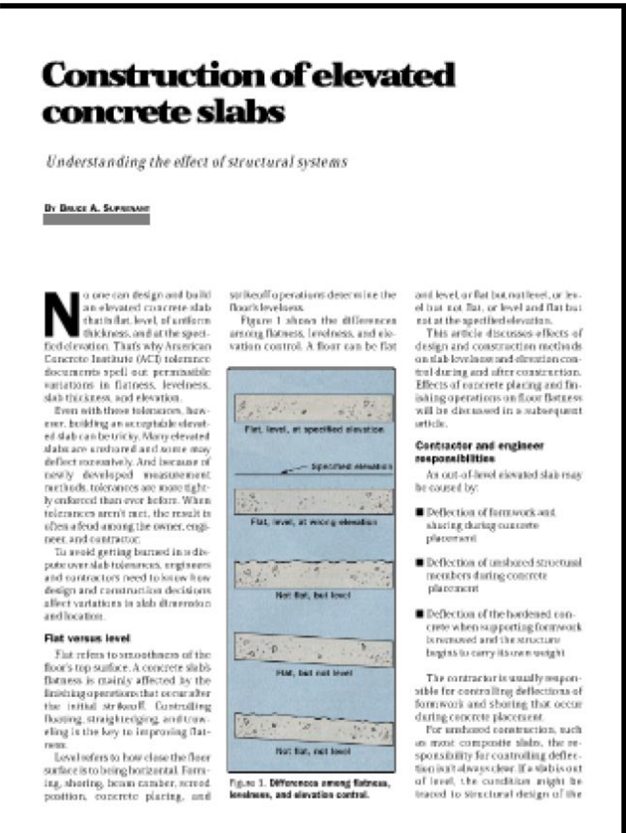
Producing Level Slab on Metal Deck Floors

Structural Services, Inc.

Eldon Tipping
Structural Services, Inc.
Dallas, Texas

1990-1991



Construction of elevated concrete slabs

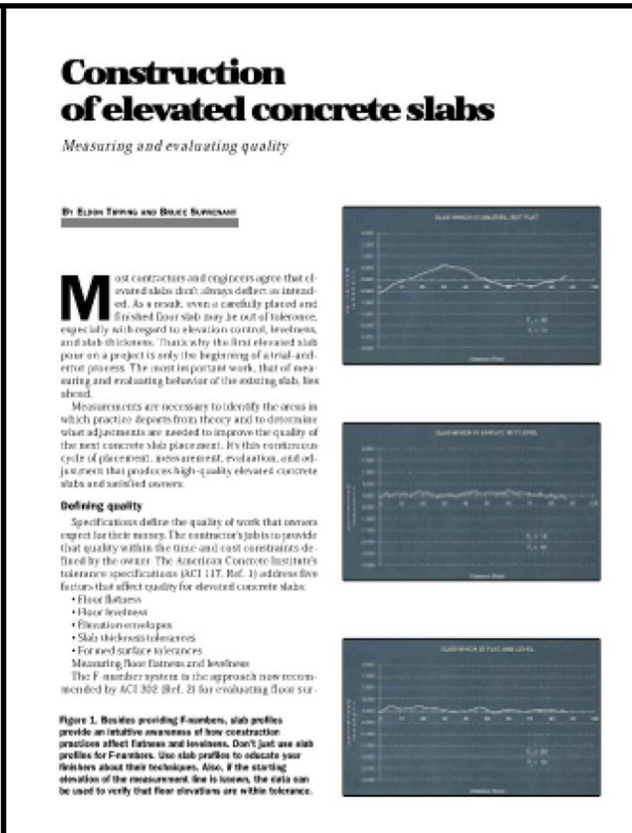
Understanding the effect of structural systems

By Bruce A. Suprenant

Flat versus level

Contractor and engineer responsibilities

Figure 1. Differences among flatness, levelness, and elevation control.



Construction of elevated concrete slabs

Measuring and evaluating quality

By Eldon Tipping and Bruce Suprenant

Defining quality

Figure 1. Besides providing F-numbers, slab profiles provide an intuitive awareness of how construction practices affect flatness and levelness. Don't just use slab profiles for F-numbers. Use slab profiles to educate your finishers about their techniques. Also, if the starting elevation of the measurement line is known, the data can be used to verify that floor elevations are within tolerance.

Construction of elevated concrete slabs

Practice and procedures

By Eldon Tipping and Bruce Suprenant

Flexibility to adjust is critical

Use preconstruction planning

Concrete consistency is a must

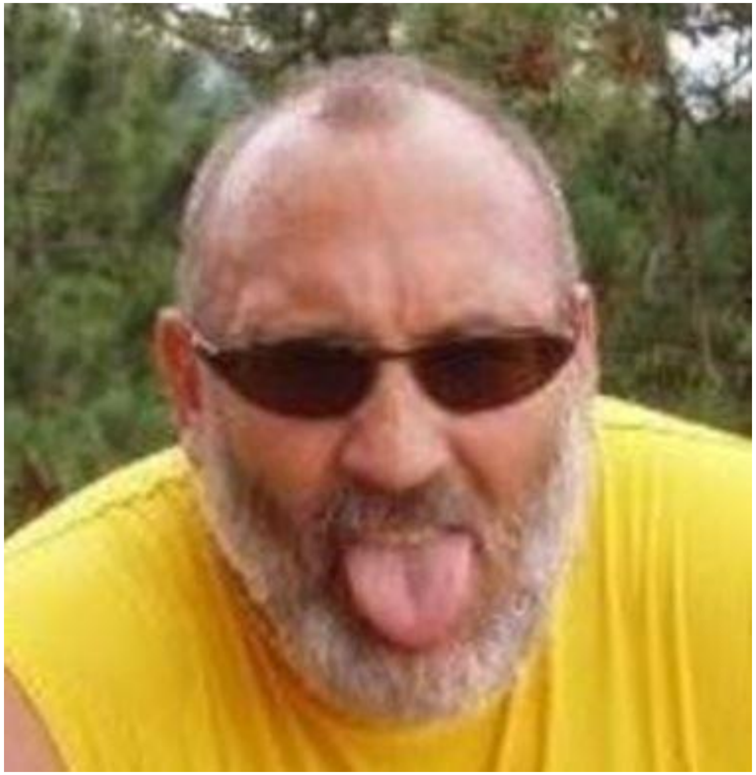
Emphasize concrete control

Various accessories are available or can be built to maintain accurate screed elevation. Poor screed elevation control decreases floor levelness

THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE

aci CONCRETE CONVENTION

Fast Forward to 2009

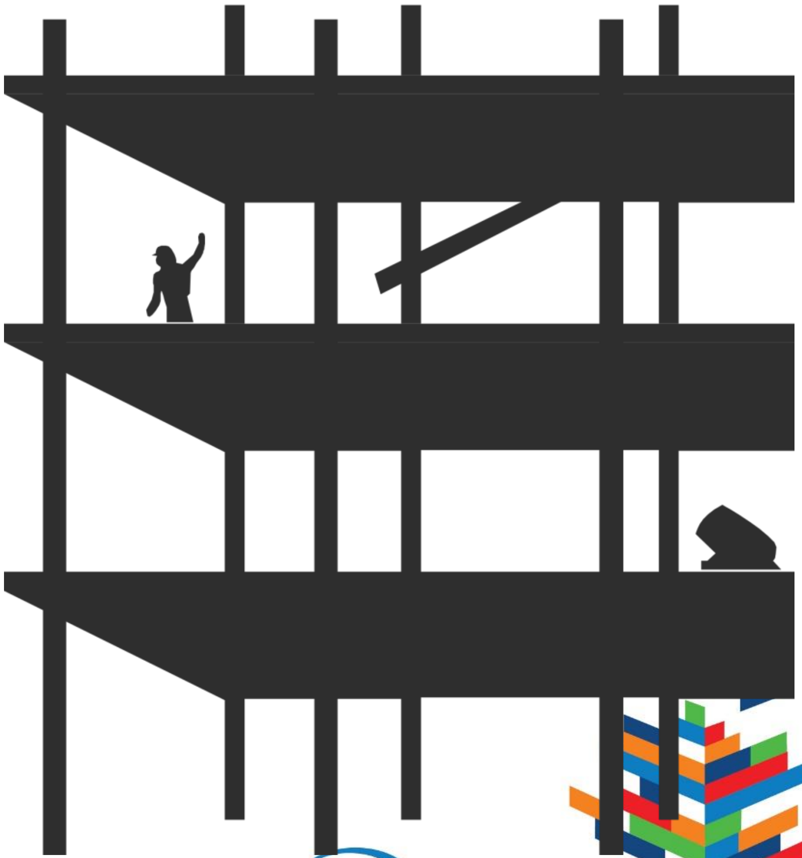


LEARNING OBJECTIVES

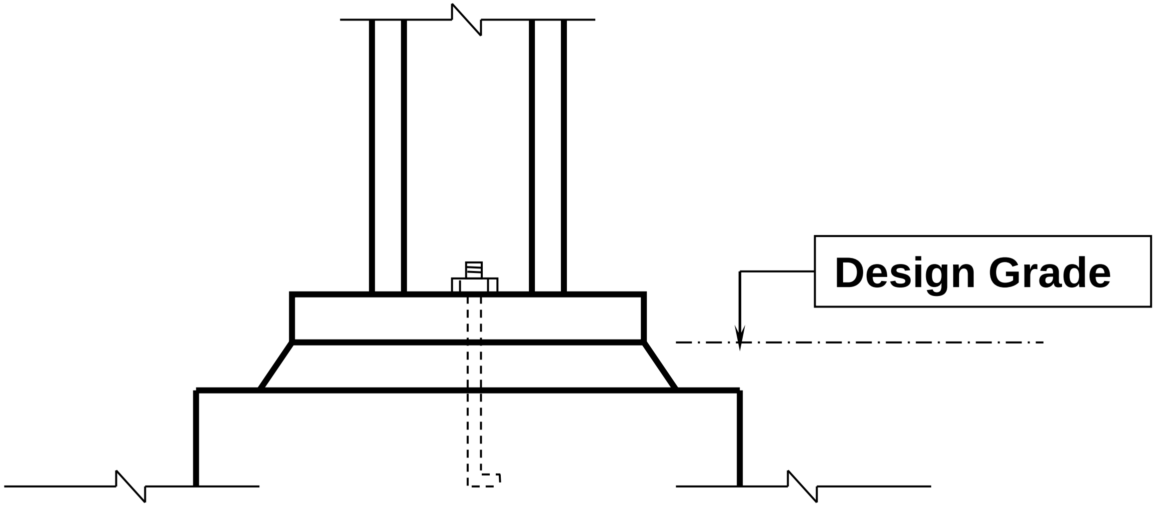
- Discuss fabrication and erection tolerances for floor construction.
- Compare design options to mitigate the impact of deflection of composite concrete on metal deck floor slabs.
- Describe construction problems for constructing a level floor.
- Summarize effective specification requirements for an un-shored composite slab on metal deck.
- Describe tools and techniques that allow the contractor to respond to deflection behavior of the slab.

OVERVIEW: Segment 1

- Elements Impacting Levelness of Deflected Floor
  - Fabrication/Erection of columns & beams
  - Deflection of erected floor frame
  - Concrete placing/finishing techniques

