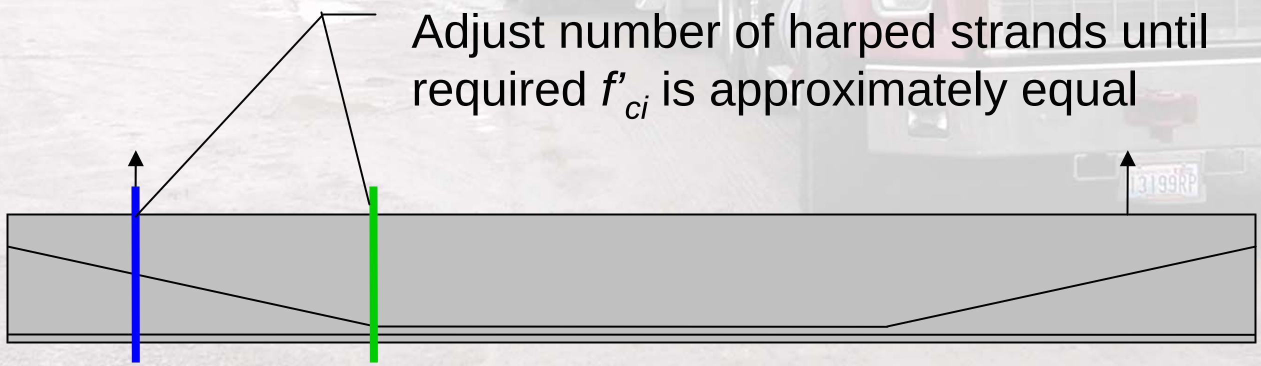
$$N = \frac{P}{a_{ps}\left(f_{pj} - f_{pT}\right)}$$ Total number of strand

