Prestressed Concrete Bridge Design Seminar

Session 1 – April 13, 2021

2a. Fabrication of Prestressed Concrete Girders

PCI Mid-Atlantic
A Chapter of the Precast/Prestressed Concrete Institute

PCI Northeast
A Chapter of Precast/Prestressed Concrete Institute

1

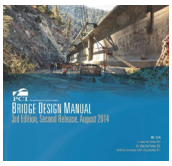
Overview

Economical fabrication depends on economical design and detailing

- Process and details of fabrication
- Design considerations (later presentations)

Much info from *PCI Bridge Design Manual*

- Chapter 2 – Material Properties
- Chapter 3 – Fabrication and Construction
- Chapter 4 – Strategies for Economy



Many fabrication details are possible – a few examples are shown

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Prestress Plants

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Materials

Prestressing strand

Mild reinforcement

Concrete

4

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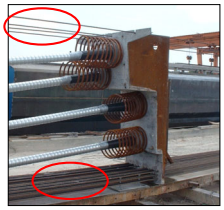
Prestressing Strand

Prestressing strand
ASTM A416 Grade 270

Strand shipped in coils



Pretensioned strands and post-tensioning anchorages, spirals and ducts

Pretensioning and post-tensioning can be combined as shown here

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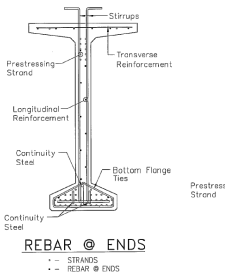
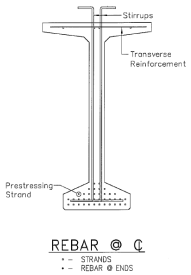
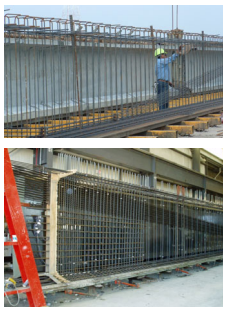
Mild Reinforcement







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Concrete

Conventional methods for proportioning and mixing concrete

- High strength mixes – up to 10 ksi at 28 days
- High flow mixes to move through congested reinforcement
- Rapid strength gain so girders can be removed from the beds quickly

Aggregate conveyer

Batch plant discharge

7

7

Fabrication

Forms

Casting beds

Strands – straight & harped

Tensioning & ducts

Embedments

Casting operations

8

8

Forms

External

- Side forms
- Soffit
- End headers
- Adjustable forms
- Internal void forms
- Self stressing bed

Internal

- Stay-in-place
- Removable

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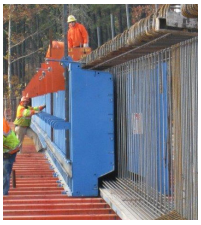
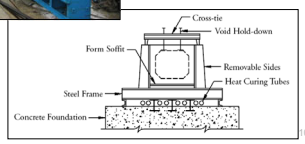
9

External Forms



Girder side forms



Box beam form

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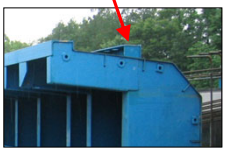
Adjustable Forms

Some prestressers use adjustable forms

Form to adjust top flange width



Horizontal joint allows insertion of filler or haunched sections

Other form modifications will be discussed later

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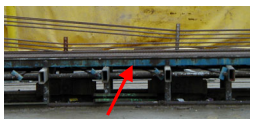
Soffit or Pallet Forms

The soffit is the form for the bottom of the girder

- Defines the width of bottom flange
- Supported by and attached to supports



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End Forms

Headers are usually fabricated of steel to allow reuse

- Avoid modifying strand patterns
- Slotted for draping strands
- Wood may be used if modifications are required

Bulb-tee end form (header)

Modification required for skewed ends

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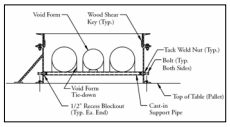
Stay-In-Place Internal Forms



Voided slab form

Waxed cardboard void forms for cored slab

Polystyrene foam billet for trapezoidal box beam – also for conventional box beams

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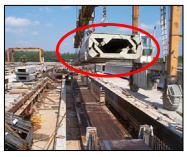
14

Removable Internal Forms



Placing expanded form for RR box beam

Removing retracted void form

Void form for cylinder pile

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Self-Stressing Forms

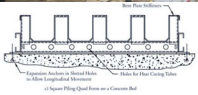
Form structure resists the pretensioning force - no abutments required