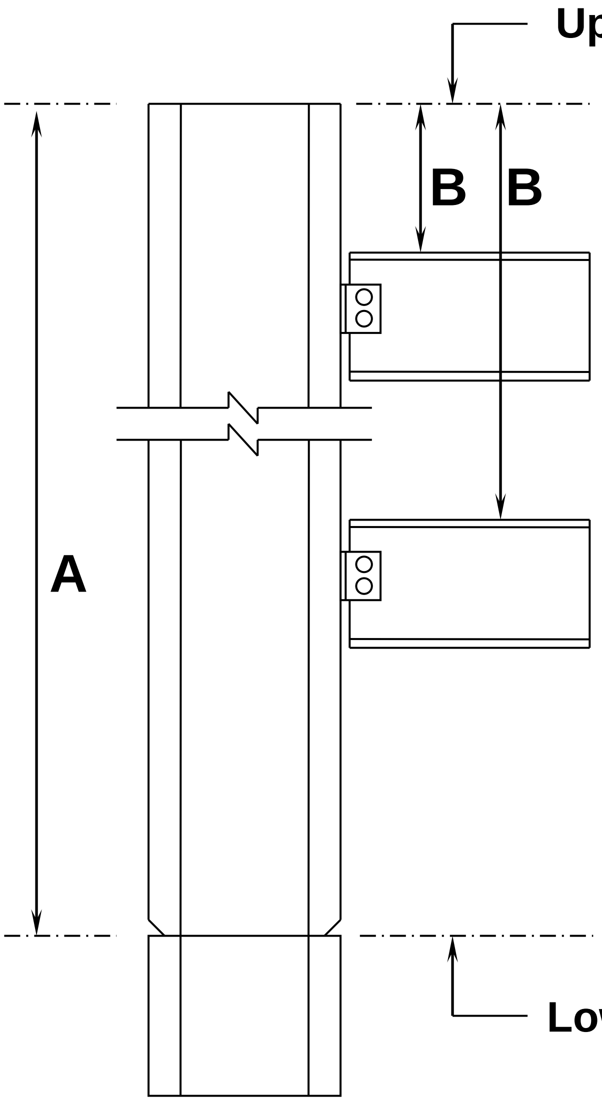


Structural Steel Tolerances

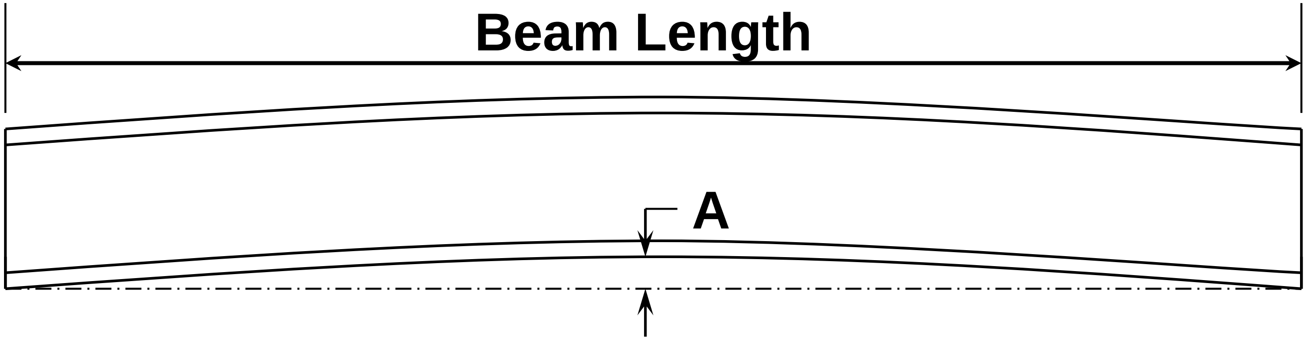


AISC CODE OF STANDARD PRACTICE – Paragraph 7.6

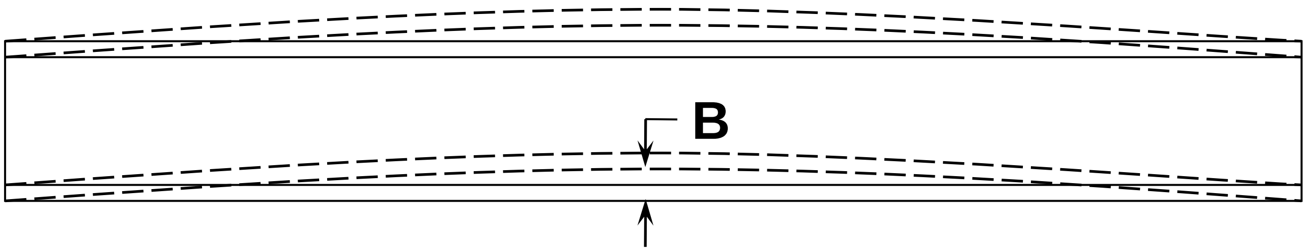
Elevation tolerance relative to established grade is +/- 1/8"



AISC STANDARD MILL PRACTICE		
Item	+/- Tolerance	Paragraph
A	+/- 1/32”	6.4.1
B	+ 3/16” - 5/16”	7.13.1.2(b)



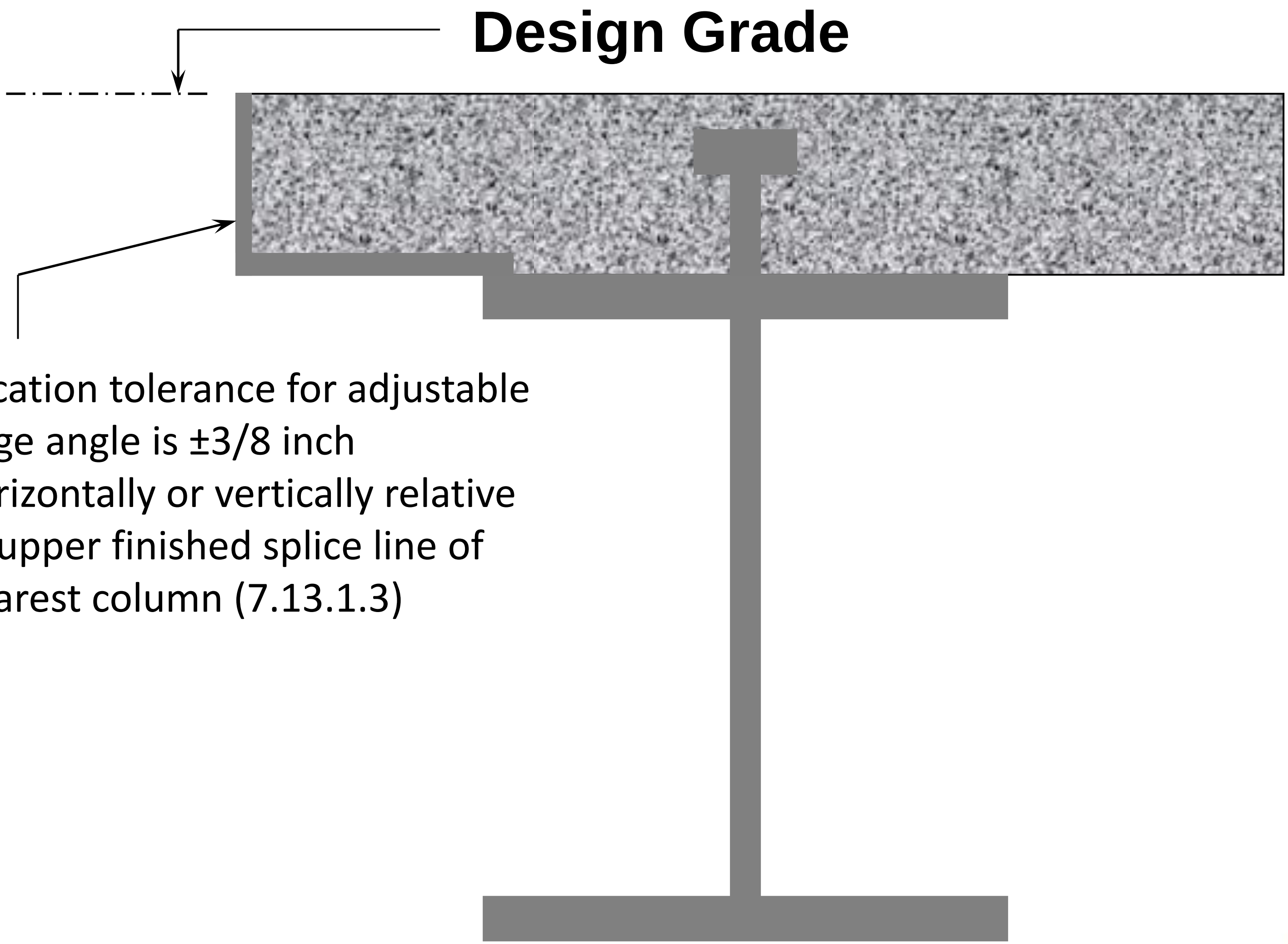
Beams With Specified Camber



Beams With No Specified Camber

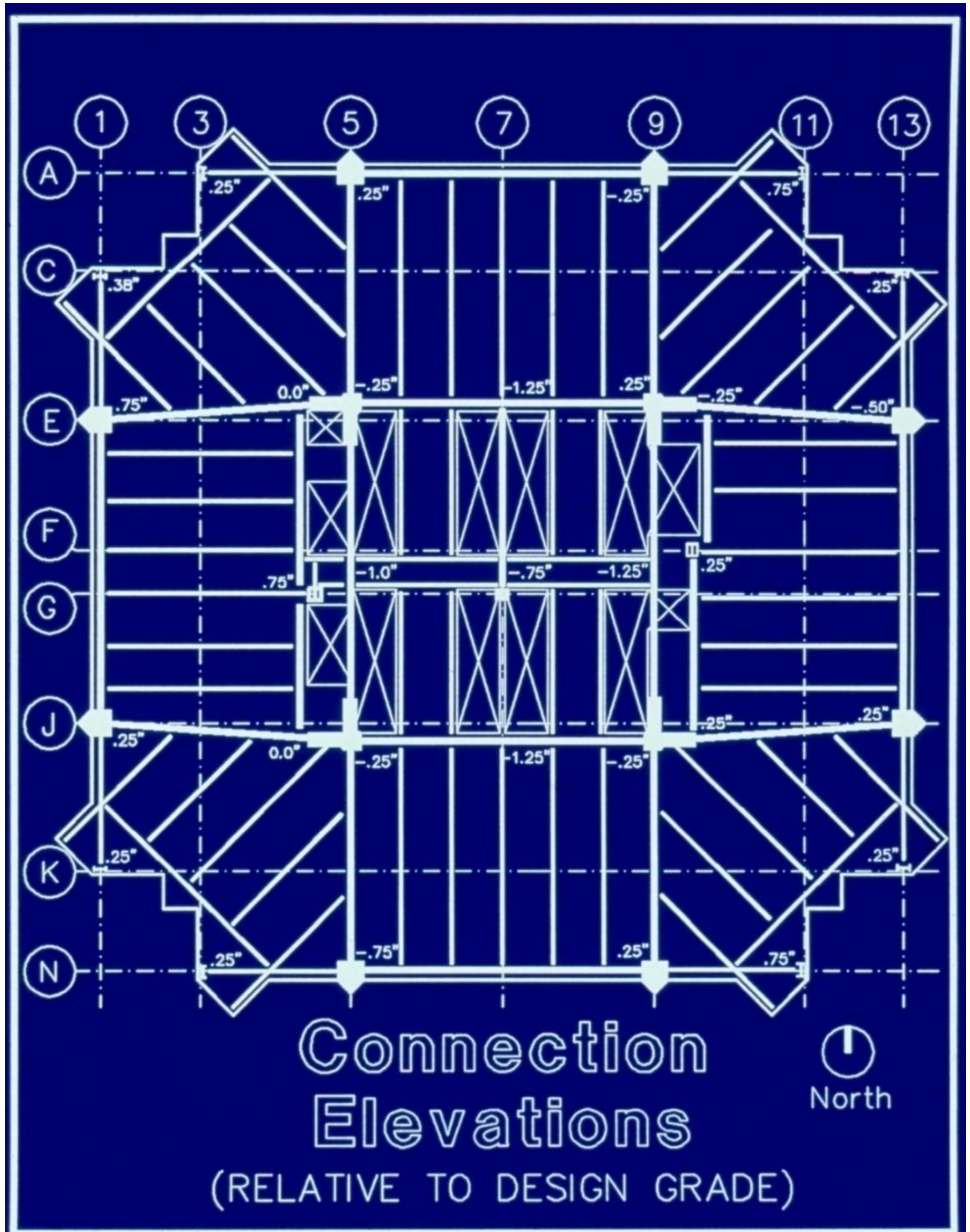
AISC STANDARD MILL PRACTICE

Item	Beam Length	Plus Tolerance	Minus Tolerance
A	50’ or Less	+ ½”	- 0.0”
A	Over 50’	+ ½” + 1/8” / 10’	- 0.0”
B	All	+ 1/8” x .2 L	- 0.0”



Location tolerance for adjustable edge angle is ±3/8 inch horizontally or vertically relative to upper finished splice line of nearest column (7.13.1.3)