$$f_c' = \frac{\left(f_{top}^{ServiceI} + f_{top}^{prestresss}\right)}{0.6}$$



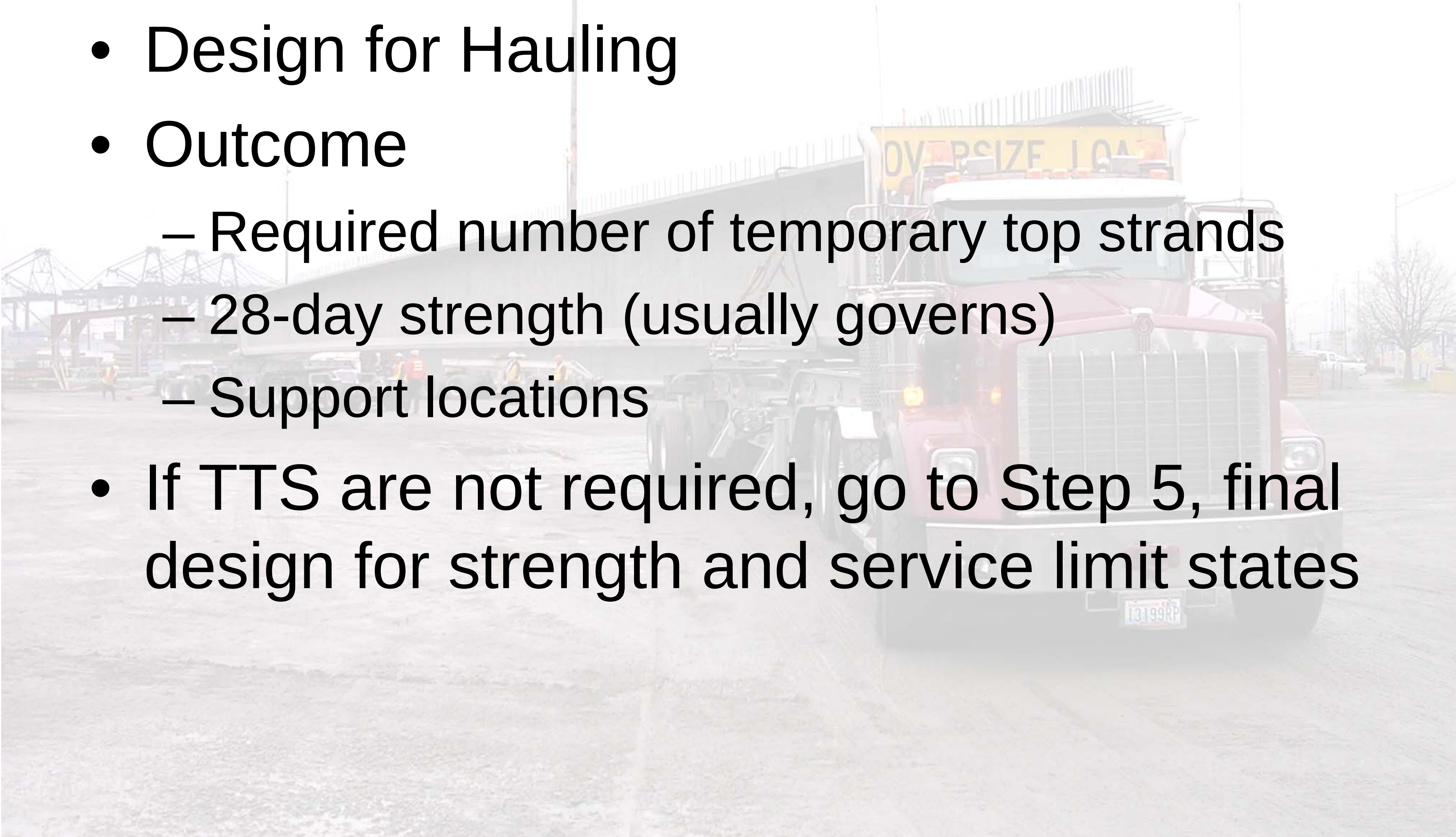
Step 2

- Design for Lifting without TTS
- Outcome
  - Optimum Permanent Strand configuration
  - Release strength (highest)
  - Lifting Location

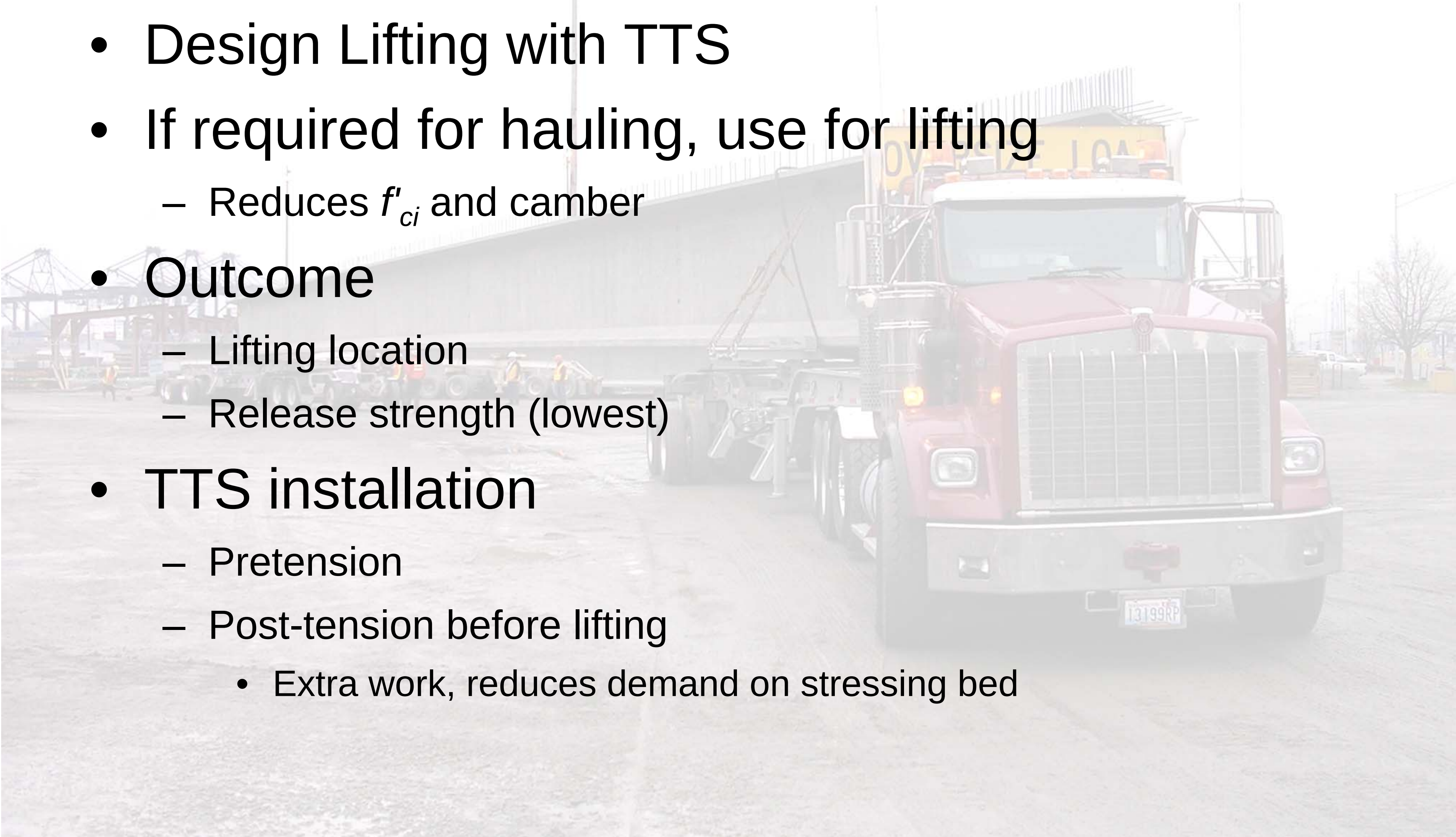


Step 3

- Design for Hauling
- Outcome
  - Required number of temporary top strands
  - 28-day strength (usually governs)
  - Support locations
- If TTS are not required, go to Step 5, final design for strength and service limit states



