PCI Big Beam Final Presentation

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Kaylynn Calvin, Lander Porter, David Lucas Macaraeg, Jonah Simminger

Introduction of Project

- Design a 17’ prestressed concrete beam
- Predict behavior at service and factored load
- Compare against tested beam

Client: Precast/Prestressed Concrete Institute

Technical Advisor: Dr. Ben Dymond

Sponsor: Tpac in Phoenix, Arizona

Figure 1: PCI Logo [1]

Figure 2: Tpac Logo [2]

Competition Guidelines

- Two 10-kip service loads & two 16-kip factored loads
- No cracking at service load (> 20 kips)
- Failure after factored load (32 < Fail < 40 kips)
- Judging based on strength, cracking, deflection, cost, weight, and report quality

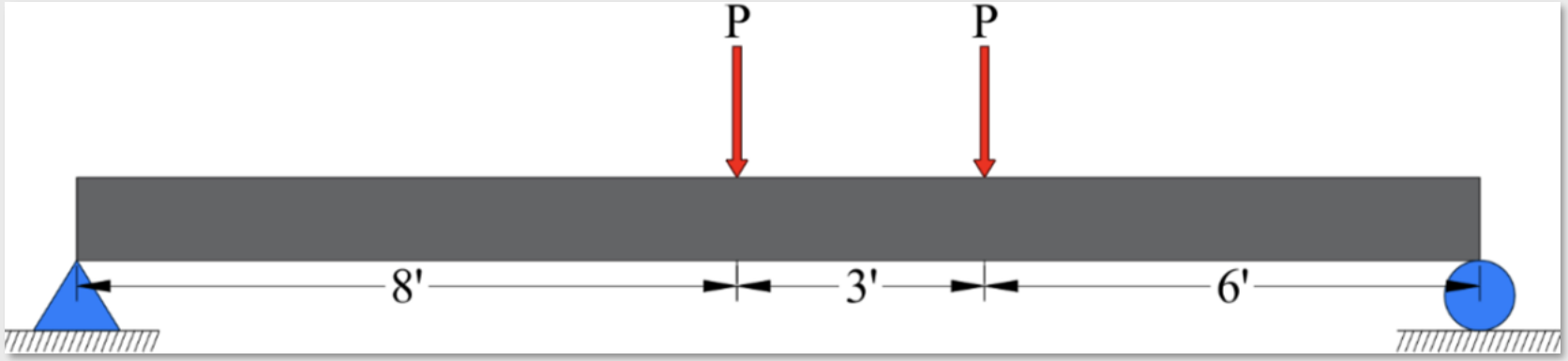


Figure 3: Competition Loading Diagram [3]

Introduction to Prestressed Beams

- Prestressed beams use tensioned steel strands to introduce compression and an internal moment into the concrete
- This pre-compression helps delay or prevent cracking under service loads
- Offsets tensile stresses that develop under bending
- Controls deflection through induced camber, improving serviceability under loading
- Concrete is poured over pre-tensioned steel strands, concrete cures, then strands are cut

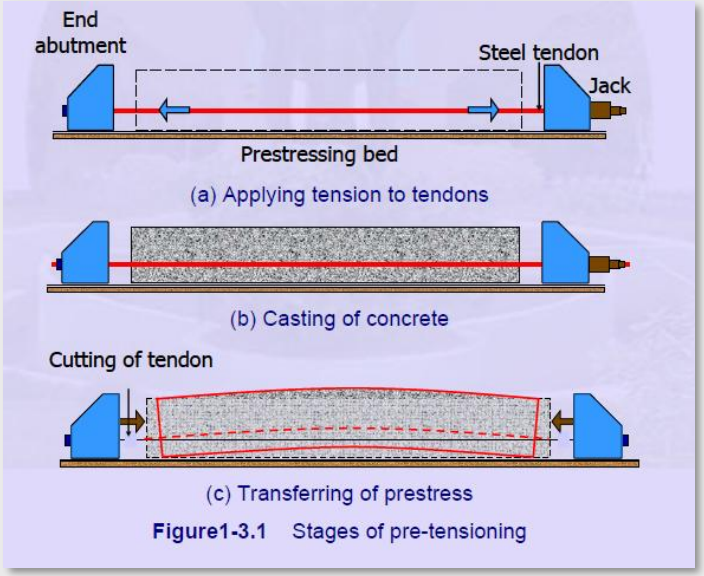


Figure 4: Stages of Pre-Tensioning [4]