EL = 34.00



1
3
5
7
9
11
13
A
C
E
F
G
J
K
N
.25"
.25"
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.75"
.38"
.25"
0.0"
-.25"
-1.25"
.25"
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-.50"
.25"
.75"
-1.0"
-.75"
-1.25"
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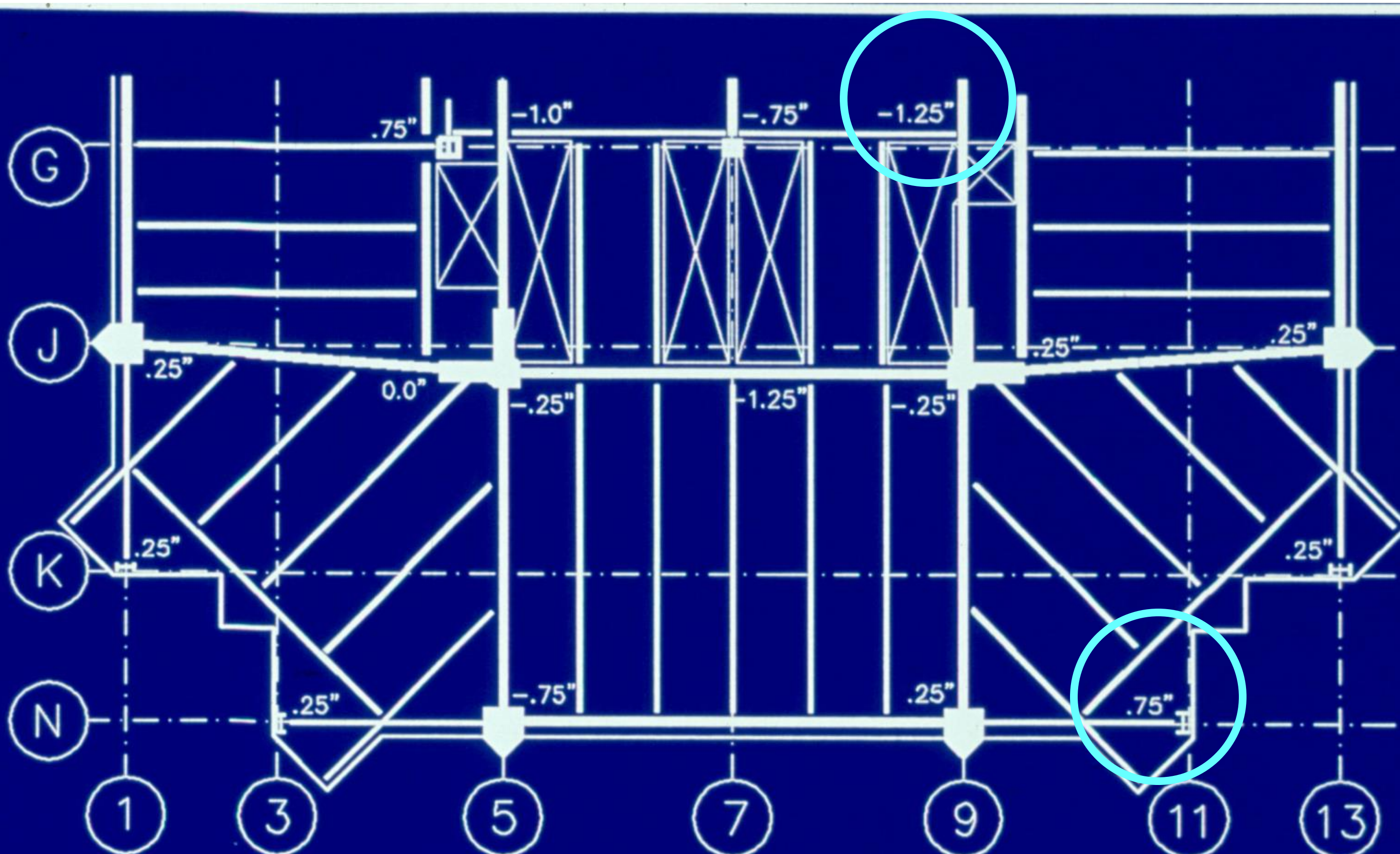
.25"
0.0"
-.25"
-1.25"
-.25"
.25"
.25"
.25"
-.75"
.25"
.25"
.75"
North
Connection
Elevations
(RELATIVE TO DESIGN GRADE)



Connection Elevations

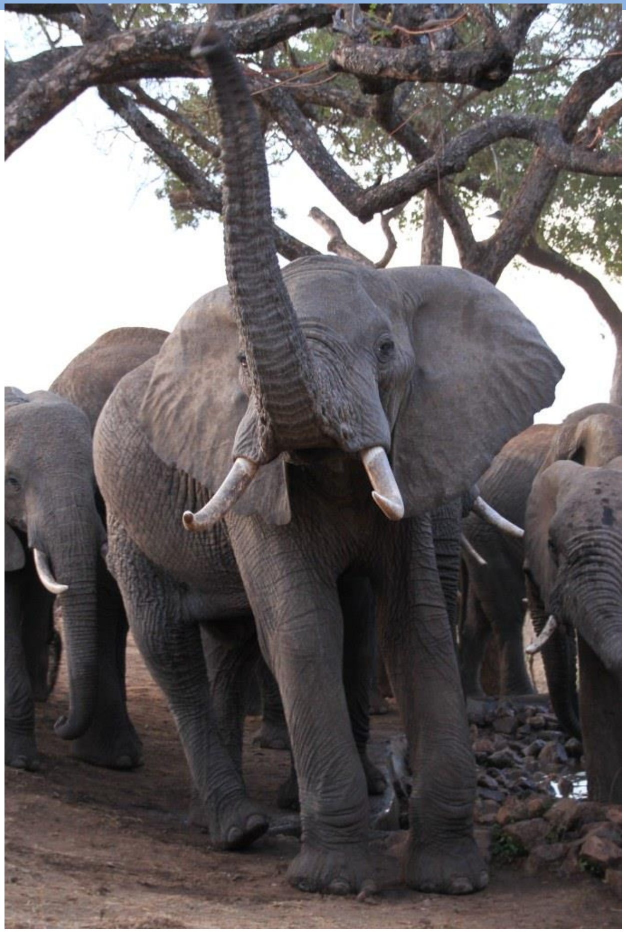
(RELATIVE TO DESIGN GRADE)

COLLECT DATA TO IDENTIFY PRE-PLACEMENT LEVELNESS OF STRUCTURAL STEEL

LEVELNESS

The levelness of suspended slabs depends on the accuracy of formwork and strike-off, but is further influenced, especially in the case of slabs-on-steel decking, by the behavior of the structural frame during and after completion of construction.

ACI 302-15 (5.3.2)



DEFLECTION

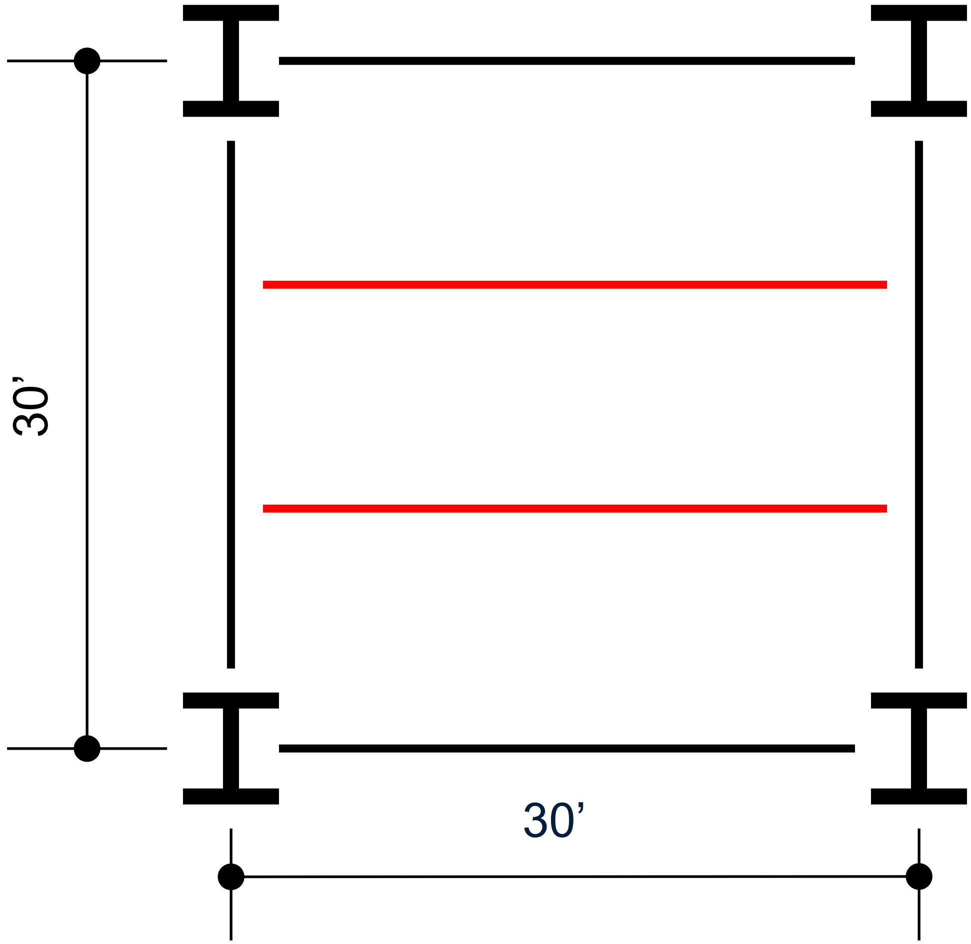
STEEL DESIGN CHOICES

Structural Steel Design Decisions

- Steel Code
  - Allowable Strength Design 13th Edition (Working Stress)
  - Load & Resistance Factor Design 13th Edition (Ultimate Strength)
- Steel Strength
  - Fy = 36 ksi
  - Fy = 50 ksi

Allowable Strength Design

13th Edition

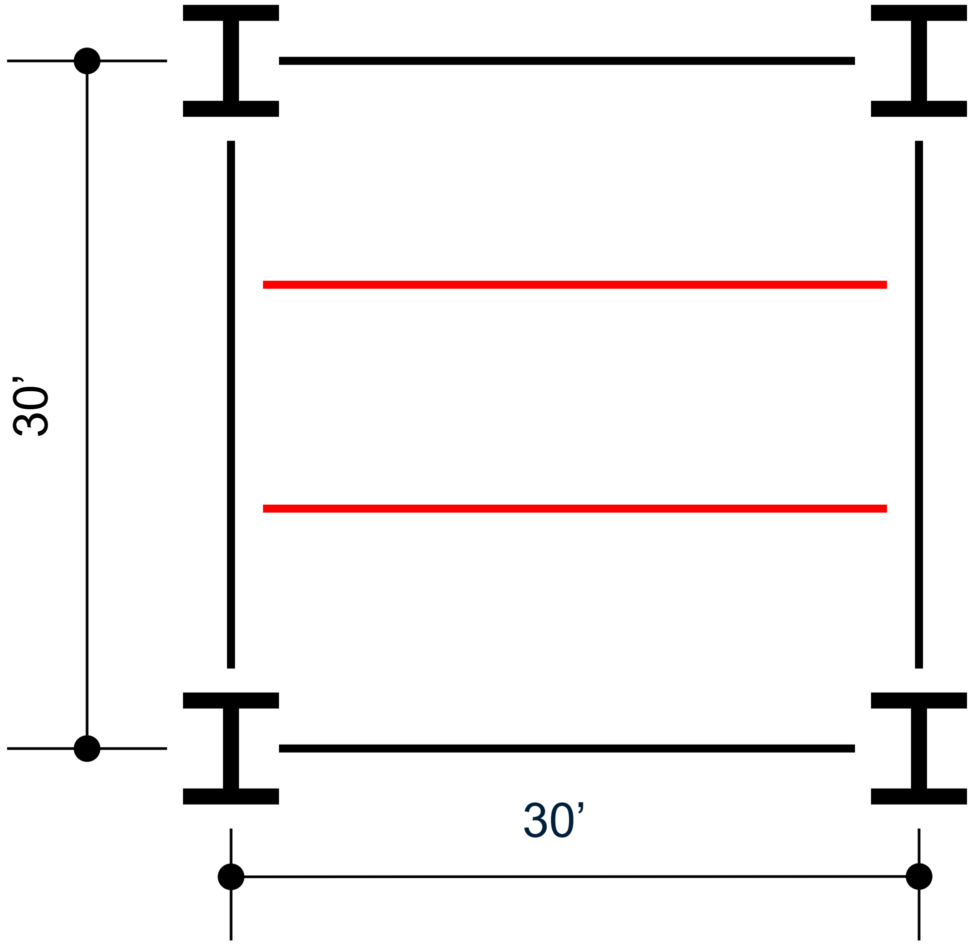


Fy = 50 ksi

W14x22

δ = -1.58"