Step 4



- Design Lifting with TTS
- If required for hauling, use for lifting
  - Reduces f'_{ci} and camber
- Outcome
  - Lifting location
  - Release strength (lowest)
- TTS installation
  - Pretension
  - Post-tension before lifting
    - Extra work, reduces demand on stressing bed

Step 5

- Final Design for Strength, Service, and Fatigue Conditions

Designing for Fabrication Options

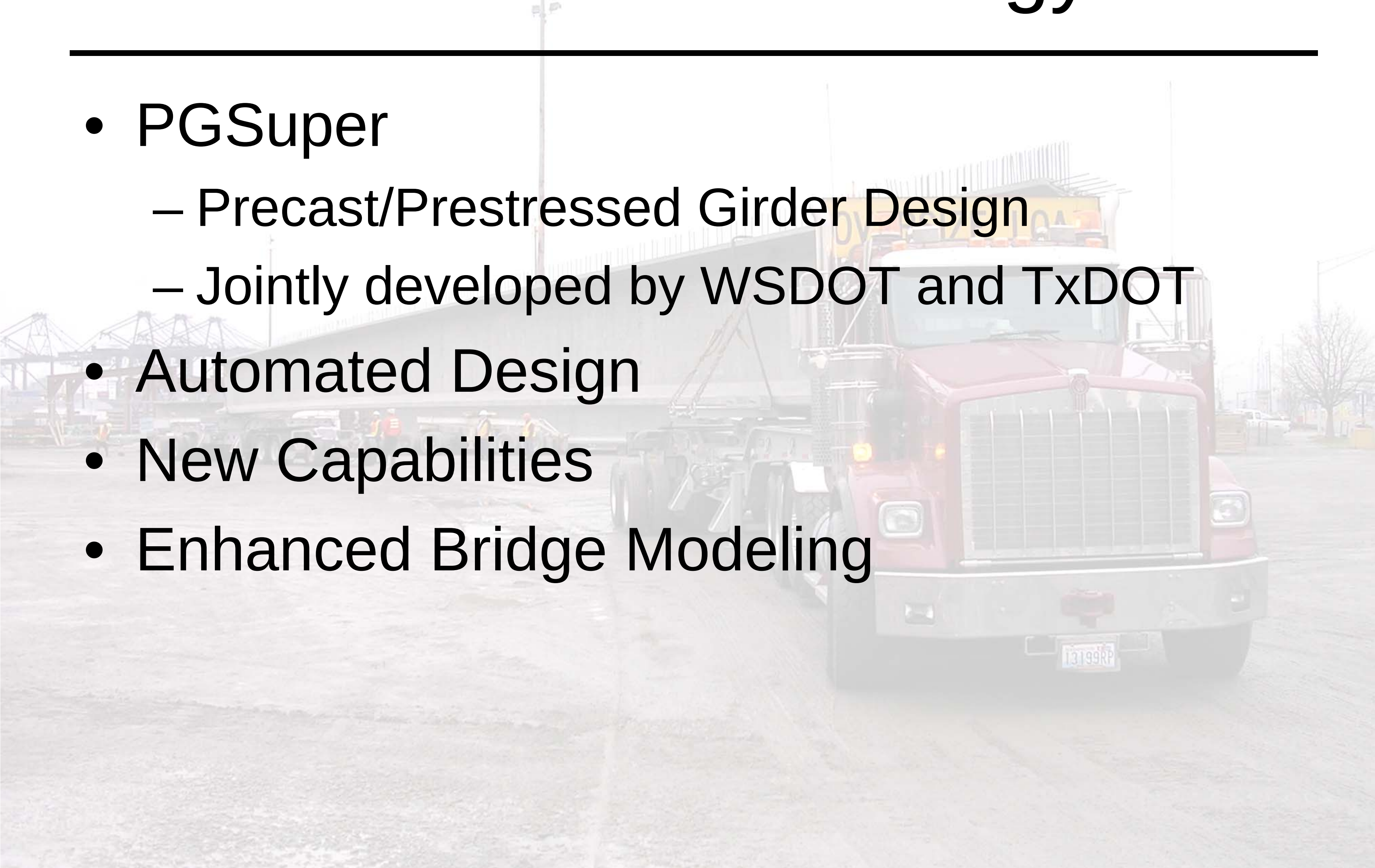
- Temporary Top Strand Options

Number of Temporary Top Strands	Jacking Force (kip)	Lifting with TTS		Lifting with Post-Tensioned TTS		Lifting without TTS*	
		L (ft)	f'_{ci} (ksi)	L (ft)	f'_{ci} (ksi)	L (ft)	f'_{ci} (ksi)
6	263.7	9.50	7.0	12.0	7.1	12.0	7.4