Concrete Mix Design

- Selected between two standard Tpac mix designs (normal weight & lightweight) to minimize variability and improve predictability in performance
- Choose the lightweight mix to reduce overall cost & weight, maximizing competition scoring despite the lower strength

	TPAC's Concrete Mix Designs	
	Lightweight	Normal weight
f'ci (psi)	5000	7500
f'c (psi)	8000	9000
Spread	27"±3"	27"±3"
W/C Ratio	0.35	0.31
Unit Weight (pcf)	124.1	147.5
Unit Weight Factor, λ	0.75	1.00

Figure 5: Concrete Mix Decision Matrix [5]

MathCAD Iteration Spreadsheet

- MathCAD is an engineering software that lets you write equations just like you would on paper, while automatically solving them and updating results whenever inputs change
- Built an iteration spreadsheet to automate beam design calculations
- Allowed for fast adjustments and immediate feedback on how changes impacted performance
- Optimized beam geometry and strand layout for strength-to-weight efficiency

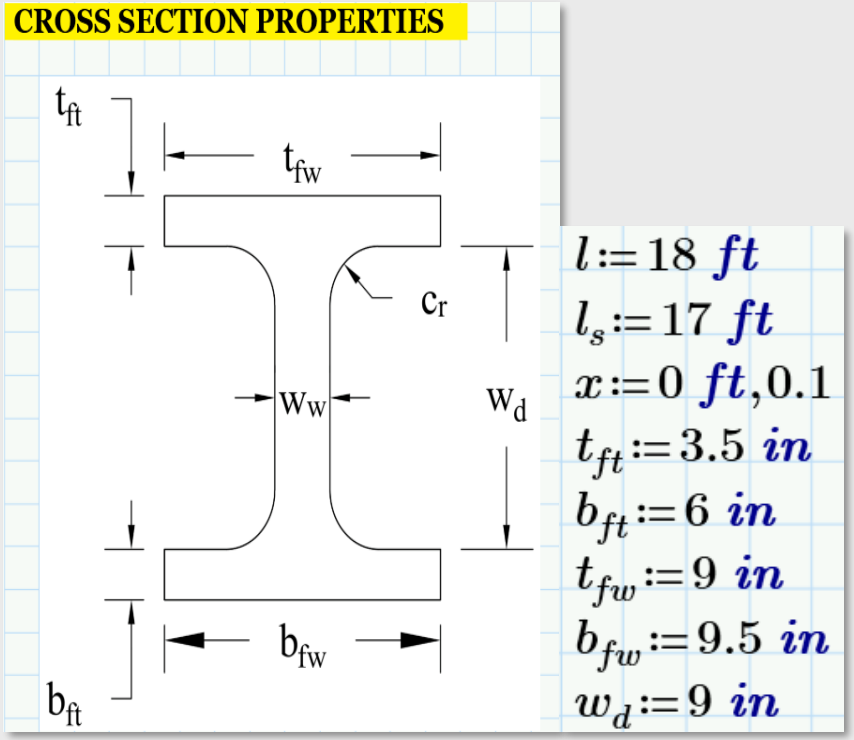


Figure 6: Initial MathCAD Analysis Spreadsheet [6]

Initial Designs and Decision Matrix

- Developed a decision matrix for initial designs passing design criteria
- Initial designs used ½" prestressing strands with varying concrete geometry
- Scoring based on PCI Big Beam scoring formula
- Iterated designs using 0.6" strands produced a lighter beam, but failed to meet transfer requirements
- Implemented tensioned top strands into MathCAD spreadsheet