Load & Resistance Factor Design



Fy = 50 ksi

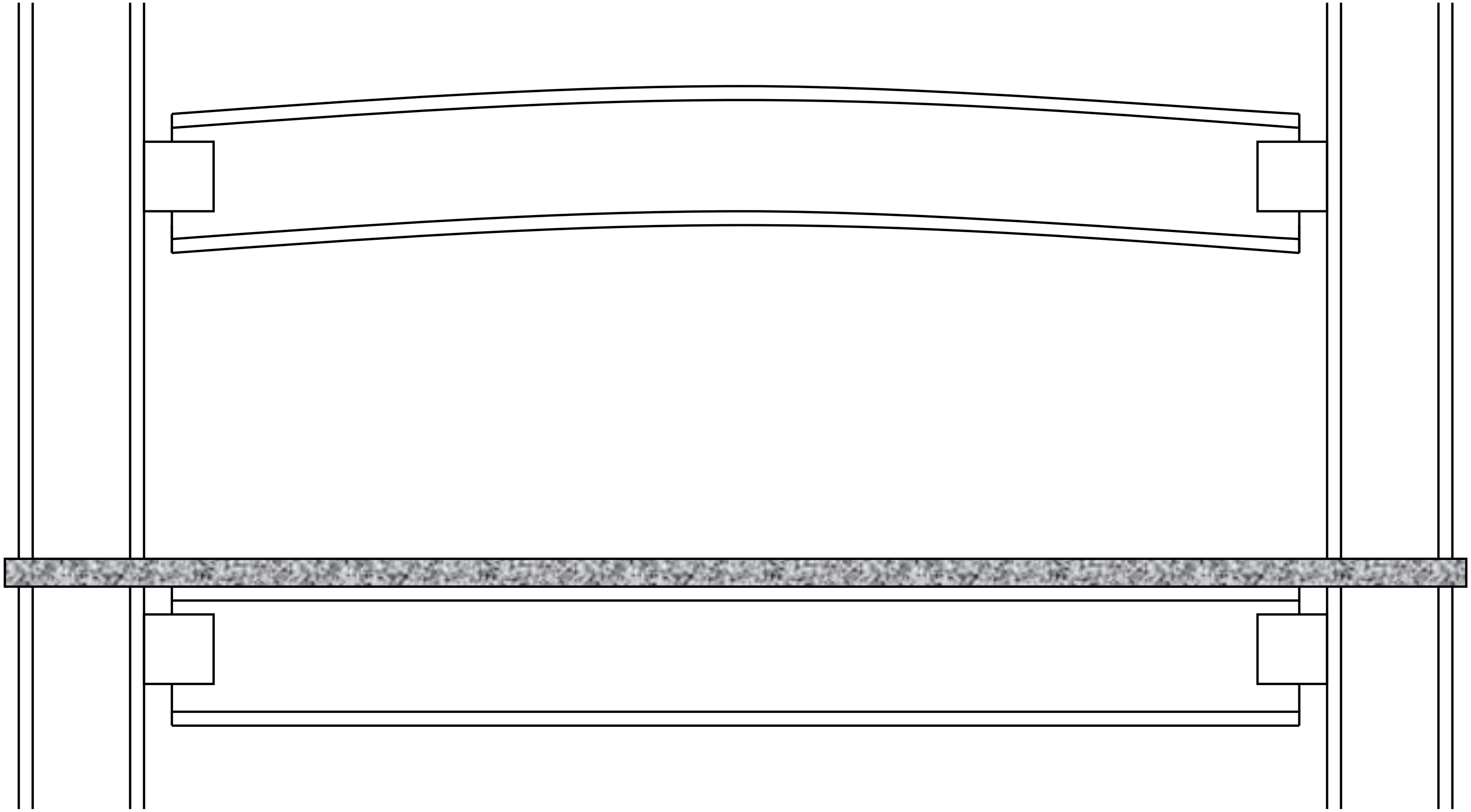
W12x19

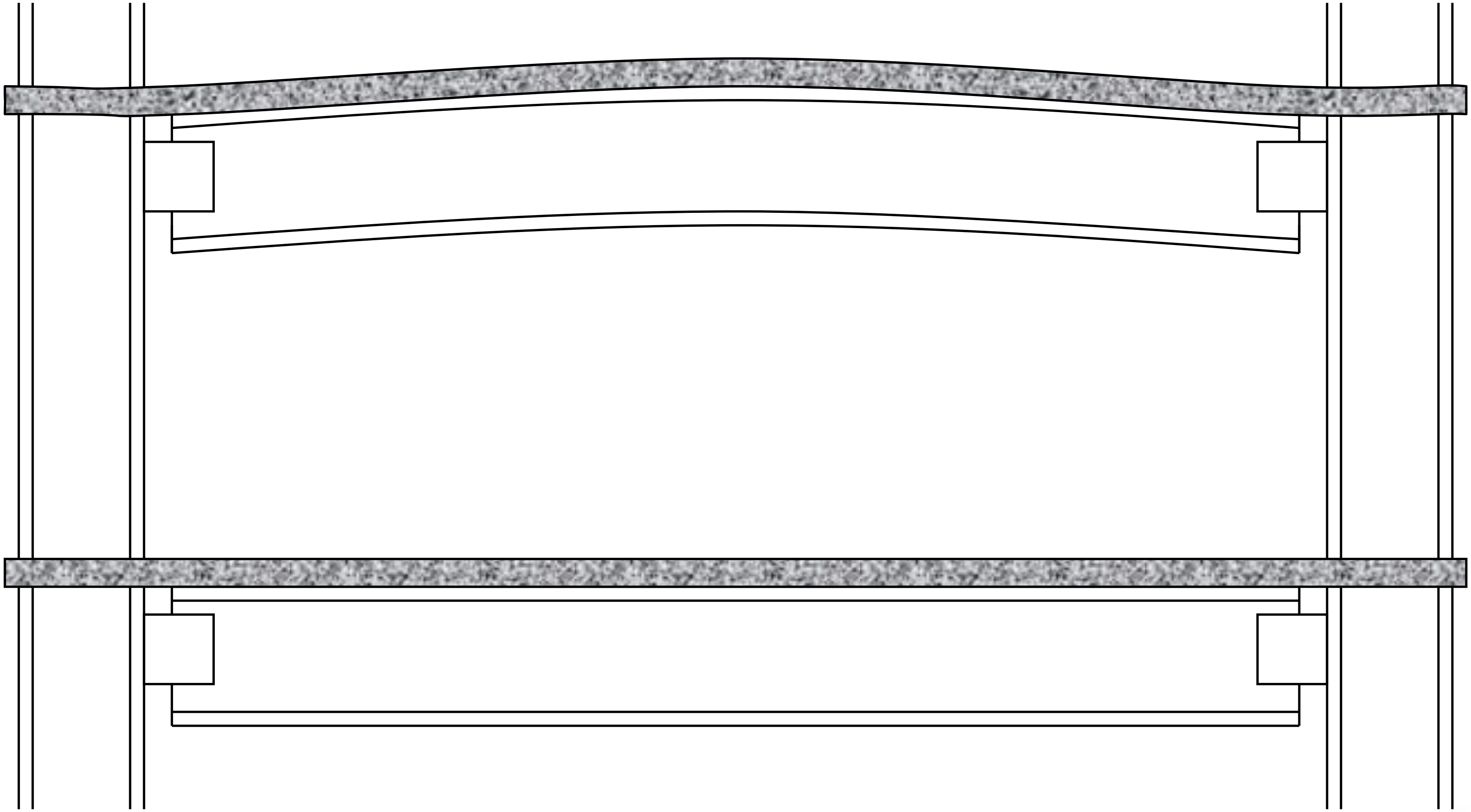
δ = -2.42"