- Look for full treatment of this topic in the Fall 2009 PCI Journal

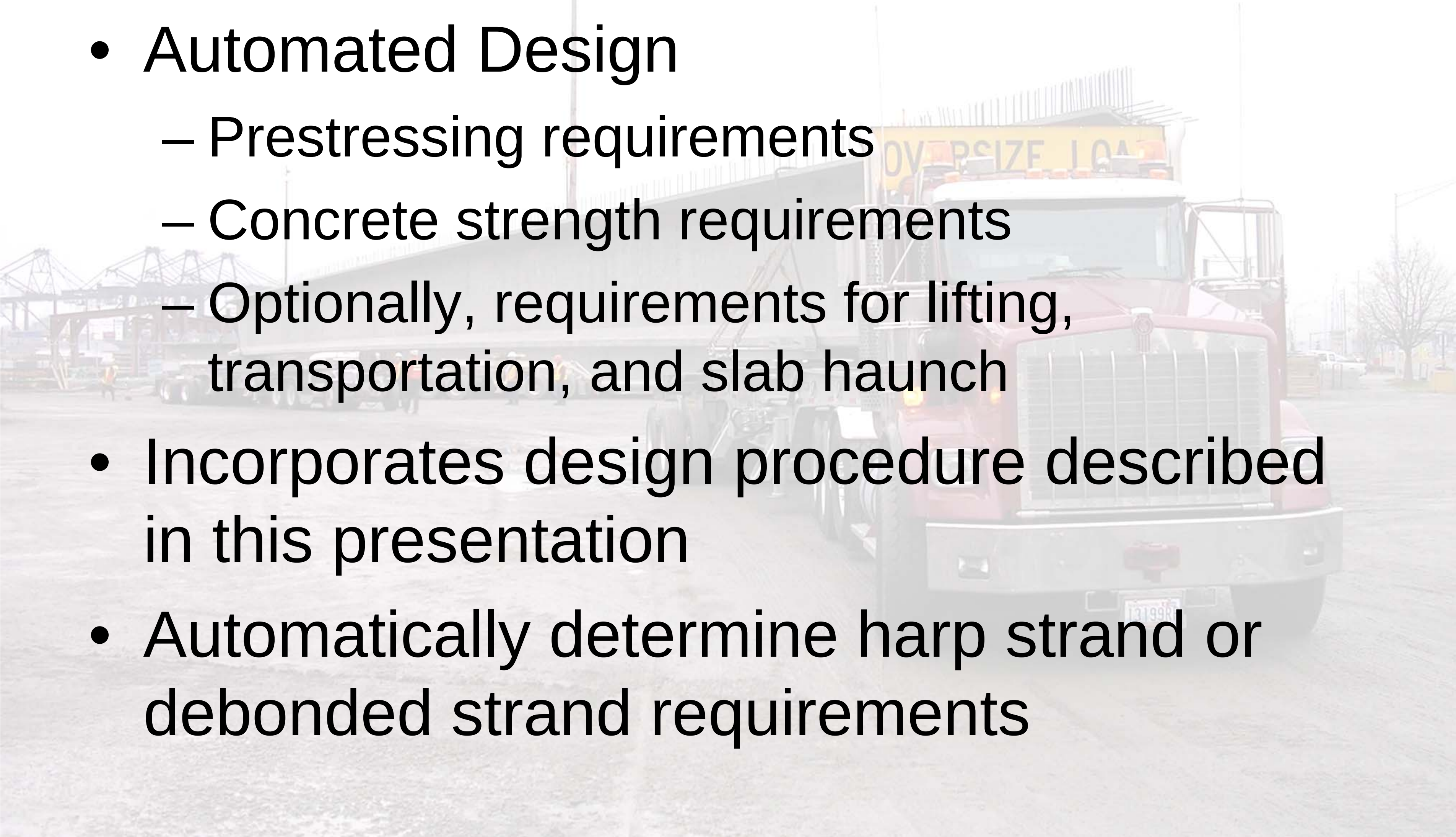
Software Technology

- PGSuper
  - Precast/Prestressed Girder Design
  - Jointly developed by WSDOT and TxDOT
- Automated Design
- New Capabilities
- Enhanced Bridge Modeling