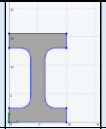
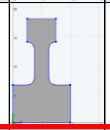
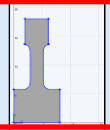
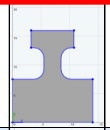
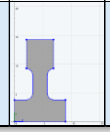
Name	Depth	Image	Cracking/ Capacity	Cost	Weight	Deflect	Pra/Inn/ Code	Total
2-Strand Symmetrical	15.5"		10	5	9	0	3	**27**
2-Strand Averaged Beam	18"		9	6	5	5	3	**28**
2-Strand Optimized Beam	18"		9	10	9	5	3	**36**
2-Strand Wide Beam	16"		19	0	0	10	3	**32**
3-Strand Beam	14.25"		6	8	10	36	3	**35**

Table 1: Initial Decision Matrix [5]

Final Decision Matrix

- Design 1 developed, initially intended to be the final design
- Iterated slender designs (Designs 2 & 3)
- Scoring based on PCI Big Beam scoring formula

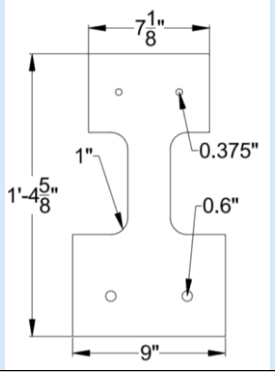
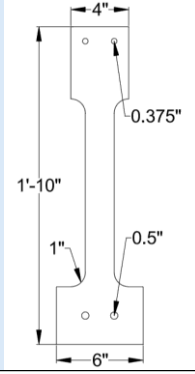
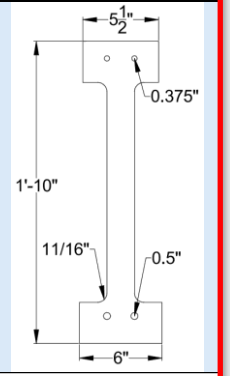
	Design 1	Design 2	Design 3
Design			
Cracking/ Capacity	20	20	20
Cost	3	10	0
Weight	0	9	10
Deflect	10	0	9
Prac/Inn/ Code	3	3	4
Total	36	42	43

Table 2: Final Decision Matrix [5]

Stirrup Design

- 14 Number 3 Bars at 8-1/4”
- 15 Number 3 Bars at 6-1/2”
- Smaller spacing for the Point Load side

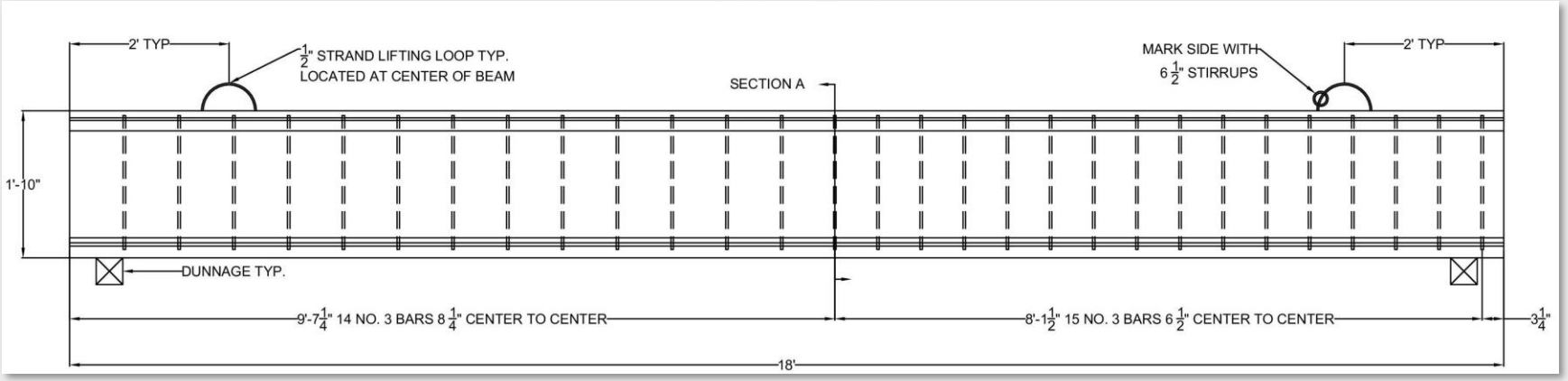


Figure 7: Stirrup Design [3]