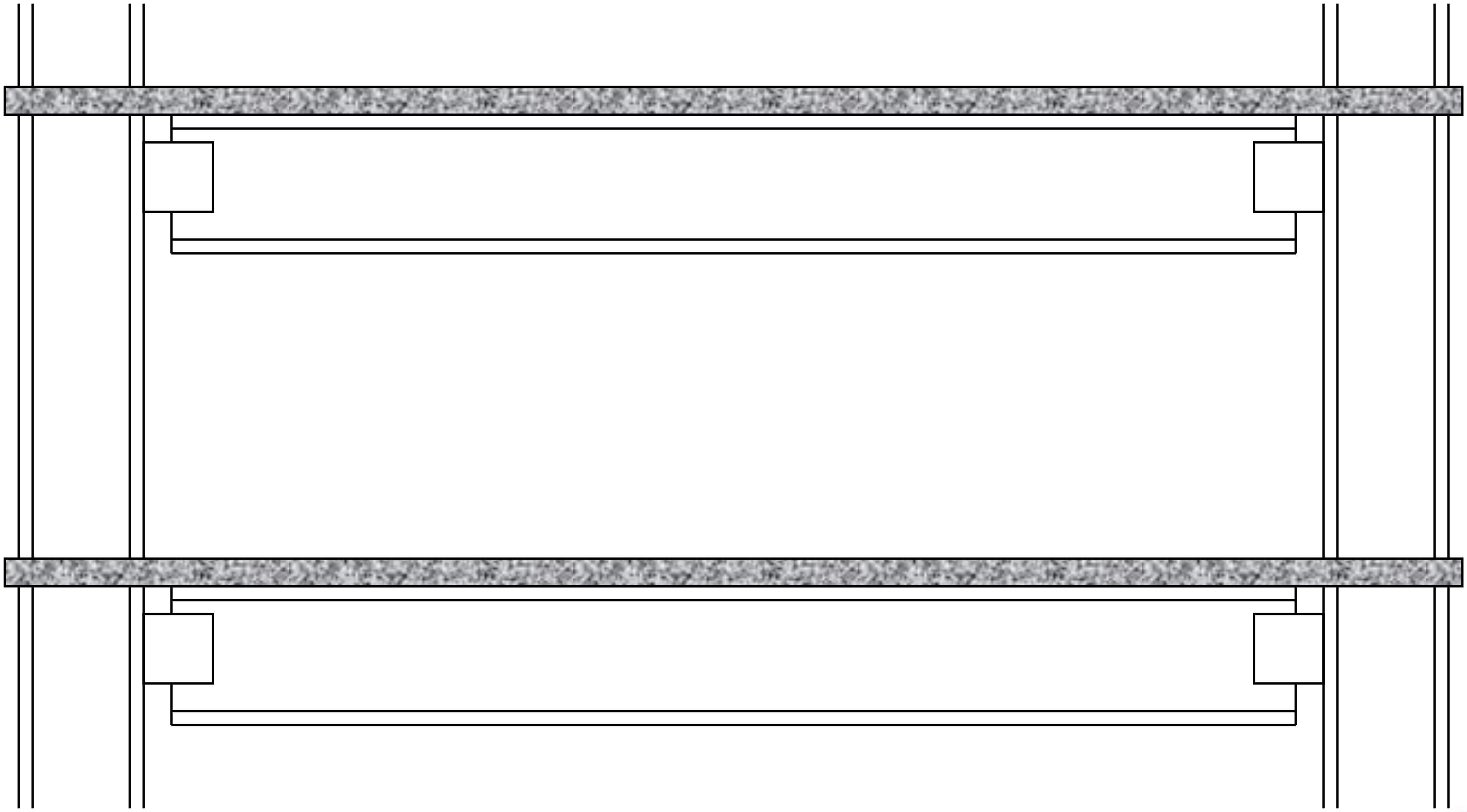
LESSON FOR THE SPECIFIER/DESIGNER

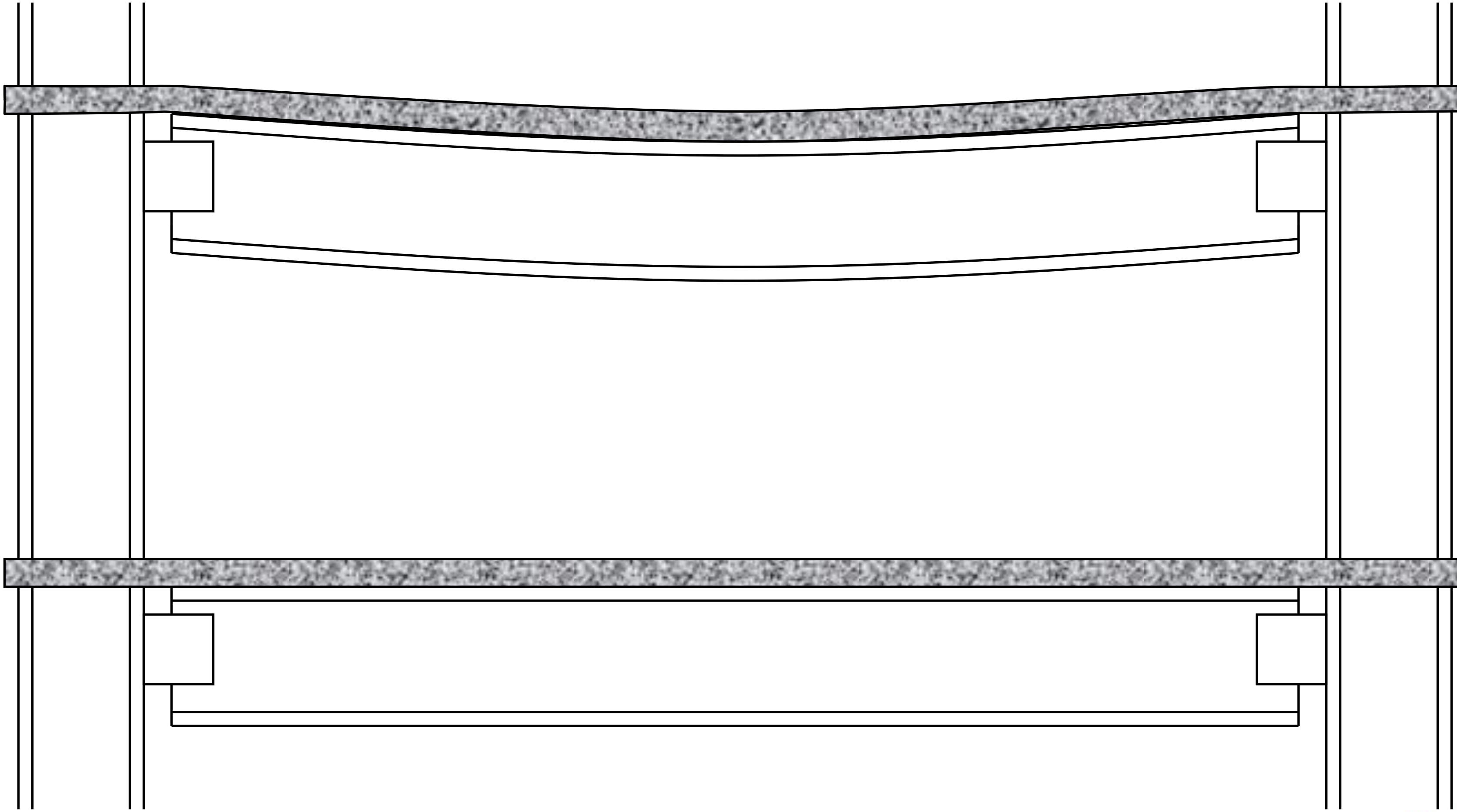
AVOID DESIGNS THAT TAKE MAXIMUM ADVANTAGE OF LRFD/GRADE 50 SOLUTIONS

Cambered Member Deflection

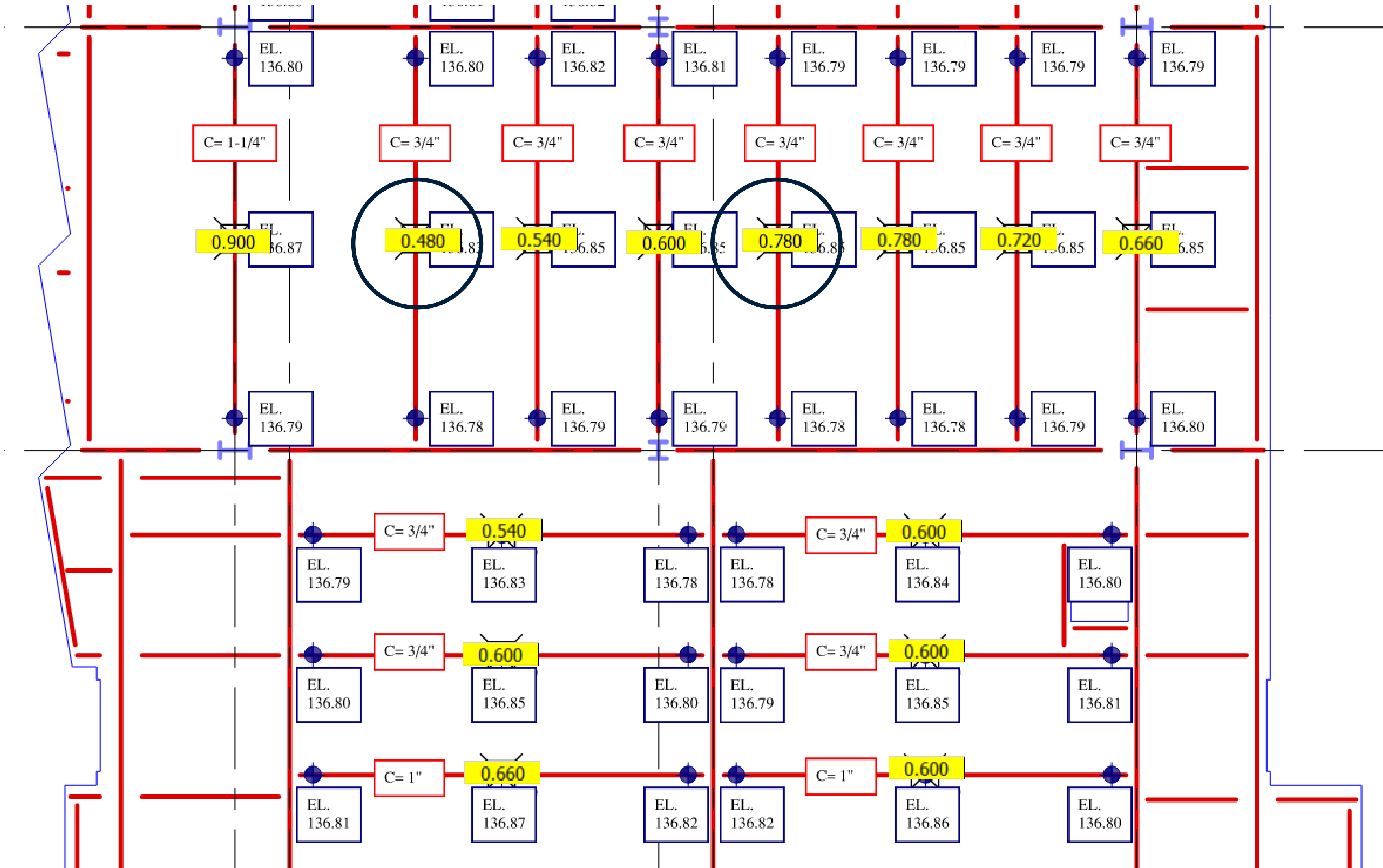








Cambering Strategy


EL. 136.80
EL. 136.80
EL. 136.82
EL. 136.81
EL. 136.79
EL. 136.79
EL. 136.79
EL. 136.79
C= 1-1/4"
C= 3/4"
C= 3/4"
C= 3/4"
C= 3/4"
C= 3/4"
C= 3/4"
C= 3/4"
0.900
0.480
0.540
0.600
0.780
0.780
0.720
0.660
EL. 136.79
EL. 136.78
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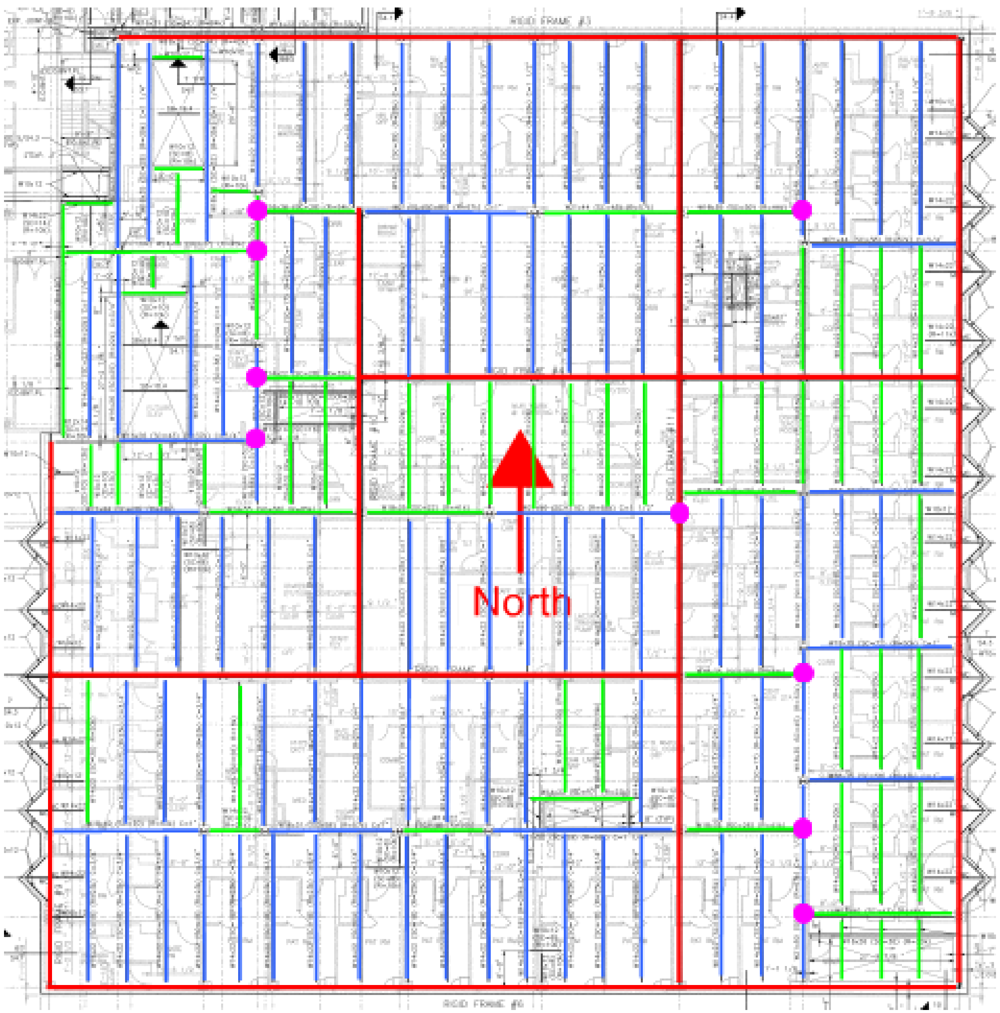
EL. 136.79
EL. 136.78
EL. 136.78
EL. 136.79
EL. 136.80
C= 3/4"
0.540
C= 3/4"
0.600
EL. 136.79
EL. 136.83
EL. 136.78
EL. 136.78
EL. 136.84
EL. 136.80
C= 3/4"
0.600
C= 3/4"
0.600
EL. 136.80
EL. 136.85
EL. 136.80
EL. 136.79
EL. 136.85
EL. 136.81
C= 1"
0.660
C= 1"
0.600
EL. 136.81
EL. 136.87
EL. 136.82
EL. 136.82
EL. 136.86
EL. 136.80



LEGEND

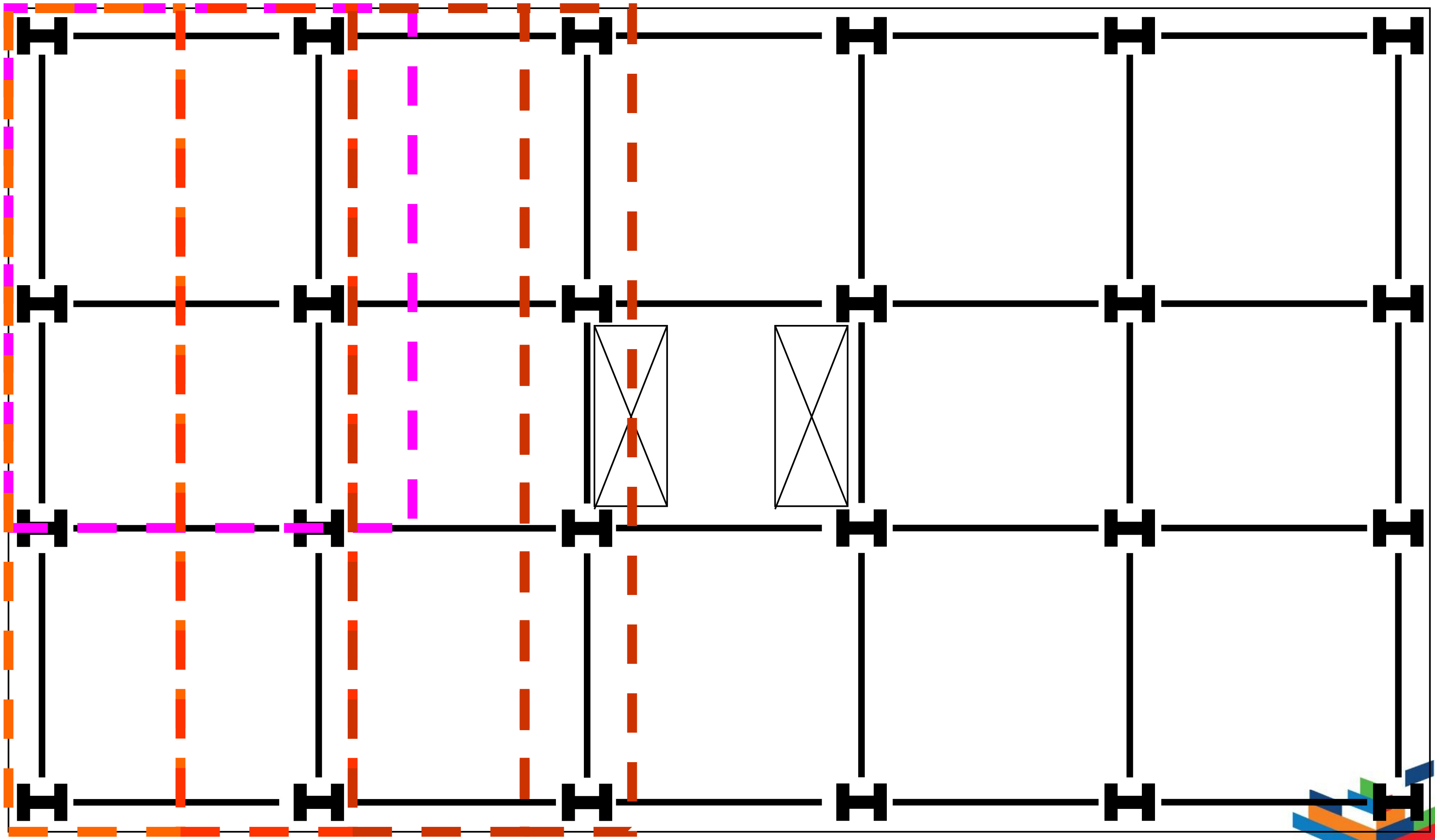
- Girder-supported Girder
- Rigid Frame
- Cambered Beam/Girder
- Un-cambered Beam/Girder

Effective Cambering Strategy

- One size does NOT fit all
- Look at deflection of the system rather than just individual members
- Recognize that members with no camber still deflect
- Recognize that members framing into columns don’t deflect like same members framing into girders

USE CAMBERING STRATEGY THAT LOOKS AT COMBINED MOVEMENTS OF GIRDERS AND BEAMS

TYPICAL CONCRETE PLACEMENT SEQUENCE



Placing & Finishing Techniques

How do you achieve an unshored structural steel monolithic floor that is level?

Place concrete to an elevation by using a rod and level…

Or…

Place concrete by gauging up off the structural steel.

Keep in mind that for un-shored construction the frame is moving the entire time concrete is being placed.