Software Technology

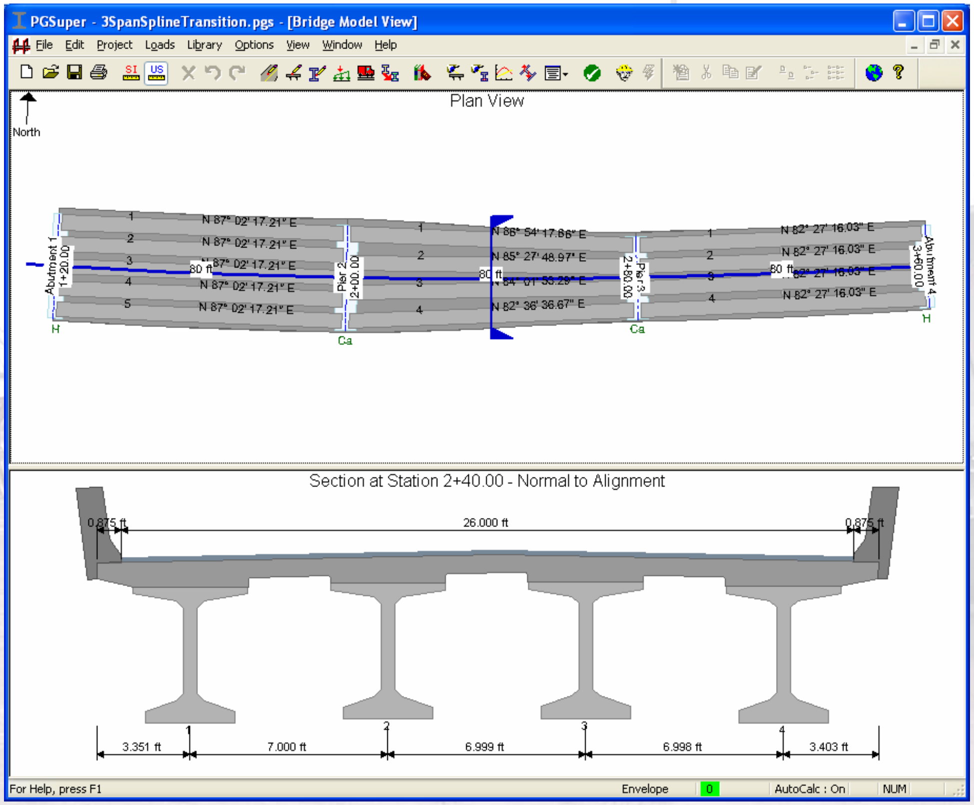
- Automated Design
  - Prestressing requirements
  - Concrete strength requirements
  - Optionally, requirements for lifting, transportation, and slab haunch
- Incorporates design procedure described in this presentation
- Automatically determine harp strand or debonded strand requirements



Software Technology

- New Capabilities
  - Framing with flared girders
  - Different girder types in a cross section
  - Different number of girders in each span
  - User defined live load vehicles
  - Pedestrian only bridges
  - Sidewalks with pedestrian loads
- Push limits of LRFD approximate method of analysis (Live Load Distribution Factors)
  - Several new methods of computing LLDF including lever rule and (# Lanes)/(# Beams)