Shop Drawings – Cross Section Design

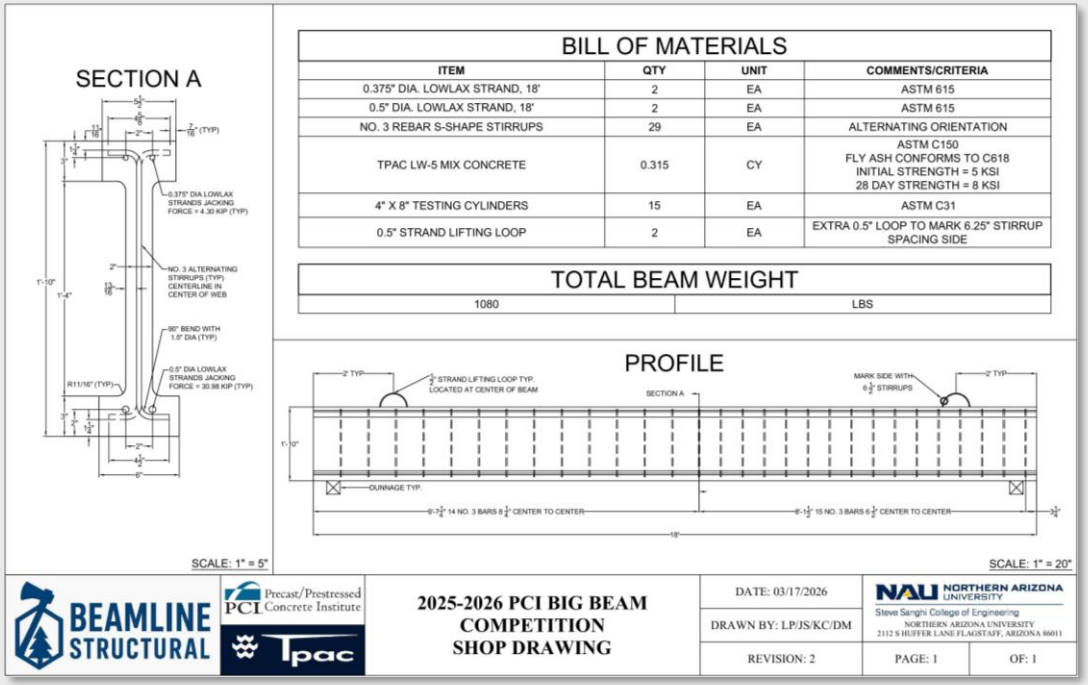


Figure 8: Shop Drawing Sent to Tpac [3]

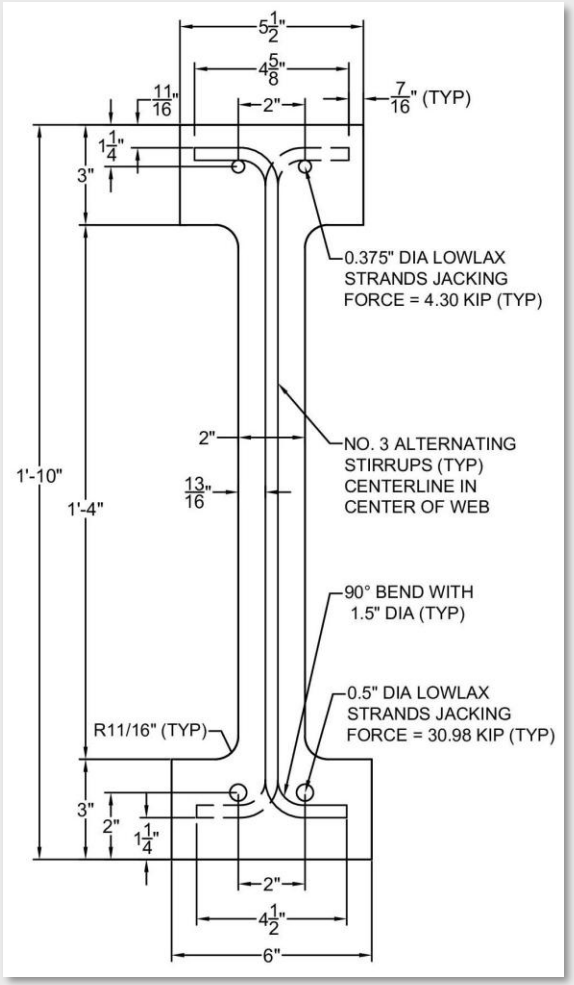


Figure 9: Cross-Section Design [3]