7 5/8
Green
MP

RECOGNIZE THAT USING A ROD AND LEVEL ON A STEEL FRAME WILL NOT PRODUCE LEVEL FLOORS

COLLECT DATA THAT ALLOWS EARLY IDENTIFICATION OF STRUCTURAL BEHAVIOR

OVERVIEW: Segment 2

- Ineffective or Incorrect Specification requirements
- Ineffective or unrealistic drawing requirements/ details

Ineffective/Incorrect Specifications

REFERENCE DOCUMENTS

ACI 302.1R-15 Guide to Concrete Floor and Slab Construction

- Guide-level documents are not written in mandatory language
- If specifier wishes to make content from a guide required, that content must be stated in the project specifications in mandatory language.

Guide-Level Documents

ACI Committee Reports, Guides, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This document is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the information it contains. ACI disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising there from.

Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/ Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

Ineffective/Incorrect Specifications

FLOOR FINISHING TOLERANCES

Flatwork Finishing Tolerances per ACI 117 and the following:

Suspended Slabs:

Overall: F_F 35 / F_L 25

Minimum Local: F_F 25 / F_L 17

Grade Tolerance: ±1/2 in.

Ineffective/Incorrect Drawings

Concrete thickness shown on metal decks is nominal and minimal. Average un-shored mid-bay deflection (steel framing plus metal decking), due to the weight of wet concrete, is estimated at 1 inch. Camber of steel members has been documented as indicated to account for a portion of this deflection. Provide additional concrete as required to make up for actual Project deflection. Finished top surfaces shall be level and flat within tolerances specified.

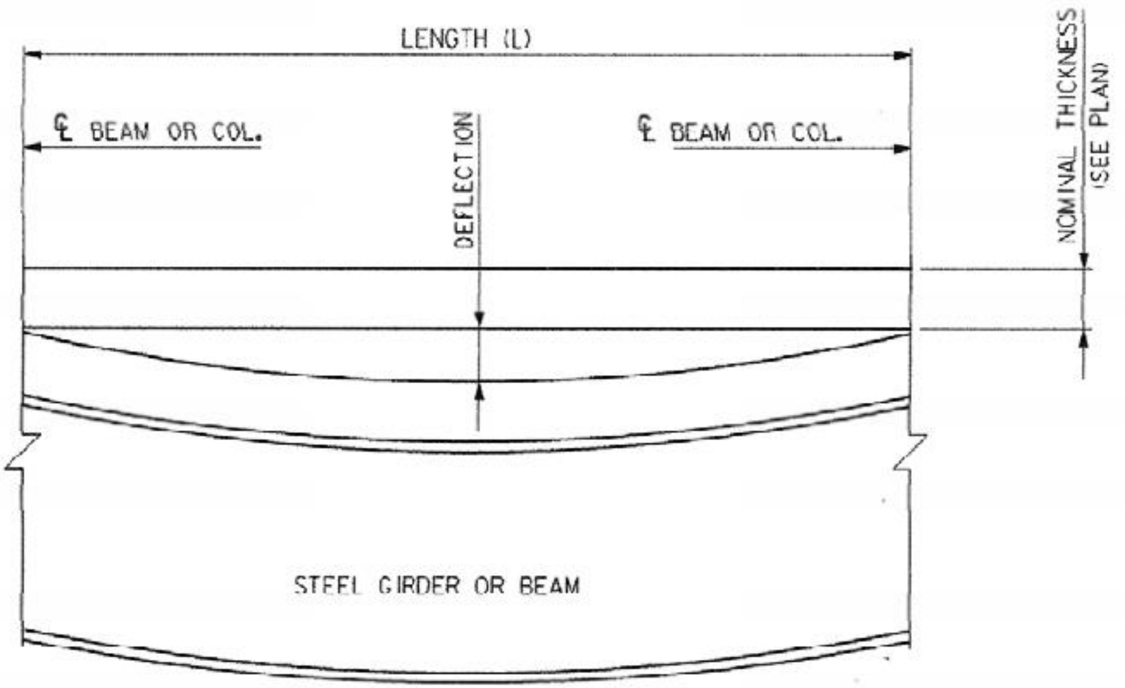
Ineffective/Incorrect Drawings

Structural Drawings – Concrete Notes

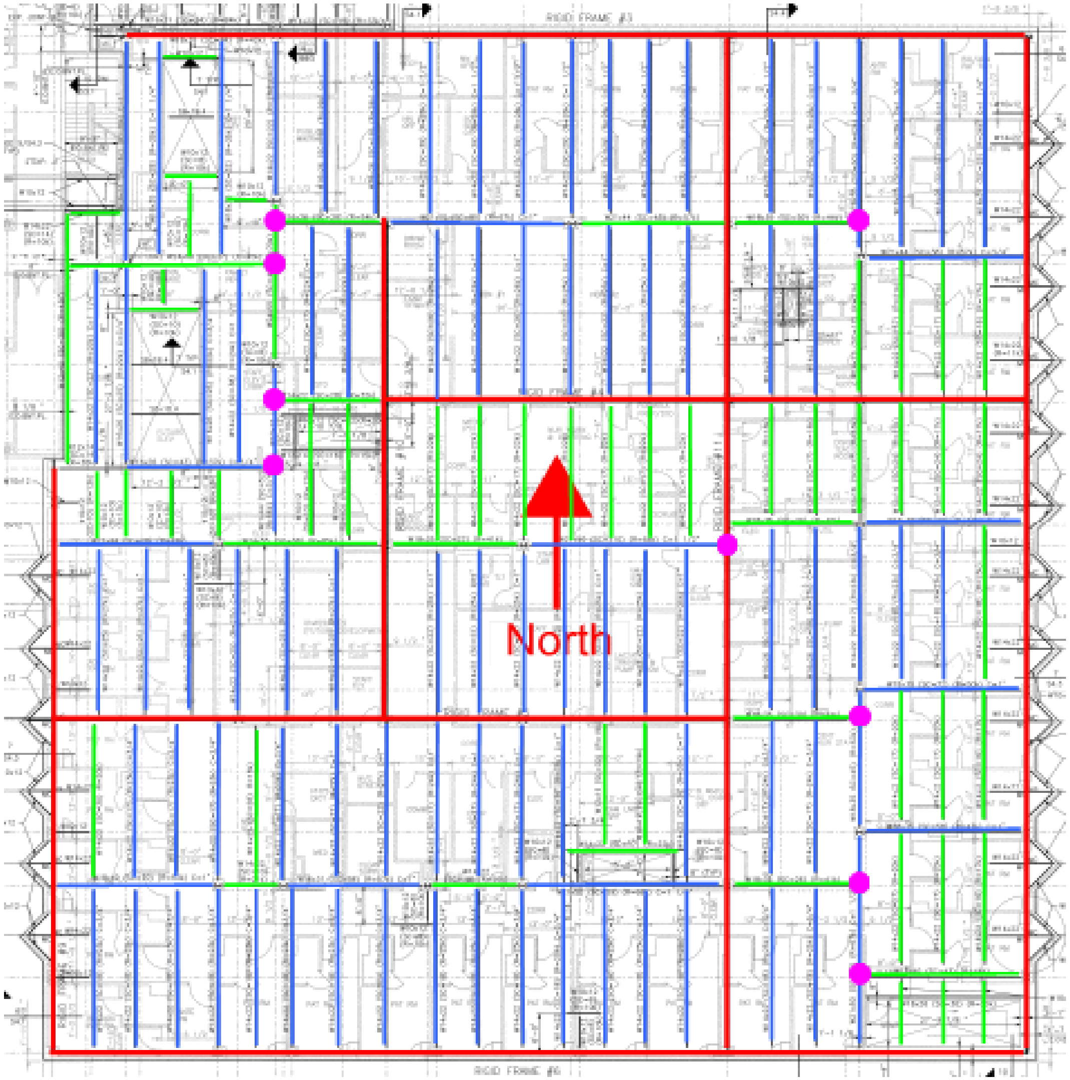
Composite deck shall be capable of supporting the loads described in the specifications and notes.

- Composite members are designed as unshored, unless noted otherwise.
- Composite floor slabs are to be finished level. The overrun of the wet concrete is to be anticipated and included in the contractors base bid.

Ineffective/Incorrect Drawings



NOTE: GIRDERS, BEAMS, AND METAL DECK WILL DEFLECT UNDER WEIGHT OF WET CONCRETE. PROVIDE ADDITIONAL CONCRETE AS REQUIRED TO COMPENSATE FOR THESE DEFLECTIONS, AND PRODUCE A LEVEL/FLAT FLOOR AS SPECIFIED AT THE CORRECT ELEVATIONS.



LEGEND

- Girder-supported Girder
- Rigid Frame
- Cambered Beam/Girder
- Un-cambered Beam/Girder

What are Unanswered Questions?

- What is the elevation of supporting steel?
- Does fabricated camber match that required?
- How much deflection will occur in key members?
- How much of estimated mid-bay deflection accounted for by cambering?
- What does contractor do if cambered steel members do not deflect to level after loading?
- What does contractor do if additional thickness required is significantly more than anticipated?

ACI 117-10 (15)

Specification for Tolerances for Concrete Construction and Materials

4.4—Deviation from elevation

4.4.1 *Top surface of slabs*

Slabs-on-ground .... ±3/4 in.

Formed suspended slabs, before removal of supporting shores .... ±3/4 in.

Slabs on structural steel or precast concrete .... no requirement

4.8.5.4 The SOF_L and MLF_L levelness tolerances shall apply only to level slabs-on-ground, or to level suspended slabs that are shored when tested.

OVERVIEW: Segment 3

- Specification provisions to improve levelness erected frame
  - Pre-and post-placement surveys
- Design options to mitigate impact of deflection
  - Cambering Strategy
- Utilize controlled method of strike-off
- Use survey data to respond to unanticipated behavior

Specification Provisions

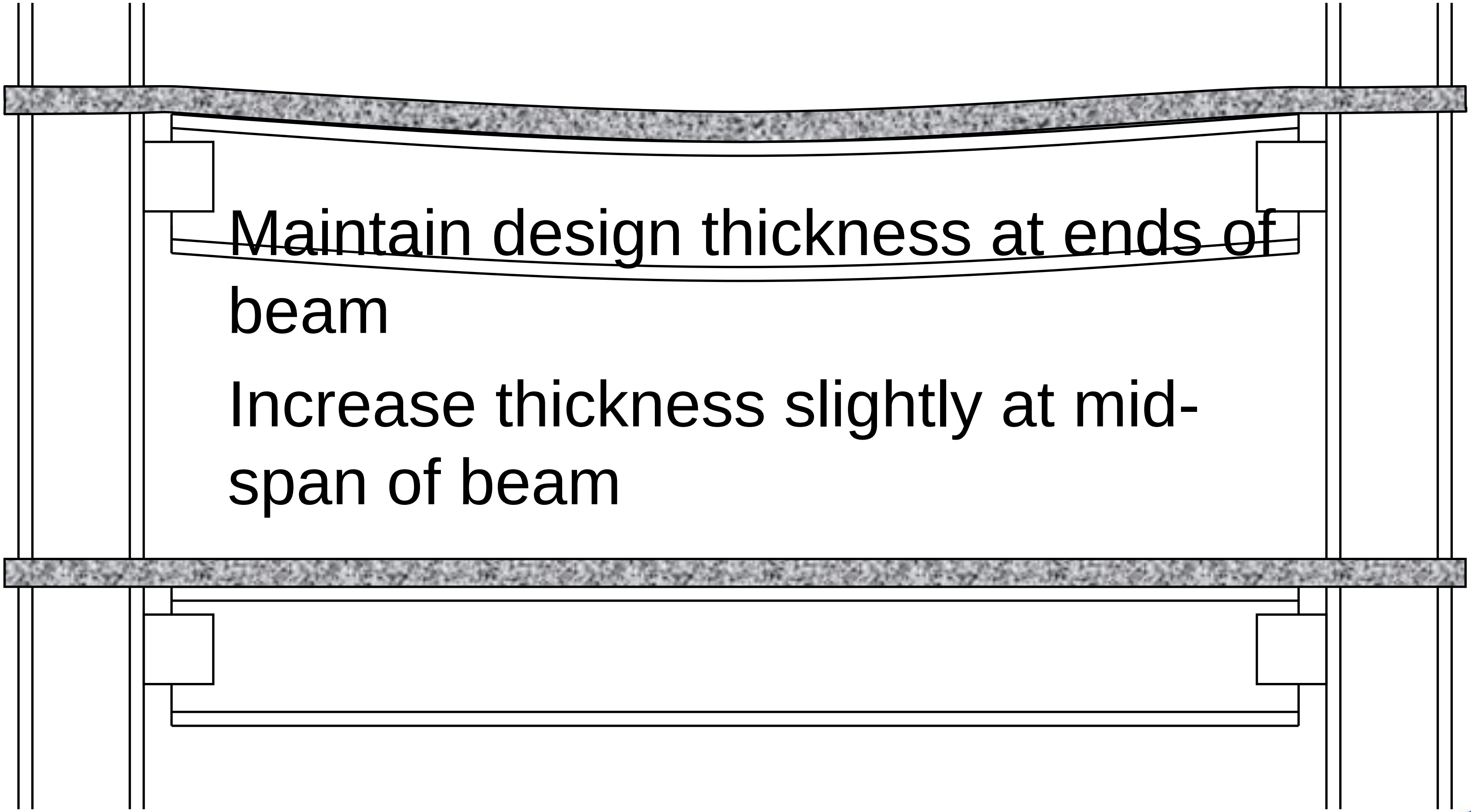
- Measure fabricated camber in the shop and attach report to members when shipped
- Survey, survey, survey

Survey, Survey, Survey!

