2014-2015 PCI Big Beam Contest

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Project Management

Senior Engineer– Catherine Irvine

Information Engineer– Abdullah Alhaddad

Design Engineer – Brian Bloom

Engineering Analyst – Mingyang Chen

Client & Stakeholders

Dr. Robin Tuchscherer
- Technical Advisor & Client

Tpac Kiewit Western Company (Tpac)
- Beam Manufacturer

Prestressed/Precast Concrete Insitute (PCI)
- Contest host and judge

Introduction

National competition hosted yearly by the Pre-stressed/Precast Concrete Institute (PCI)

Purpose of Project

- Design pre-stressed concrete beam
- Apply education through real design experience

Figure 1: "Pre-stressing Strands"

Picture Credit:
ArchiExpo <http://www.archiexpo.com/>

Project Description

Design of a pre-stressed concrete beam

- Maximum simply supported span of 17 ft
- Maximum length of 19 ft

Load requirements

- Must crack above 20 kips
- Must fail between 32 and 40 kips

Design judged for lowest weight, lowest cost, and maximum deflection

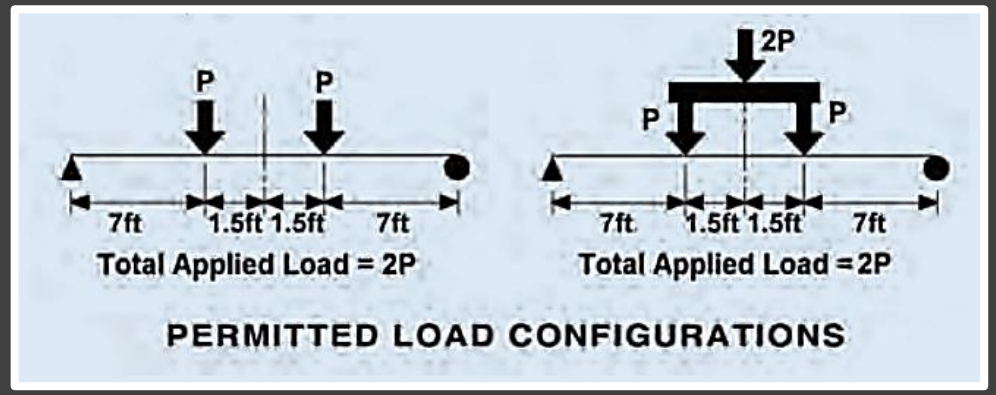


Figure 2: "Permitted Load Configurations"

Picture Credit:
PCI Big Beam Contest Official Rules <http://www.pci.org/>

Pre-stressed Concrete

Normal concrete tensile strength: 8-14% of compressive strength

- Cracks develop early in life cycle of structure

Pre-stressed concrete extends life of structure prior to crack

- After service load cracks, behaves essentially the same as Ordinary Portland Cement (OPC)