- Strand anchor plates bear on form

Double-Tee Form

- Similar to NEXT Beam

Square Piling Form



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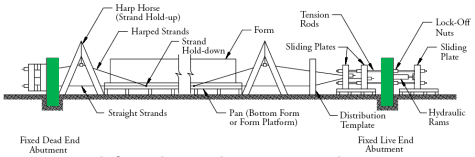
16

Prestressing Bed

The structure that resists the pretensioning force on the strands

Abutment type bed – most common

- Abutments are typically fixed in foundation
- Slab may be used as strut between abutments
- Typical bed length: 300 – 500 ft long; can be ≤ 200 ft



Details for multi-strand tensioning are shown

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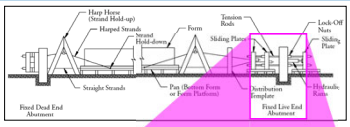
17

Abutments



Tied

Cantilever – most common

18

18

Strutted-Type Bed

Raised structural elements resist forces

Pile sections used as struts

Strands are in top flange for haunched pier segments of spliced girder bridges

- Struts provide reaction for strands anchored at level of strut

Strands at top of haunched segment

19

19

Strand Anchor Plates

Anchor plates span between abutments – major structural elements

- Strand pattern is set – 2 in. x 2 in. grid is standard
- Assembly can usually be raised or lowered as needed

20

20

Strand Anchor Plates

Self-stressing piling form

- Strand pattern is set using heavy end plates
- NEXT Beam is similar

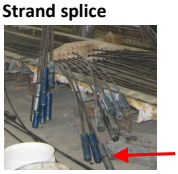
21

21

Strand Anchorage

Strand chucks

- Reusable type is standard
  - Spring-loaded at stressing end
  - May use non-spring-loaded at dead end
- Single use
- Strand splice



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22

Single Strand Tensioning

Strands are tensioned from one end of bed

Single strand tensioning with long ram

Elongation measurement

Pressure gages on pump

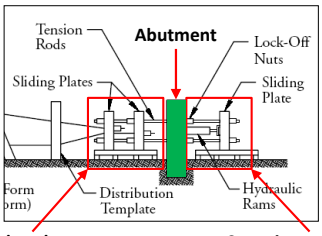
Elongation and pressure gage readings must agree within 5%

Elongation for 500 ft bed is 42.6"; 25.6" for a 300 ft bed

23

23

Multi-Strand Tensioning & Detensioning



Strand anchorages

Stressing equipment

Also called "gang" tensioning

24

24

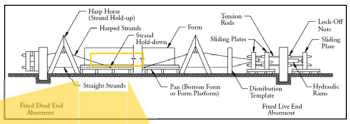
Multiple Strand Tensioning & Detensioning

Separate anchorages for top (draped) and bottom (straight) strands

Stressing rams behind the abutments pull large rods to stress strands

25

Straight Strands



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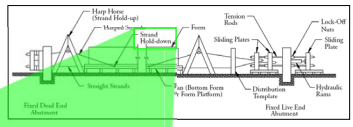
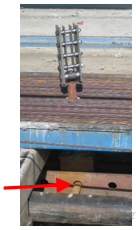
26

Draped Strands – Hold Down



Hold down anchored to rail under bed



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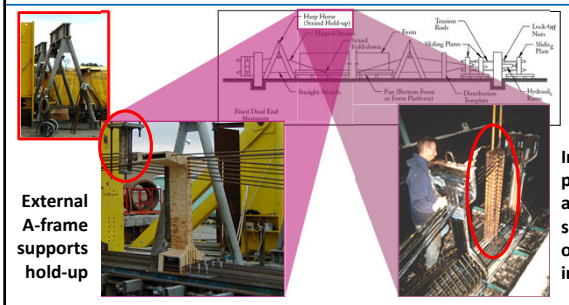
Draped Strands – Hold Up



External A-frame supports hold-up

Internal plate assembly supported on pallet inside bed

28

28

Draped Strands – Hold Up

Example of internal plate hold up device

Crane lift point

In lowered position

In raised position

Pin

In raised position with pin to fix elevation

Rollers

29

29

Stressing Strands

All strands are tensioned in 2 steps

- Initial tension of 2000 to 4000 lbs, depending on bed length
  - Removes slack and seats dead end chuck
  - Provides reliable starting point for QC readings
- Remaining stress is then applied to full tension
  - For Grade 270 0.6-in.-diam. strands = 43.9 kips
- Corrections may be needed for abutment movement, chuck seating, and temperature

Draped strands will have different forces or elongations from straight strands, adding complexity to stressing operations

30

30

Debonding

Plastic sleeve or tubing prevents bond between strand and concrete

- Option for stress control at ends of girders instead of draping
- Preferred over draping by most fabricators
- May also be used for top strands in center portion of girder