- Survey prior to concreting to establish relative levelness of beam-to-column connections and camber of beams
- Survey following concreting to establish movement of members when loaded

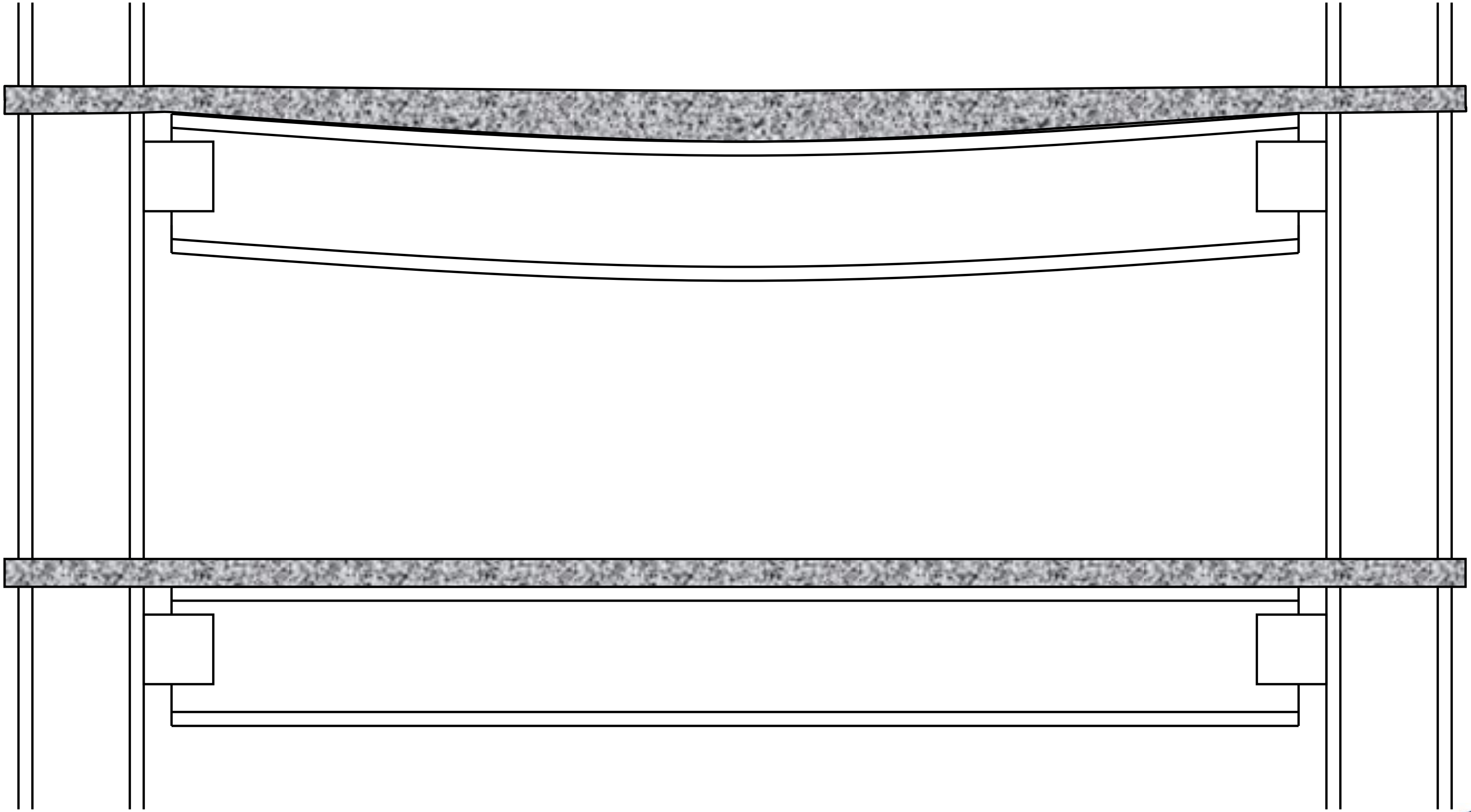
Respond to Deflection Behavior

When deflection past level is small (<3/4")...

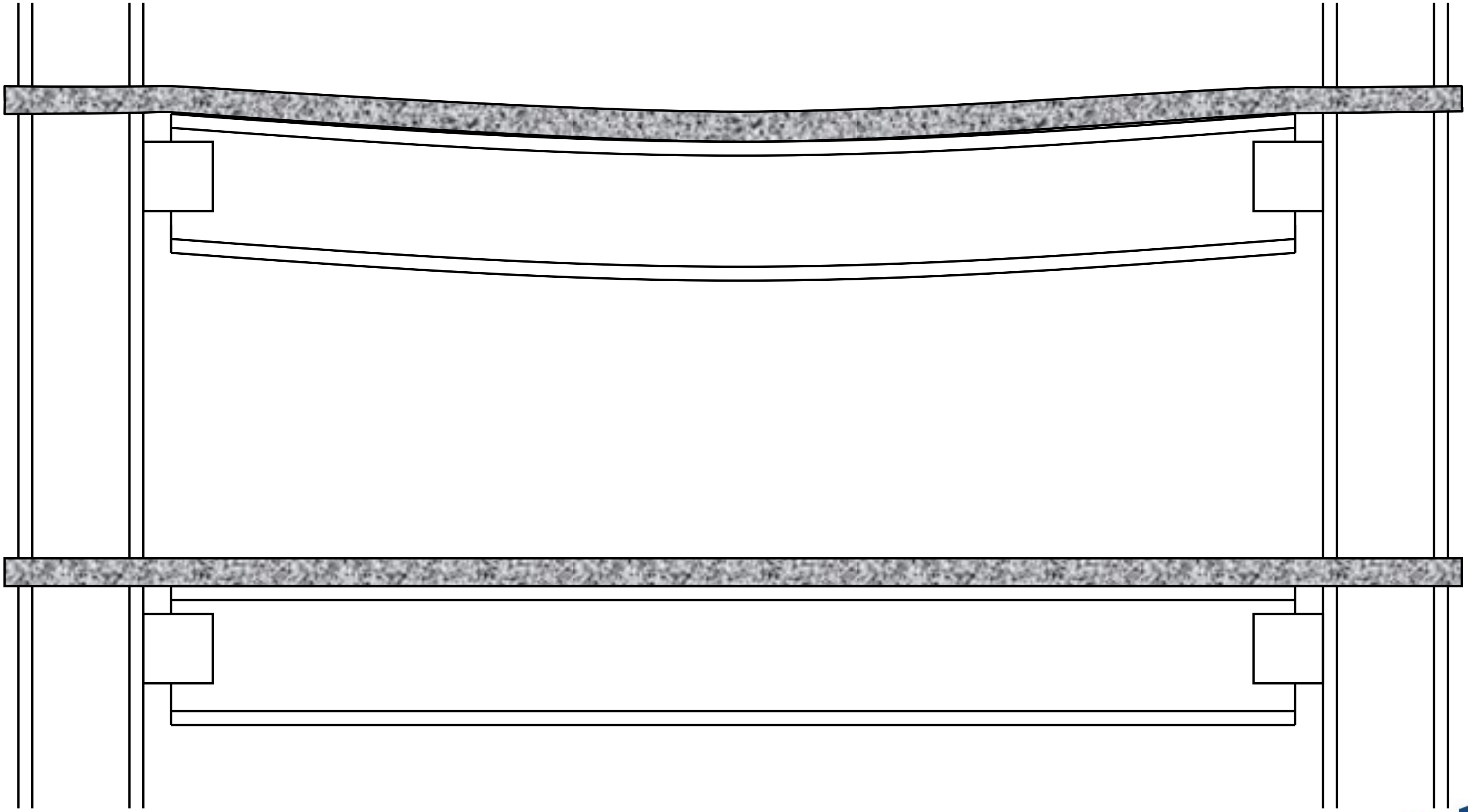


Maintain design thickness at ends of beam

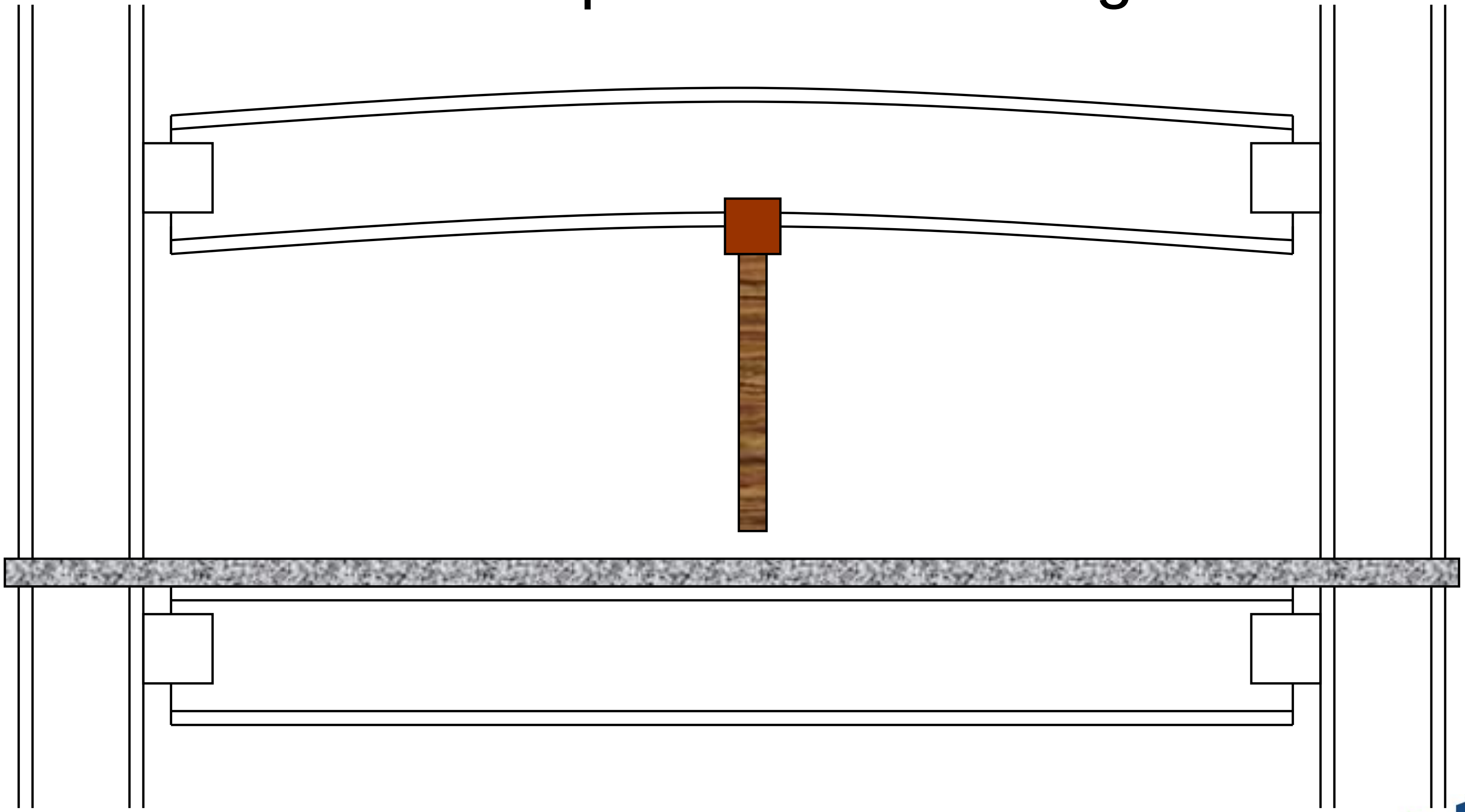
Increase thickness slightly at mid-span of beam