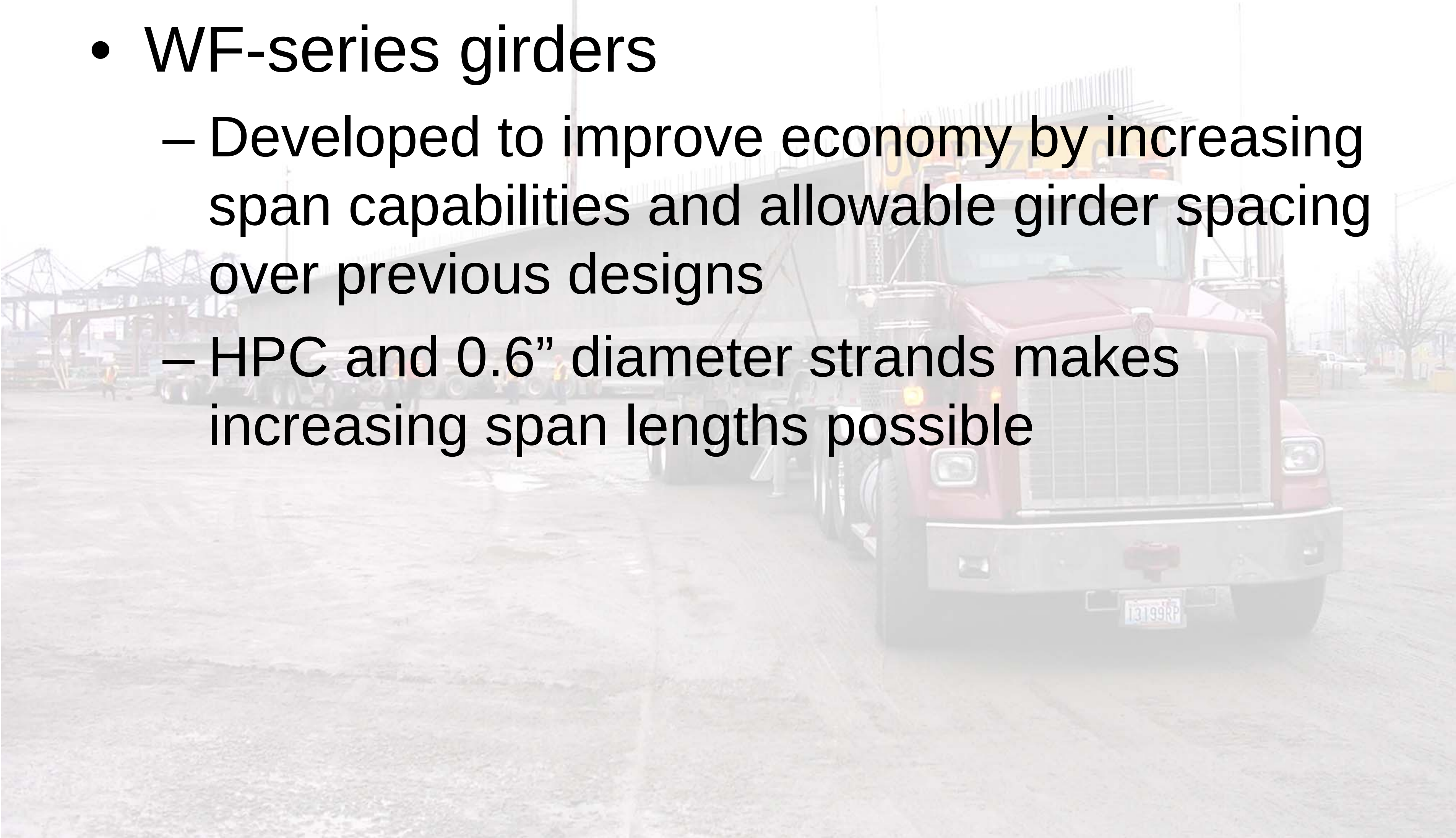
Software Technology



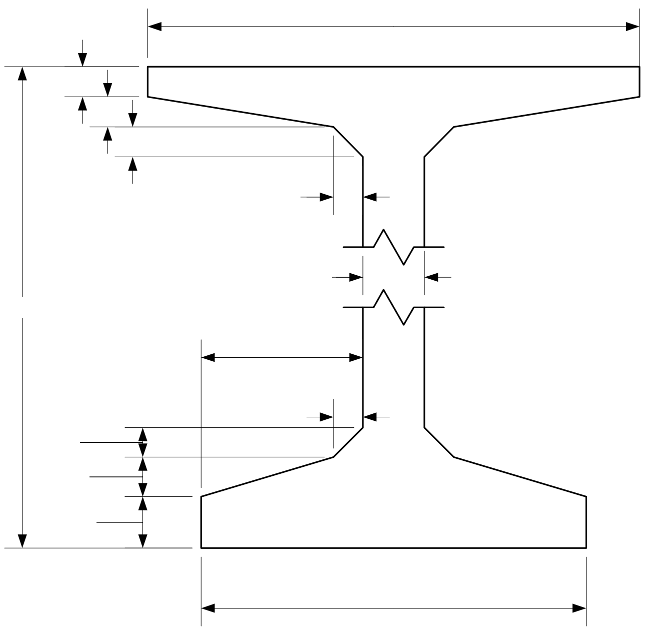
- www.wsdot.wa.gov/eesc/bridge/
- Tutorials and support available at PGSuper.com

New Girder Sections

- WF-series girders
  - Developed to improve economy by increasing span capabilities and allowable girder spacing over previous designs
  - HPC and 0.6” diameter strands makes increasing span lengths possible



WF-Series Girders



Girder	Depth (in)	Area (in^2)	Y_t (in)	Y_b (in)	I (in^4)
WF36G	36	692	18.5	17.5	125067
WF42G	42	728.5	21.7	20.3	184043
WF50G	50	777.5	25.9	24.1	283126
WF58G	58	826.5	30	28	407028
WF66G	66	875.5	34.2	31.8	557328
WF74G	74	924.5	38.4	35.6	735603
WF83G	82.625	977.4	42.8	39.8	960951
WF95G	94.5	1050	49	45.5	1331041
WF100G	100	1083.8	51.8	48.2	1527209