Installation

- Must access strands to place and seal with tape
- Not all strands are easily accessible
- Ends of sleeves sealed to prevent entry of concrete

31

31

Debonding

Material

- Two-piece snap together sleeves
  - Easy to use
- Solid tube
  - Placed on strand as installed in bed
  - Not as easy to install
- Split sleeve (not allowed by some DOTs)
  - Has to be taped for full length to prevent concrete from entering sleeve
- Ends of all types of sheath must be sealed
- If sheath is not continuous, joints must also be taped

32

32

Debonding Considerations

For economical design, engineers need to understand how girders are manufactured in a plant

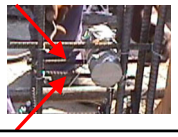
- Provide minimum debond length required by design to control stresses
- Stagger terminations of debonding to avoid potential cracking
- Consider access when selecting debonded strands
  - Workers must access strands to apply and seal debonding
  - Special attention may be required for NEXT beams where side forms are fixed and strands can only be accessed from above
  - Discuss with local fabricators

33

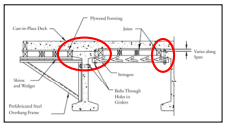
33

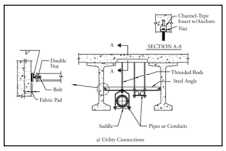
Embedments

Bearing plates and diaphragm holes



Additional bars used to secure hole form





Form and pipe hangers

34

34

Quality Control

Bed setup

Stirrup spacing

Cross-section dimensions

35

35

Quality Control

Mix development & concrete testing

Concrete strength testing

Slump test

36

36

Concrete Delivery and Placement

Concrete delivered to and placed in forms

- Various methods used
- Units shown do not agitate the concrete, which is delivered by auger

Concrete delivery

Concrete placement

37

37

Concrete Delivery and Placement

Vibration is typically used to consolidate concrete

Self-consolidating concrete (SCC) or high slump concrete is often used

- Facilitates placement, promotes good consolidation, and reduces vibration requirements

Internal vibration

External (form) vibration

38

38

Top Flange Finishes

Typically the top flange receives a raked finish with minimum amplitude of ¼ in. for composite behavior

May be partial width if partial depth prestressed deck panels are used

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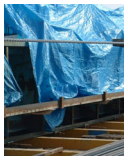
39

Curing

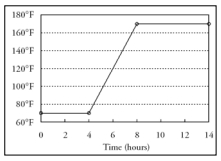
Curing is important

- Forms are typically covered to retain temperature and moisture

Accelerated (elevated temperature or steam) curing may be used



Curing tarps are used to retain heat for initial curing



Theoretical time-temperature curve for accelerated curing

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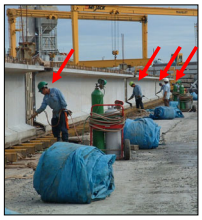
Detensioning

Initial concrete strength, f'_{ci}, must be achieved before detensioning

Tarps and side forms are removed

Single strand detensioning

- Workers simultaneously detension each strand according to pattern in shop drawings
- Strands are heated with a torch until wires relax and break – they are not cut
- Specified procedure and pattern
- Hold downs must be released to avoid damage as girders shorten and camber



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41

Detensioning

Gang detensioning

- Repressurize rams
- Release hardware holding load, then depressurize rams
- Girders will move down bed as they are detensioned
- Since girders move, hold downs must be released to avoid damage
  - May lead to high stresses in girders before strands are detensioned
  - If so, may require additional reinforcement or other measures

42

42

Detensioning

Girders camber up and the ends slide on the bed as they are detensioned

- Initial camber measurements are often made while still on bed
- Fabricators may lift girder ends before taking camber reading to relieve any drag force at ends

Sliding can cause spalling at the ends of a girder

- Bearing plates help prevent spalling
- Skewed ends on bottom flange should be avoided

43

43

Finishing Girder Ends

Strands extending from girder after transfer

Strands cut flush & sealed on ends at expansion joints

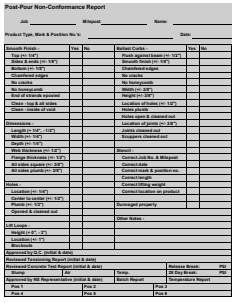
Strands burned off with short projections on ends cast into diaphragm

Foam recess form for cutting and patching strands

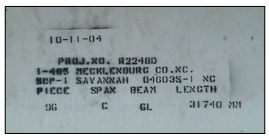
44

44

Quality Control



Post-pour inspection



Product tracking

RFID tag

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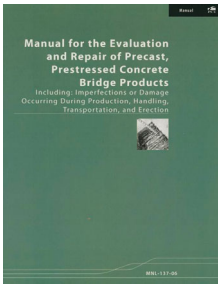
Fabrication Defects and Repairs

PCI Repair Manual (MNL 137-06)



This guide helps provide a uniform assessment and approach to fixing many defects to ensure that responses are measured, appropriate and cost-effective for the situation.