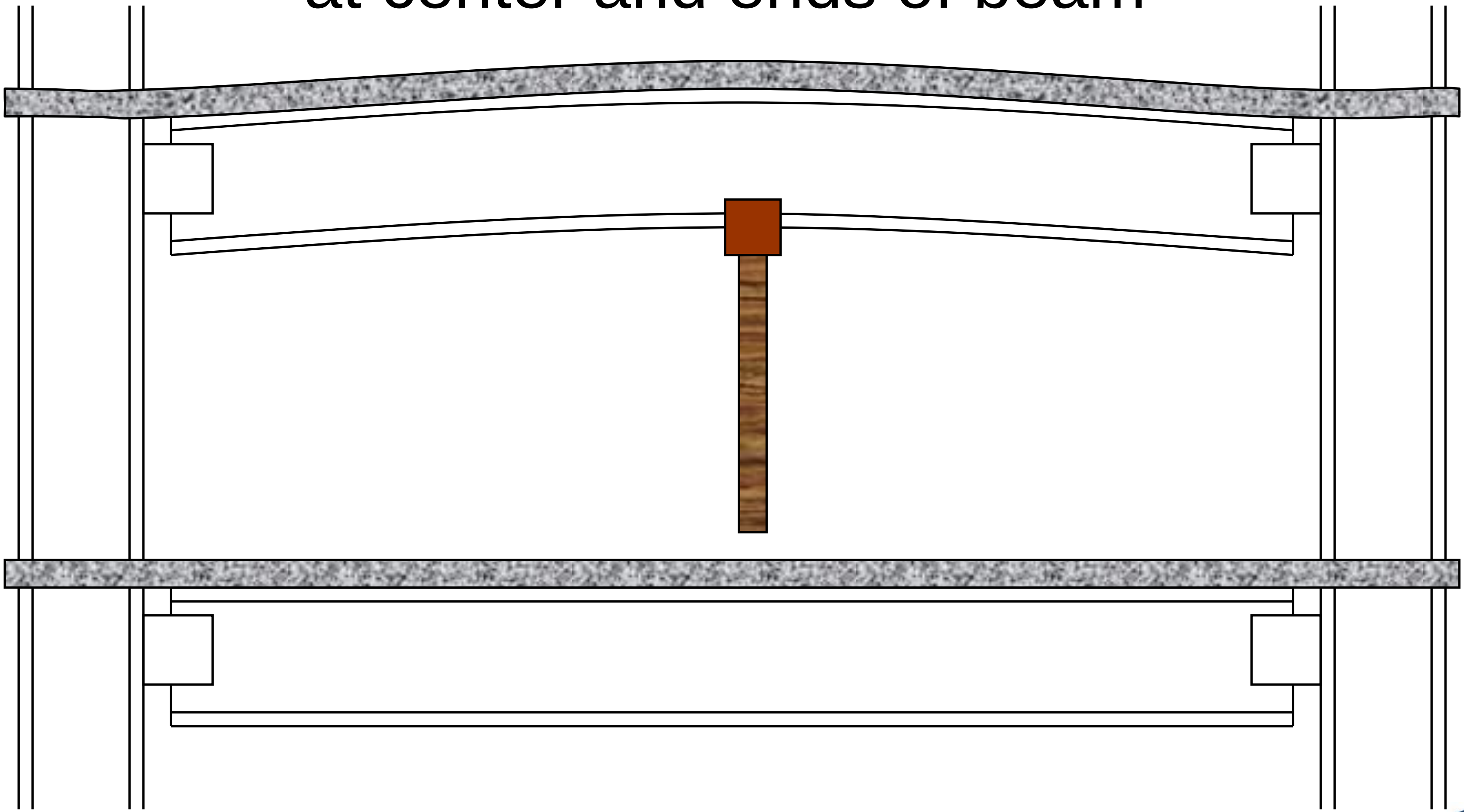
When deflection past level is large or member is cambered...



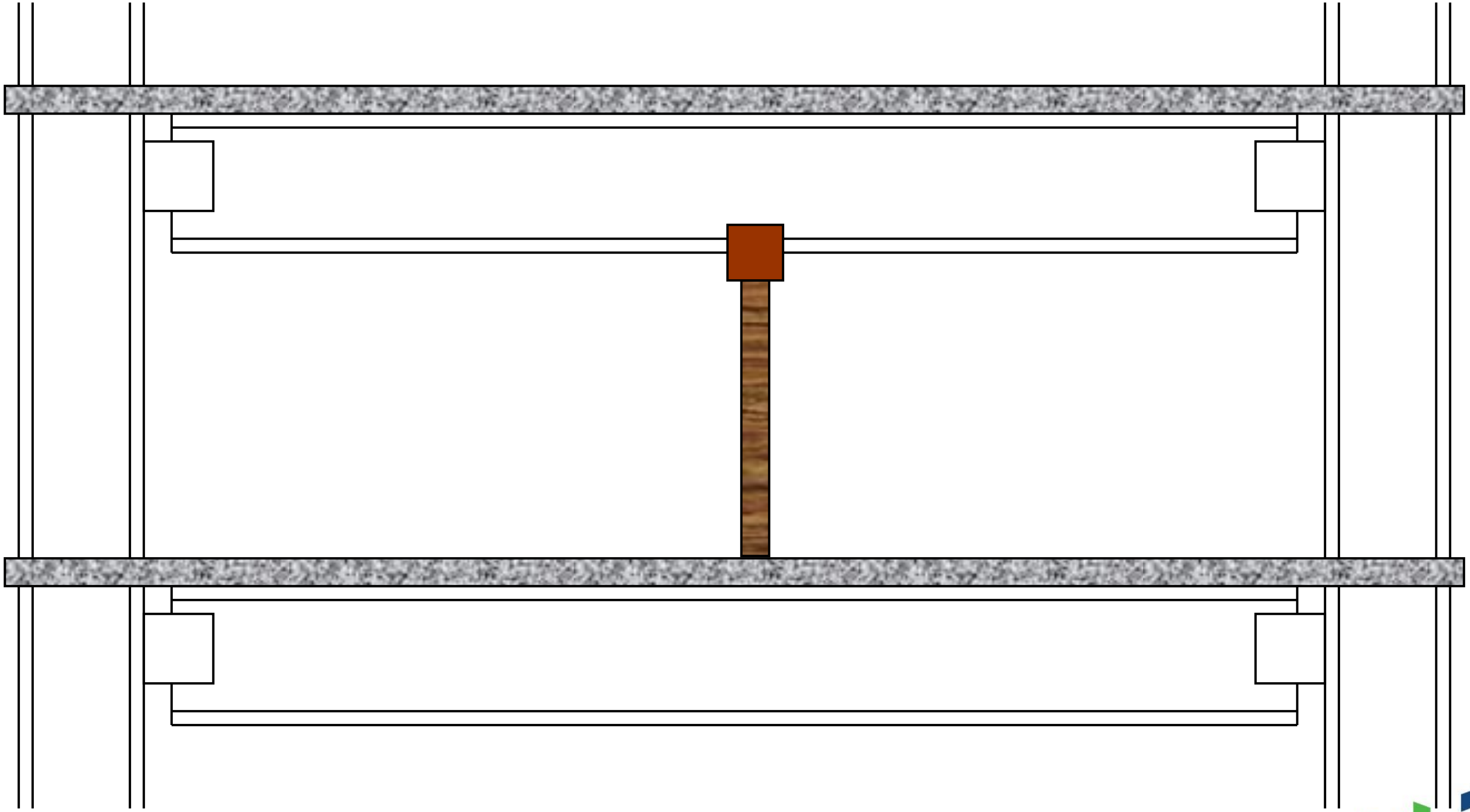
Attach loose shore to center of beam prior to concreting



Maintain design thickness at center and ends of beam



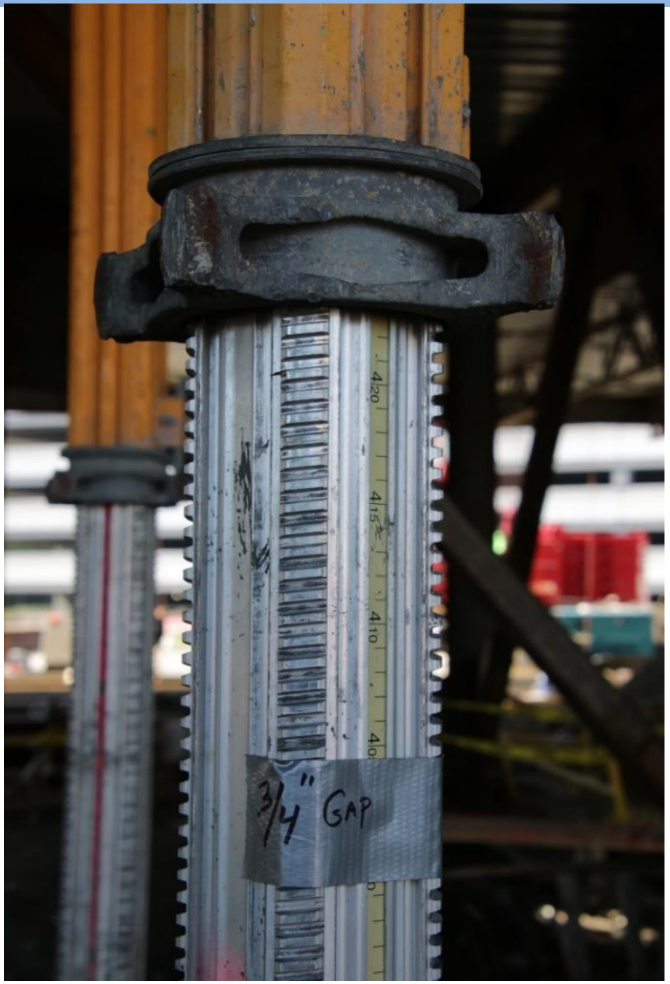
When desired deflection has taken place, shore will stop further movement



Why does the loose shore approach work??

The composite section, once the concrete has hardened, is 3-to-5 times as stiff as the steel beam alone. Deflection is the inverse of stiffness.


3/4" GAP


3/4" GAP


7 5/8
Green
MB

Time-Related Composite Beam Deflection

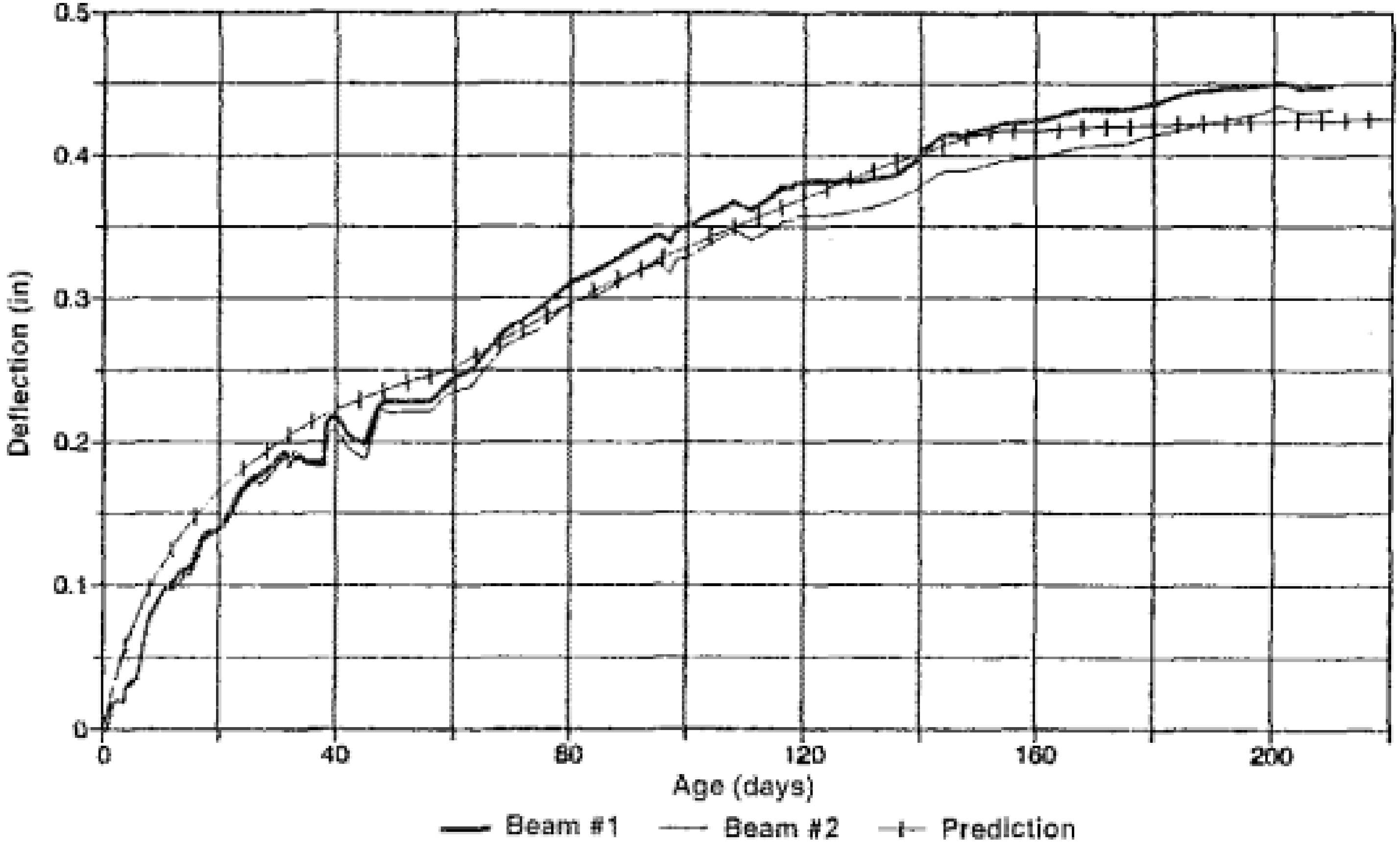


Figure 3.20 Predicted vs. measured shrinkage deflections adjusted for humidity.[073]

Composite Construction – Design for Buildings, Viest, Colaco, Furlong, Griffis, Leon, and Wylie, Chapter 3, page 3.34