3 Girders – 3 Stories

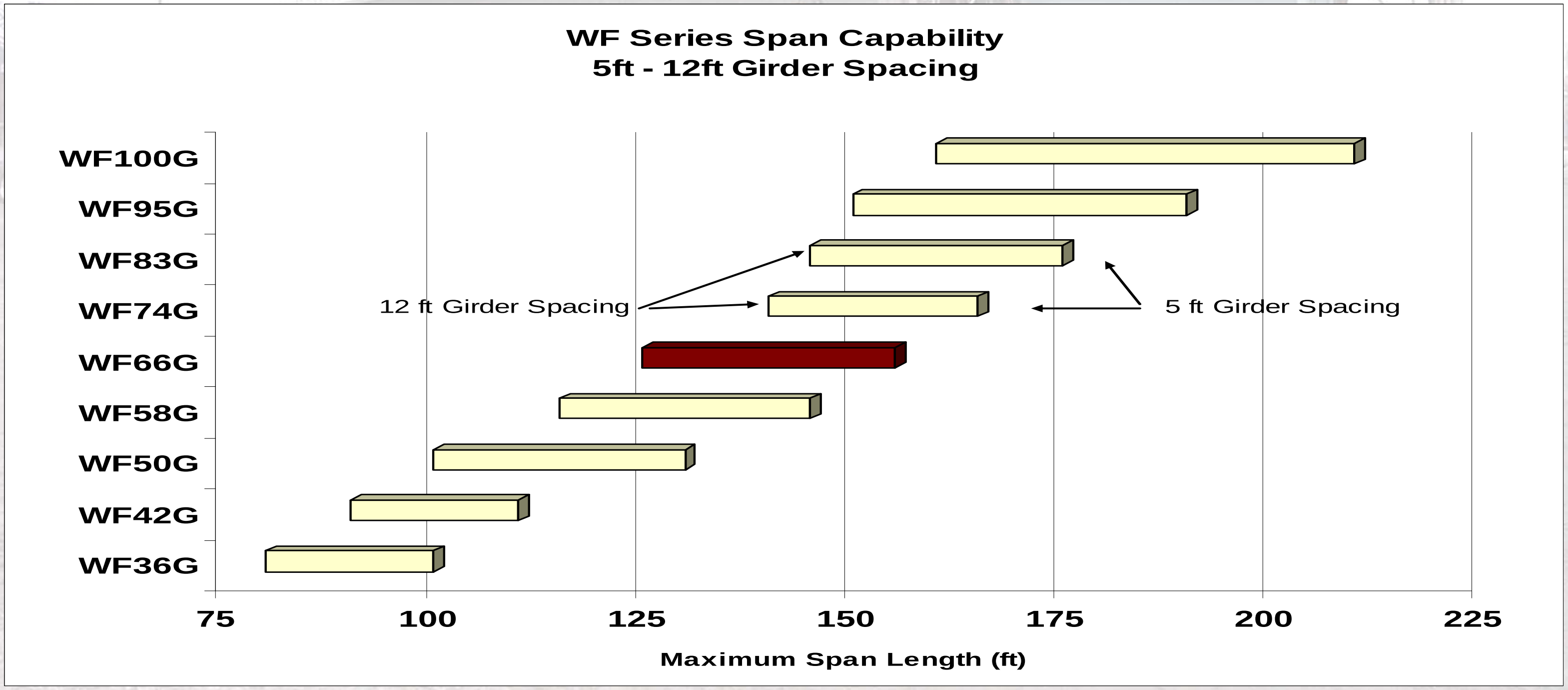
4' 1"

WF36G Girder

- Needed a cost effective “long span” girder for low profile applications
- Traditionally use voided slabs
  - Had problems with camber at span length of 80ft
  - WSDOT limits S/D to 33 for voided slabs
- WF36G
  - Weighs half as much as slab for same span length
  - Greater structural efficiency than slabs
  - More economical to fabricate
  - Span Capability:
    - 80ft @12ft spacing – 100ft @ 5ft spacing