Beam Fabrication – Quality Assurance

- Visited Tpac on March 27th
- Verified dimensions

Figure 12: Beamline Structural at Tpac

Figure 10: Verification of 8.25 in. Stirrups

Figure 11: Verification of 6.50 in. Stirrups

Figure 13: Verification of Web Thickness

Beam Fabrication – Spread Test

- Spread test results
  - Actual Spread: 21.5 in
  - Expected Spread: 27 ± 3 in

Figure 14: Spread Test Setup

Figure 15: Spread Test

Beam Fabrication – Formwork

Figure 16: Beam Formwork

Figure 17: Tpac Workers Placing Formwork Together

Beam Fabrication – Pour

Figure 18: Concrete Truck

Figure 19: Concrete Pour

Figure 20: Finished Pour

Beam Setup

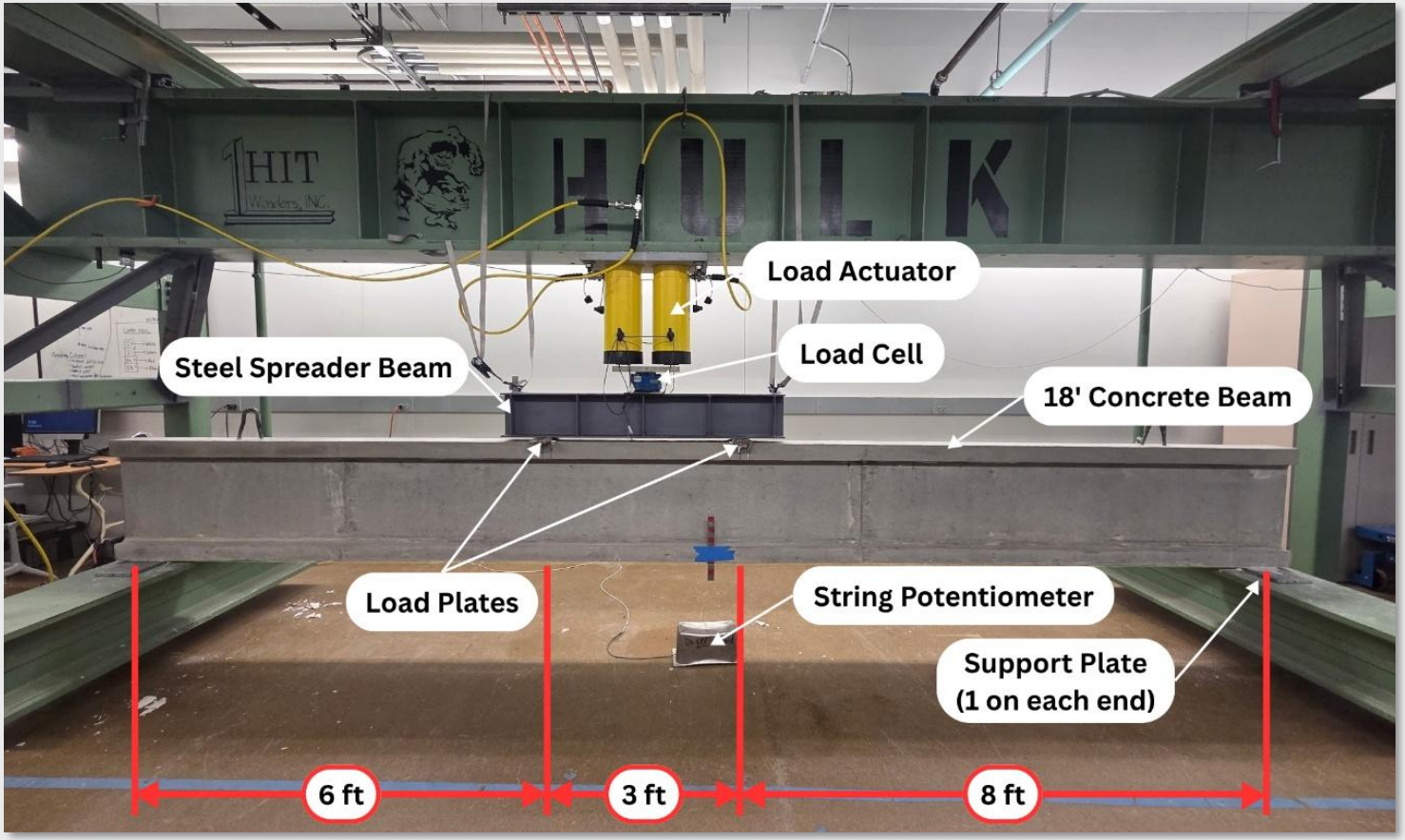


Figure 21: Beam Test Setup

Cylinder Tests

- Tests conducted at CEMEX (ASTM C39)
- Tested 5 cylinders, day of test
- Compared to published 8000 psi from Tpac

	Age (days)	Compressive Strength (psi)
1	26	7800
2	26	8300