Currently being updated

Discussed in later presentation

46

46

Handling and Transportation

Plant Handling and Storage

- **Lift points**
- **Storage & stacking**

Transportation

- **Trucking**
- **Barge**
- **Rail**

47

47

Lifting and Storage

Lifting loops and other lifting devices

Typical strand loops

Rigid lifting devices

Sling

48

48

Lifting and Storage

Stacking & Storage

Precast deck panels

Girders on dunnage in plant

49

49

Shipping

Stacking & Storage

Loading girder on a truck

Specialized equipment is used

50

50

Shipping

Remotely steered trailer

51

51

Shipping Considerations

Increase overhang over supports to improve stability
- Need to consider stresses
- Full f'_c is usually available by time of shipping

Several methods to attach girder to hauling equipment
- Fabricator may request holes through web or flange



52

52

Shipping Considerations

Shipping route
- Will load be permitted on route?
- Length of girder for curves and obstacles
- Roll stiffness of the hauling system
- Consider superelevation along route
- Access to the site

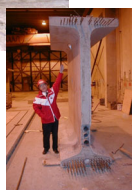
If questions – discuss with fabricator and/or hauling contractors

Issues related to lateral stability are discussed in later presentation

53

53

Shipping Record Length Girders



210 ft long single-piece girder - NU 2800 (110 in.)

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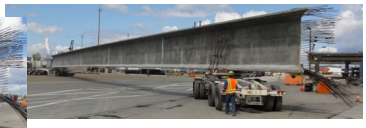
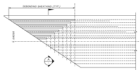
New Record Longest Single-Piece Girder in US

Mod WSDOT WF100G – 223 ft long at CL; add 7 ft for skew

- LWC was used to reduce weight for hauling



See article in Fall 2019 issue of *ASPIRE*

55

55

Barge & Rail


Barge loaded with beams

Barge loaded with piles

Loading box beams on railcar


Load must be balanced

56

Installation

Jobsite Handling

- Crane lifting
- Launching truss
- Shoring

Connections

Lateral Stability



Two-crane lift

One-crane lift with long slings

One-crane lift with spreader bar

57

Launching Beam or Truss

Setting precast beam with launching beam

- Crane lifts girder from truck and sets on dolly on the launching beam
- Truck backs up to push girder across launching beam where it can be picked by crane at other end

58

58

Launching Beam or Truss

Launching beam on steroids in Oregon

59

59

Launching Beam or Truss

Placing one end of girder on dolly on launching beam

Truck will back up to push it across launching beam

60

60

Launching Beam or Truss

Two cranes lift girder while dollies are repositioned

61

61

Launching Beam or Truss

Motorized dollies move girder across the launching beams to the next span

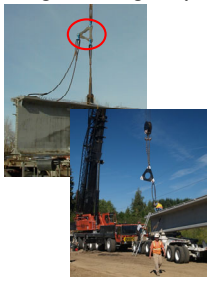
Photos are from the late Dr. Keith Kaufman with Knife River PS in OR

62

62

Launching Beam or Truss

Using load triangle to pass girder between two cranes



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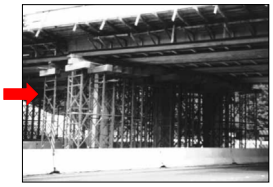
Launching Beam or Truss

Using load triangle to pass girder between two cranes

64

64

Shoring



Shoring

Strongback

Temporary support tower
for spliced girder erection

65

65

Summary

Keys to economical prestressed concrete bridges

- Understanding production of girders
- Proper design and detailing
- Local availability of products
- Repetitive use
- Open communications

Contact your local fabricators!

66

66

Crane Lifting

Pop quiz!!

Why are they having to use a come-along along to set this girder?

- **Girder is being set with a single crane with inclined leads**
- **Far end of girder is higher, so it is already on the bearing**
- **Inclined pick on this end creates thrust**

67

67

Prestressed Concrete Bridge Design Seminar

Session 1 – April 13, 2021

2a. Fabrication of Prestressed Concrete Girders

Questions?

PCI Mid-Atlantic
A Chapter of the Precast/Prestressed Concrete Institute

PCI Northeast
A Chapter of Precast/Prestressed Concrete Institute

68