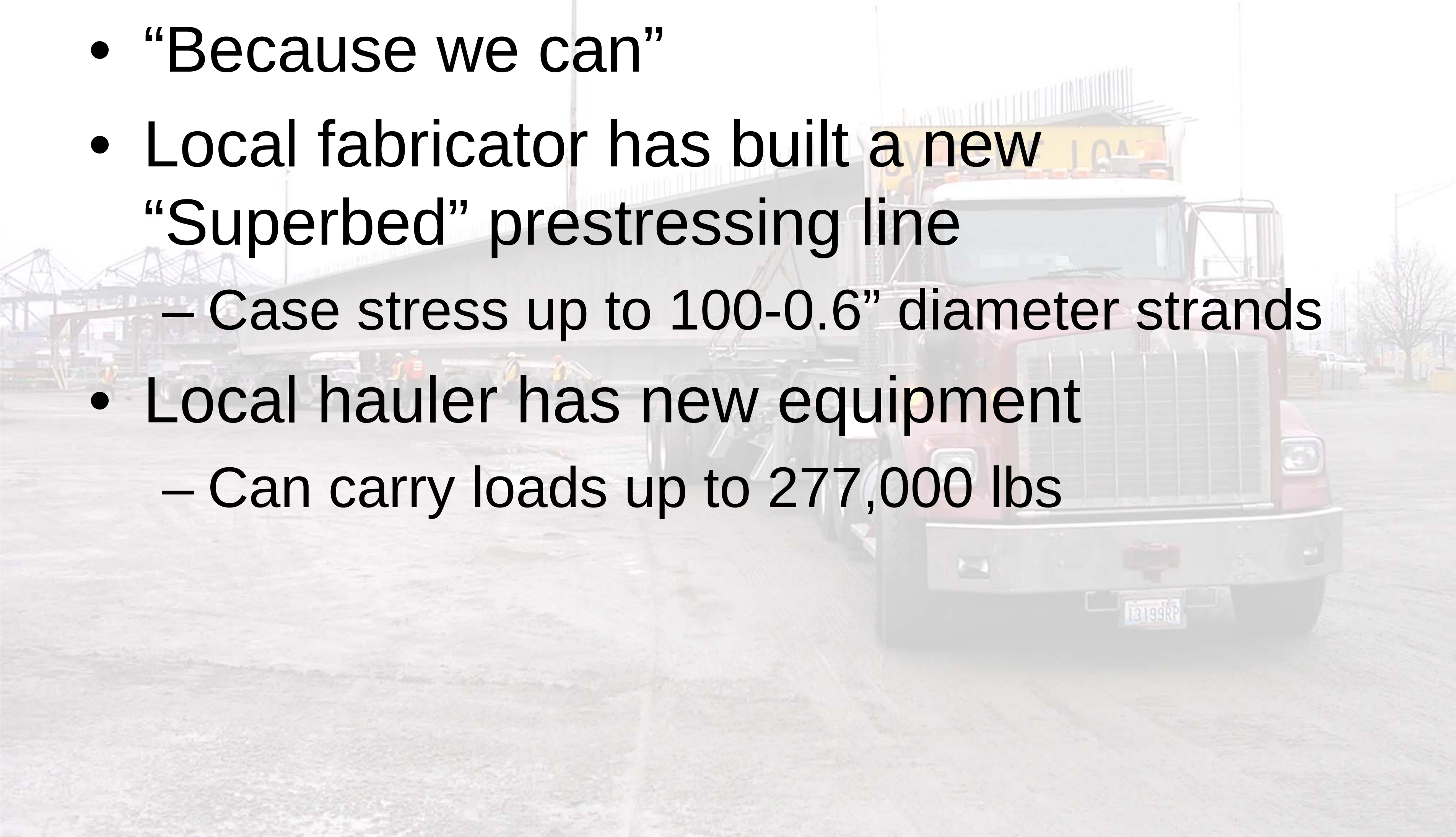
WF66G Girder

- Developed to “fill in the gap” of span capabilities
- Provides economical solutions in the 125' – 160' span length range



WF100G Girder

- “Because we can”
- Local fabricator has built a new “Superbed” prestressing line
  - Case stress up to 100-0.6” diameter strands
- Local hauler has new equipment
  - Can carry loads up to 277,000 lbs



WF100G Girder

- Maximum Span Length
  - 170 ft at 12ft girder spacing
  - 210 ft at 5ft girder spacing
    - 70 permanent strands
    - 10 temporary strands
    - f'_{ci} = 7,100 psi
    - f'_{c} = 11,700 psi
    - Total weight = 265,000 lbs

Hauling Equipment

WF83G girder

Photograph courtesy of Concrete Technology Corporation, Tacoma, WA

Superbed

Photograph courtesy of Concrete Technology Corporation, Tacoma, WA

Conclusion

- Recent innovations touch many aspects of precast-prestressed girder bridge solutions
  - Development of a design method that accounts for fabrication options
  - Software tool for robust design solutions
  - New girder sections that provided efficient and cost effective solutions for span lengths ranging between 60 and 210 ft.
- Key to success is cooperation between WSDOT and its PCI industry partners