3	26	7700
4	26	7720
5	26	7530
Value Used in Prediction		7810

Table 3: Cylinder Test Results [5]

Figure 22: Broken Test Cylinder

Final Design Calculations

- Cylinder compressive strength of concrete incorporated
- Final deflection calculations using Response 2000 Moment-Curvature data
- Verified moments with both softwares

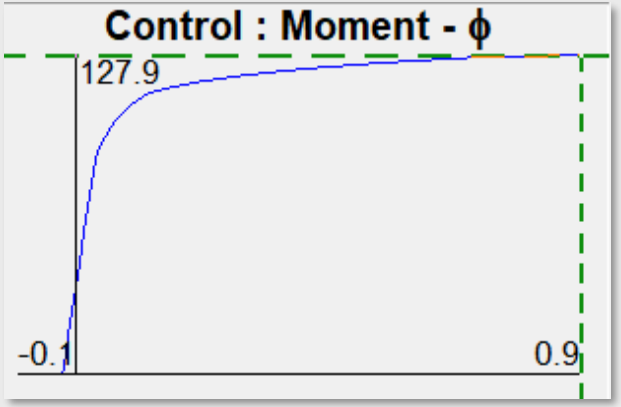
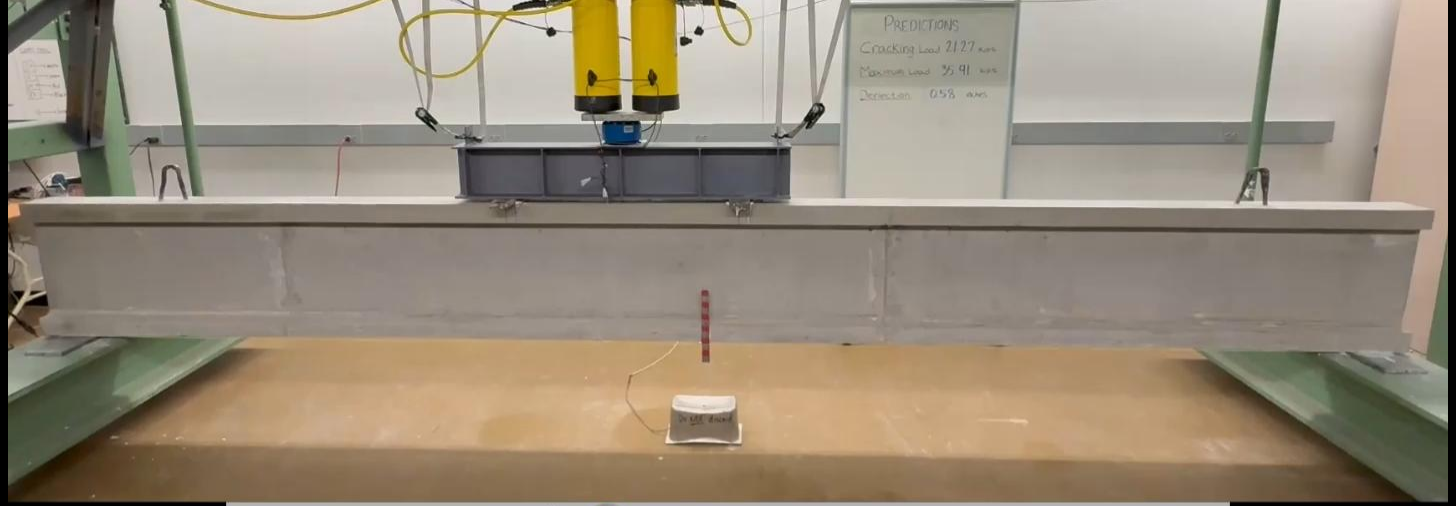
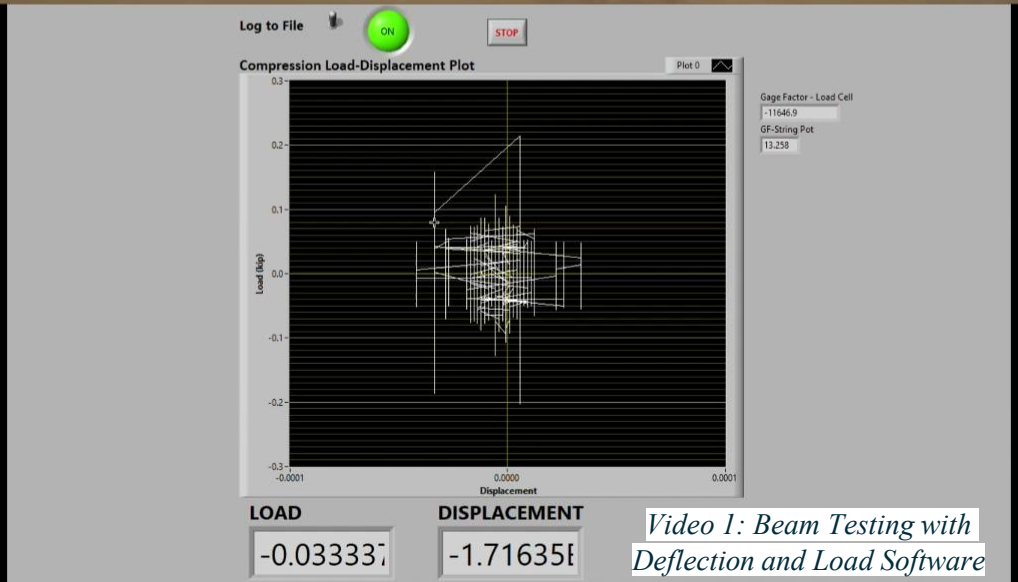


Figure 23: Response Moment Curvature [7]

	Beam Predictions		PCI Ranges
	MathCAD	Response 2000	
Cracking Load (kip)	21.27	23.53	> 20
Breaking Load (kip)	35.91	35.63	32 < Fail < 40
Deflection @ 32 kips (in)	0.37	0.58	-

Figure 24: Beam Predictions Comparison [5]





Video 1: Beam Testing with Deflection and Load Software

Results of Test

- Tested April 22nd
- Cured for 26 days

	Beam Predictions	Test Results	% Difference
Cracking Load (kip)	21.27	21.2	-0.3%
Breaking Load (kip)	35.91	38.2	6.4%
Deflection @ 32 kips (in)	0.58	0.85	46.6%

Figure 25: Beam Prediction & Results [5]

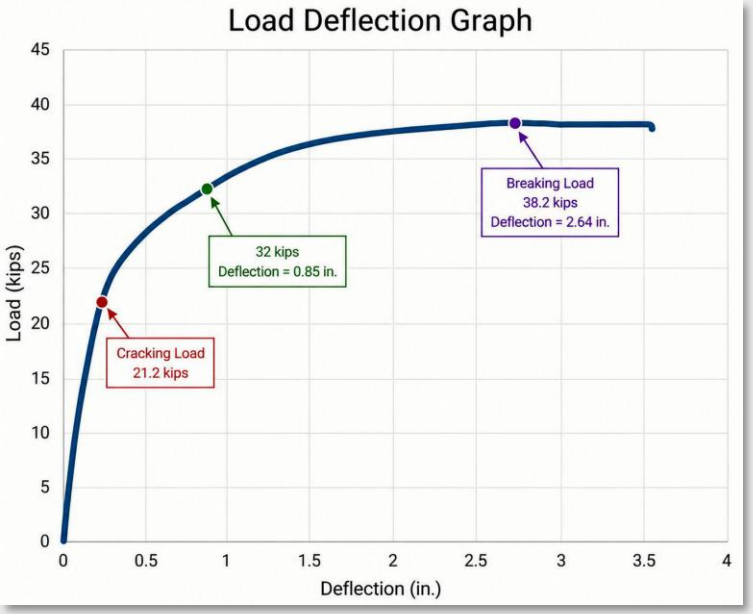


Figure 26: Load Deflection Graph [5]

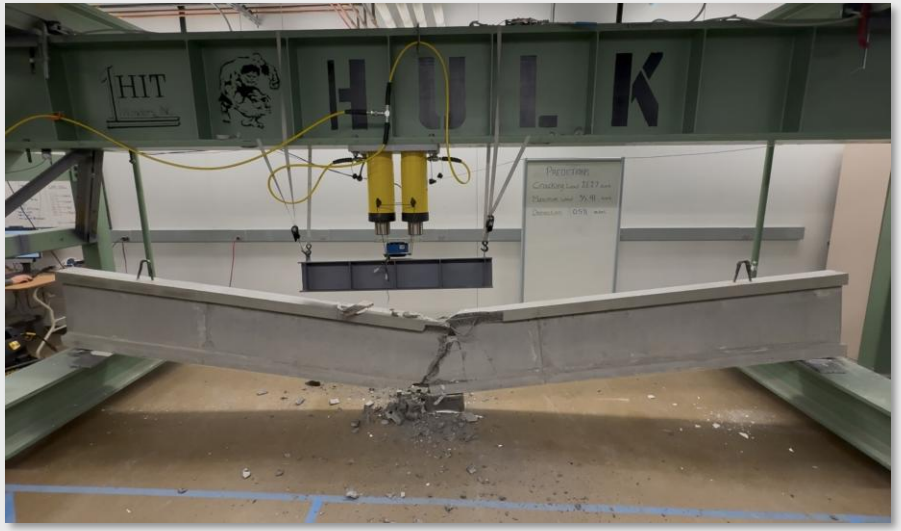


Figure 27: Beam At Failure

Impacts of PCI Big Beam Competition

Category	Positives of PCI Big Beam Competition	Negatives of PCI Big Beam Competition
Economic	■ Industry sponsorship (e.g., fabrication and materials) reduces direct student costs ■ Provides practical experience that improves employability after graduation	■ Requires funding for materials, transportation, and testing ■ Significant time investment from students and faculty
Social	■ Enhances hands-on learning, teamwork, and communication skills ■ Builds connections between students and industry professionals	■ High workload and time pressure on students ■ Resource differences between universities can impact competitiveness
Environmental	■ Encourages efficient structural design and material use	■ Concrete production contributes to carbon emissions ■ Transportation of beams adds to environmental impact

Table 4: Impacts Pros & Cons [5]

Citations

[1] “PCI Big Beam Competition,” 2024. https://www.pci.org/bigbeam/

[2] “Home - TPAC,” TPAC - Providing Engineered Concrete Solutions, 2024. https://www.tpacaz.com/

[3] Autodesk, “Autodesk | 3D Design, Engineering & Construction Software,” Autodesk.com, 2025. https://www.autodesk.com/

[4] “Prestressed Concrete 101,” *williams-works.com*. https://williams-works.com/prestressed-concrete-101/

[5] “Microsoft Excel Online,” Microsoft Excel Online, 2025. https://excel.cloud.microsoft/en-us/

[6] “Mathcad: Math Software for Engineering Calculations | Mathcad,” www.mathcad.com. https://www.mathcad.com/en

[7] E. Bentz, “Response-2000,” Software Informer, Apr. 14, 2026. https://response-2000.software.informer.com/ (accessed Apr. 28, 2026).

Thank you!

Any questions?