Pre-compresses tension zone of a beam to counter tension

Pre-stressed Concrete

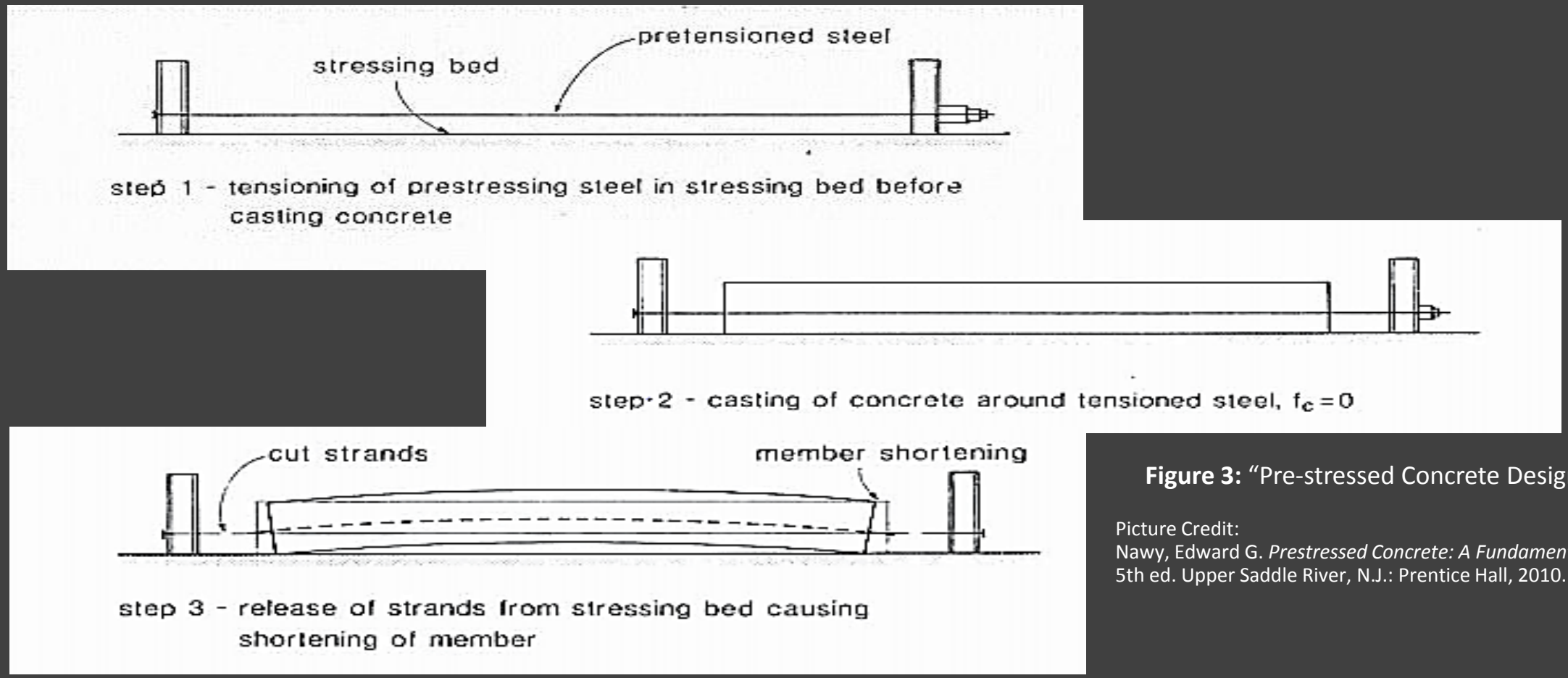


Figure 3: "Pre-stressed Concrete Design Steps"

Picture Credit:
Nawy, Edward G. *Prestressed Concrete: A Fundamental Approach*. 5th ed. Upper Saddle River, N.J.: Prentice Hall, 2010. Print

Concrete Mix Design

Two alternatives

- Lightweight (Avg Unit Weight=120 pcf)
  - Lower weight
  - Higher cost
- Normal-weight (Avg Unit Weight=150 pcf)
  - Larger weight
  - Lower cost

Both concrete mixes were used during design process

- Ultimately the final design used lightweight concrete

Picture Credit: Catherine Irvine

Figure 4: "Broken Concrete Mix Cylinders"

Structural Design Alternatives

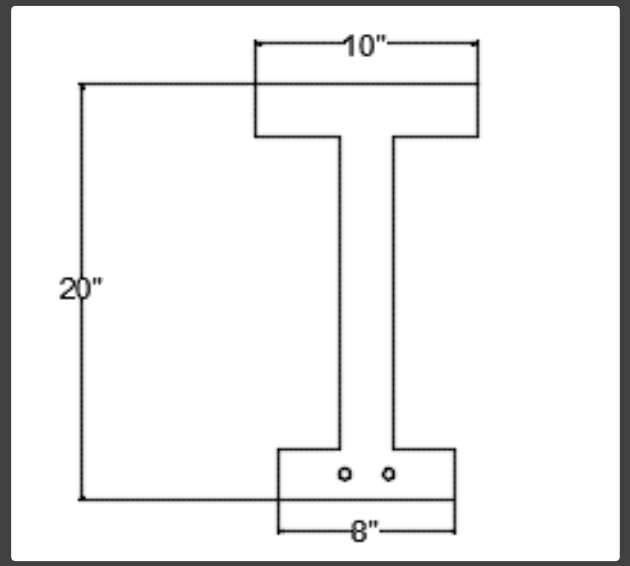


Figure 5:
Lowest Cost Alternative

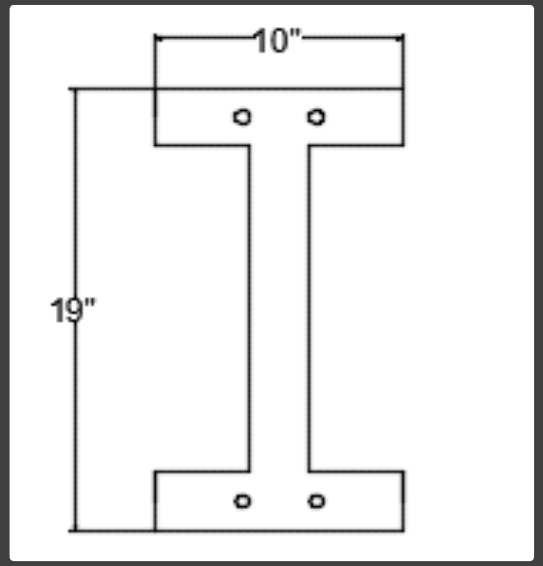


Figure 6:
Lowest Weight Alternative

Picture Credit:
Abdullah Alhaddad in AutoCad 2013

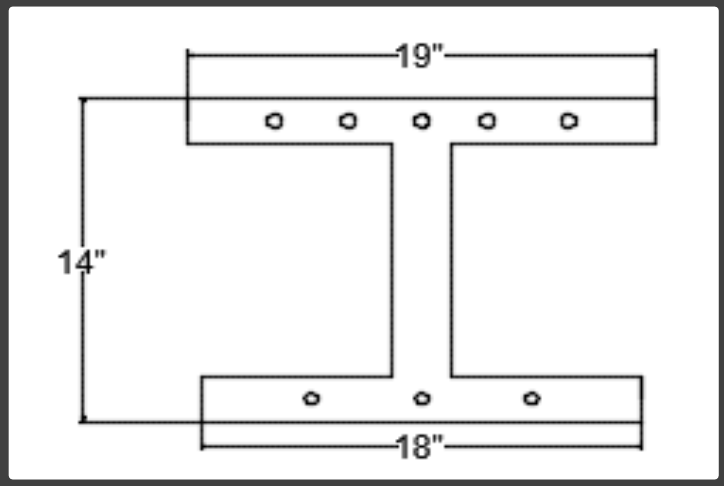


Figure 7:
Highest Deflection Alternative

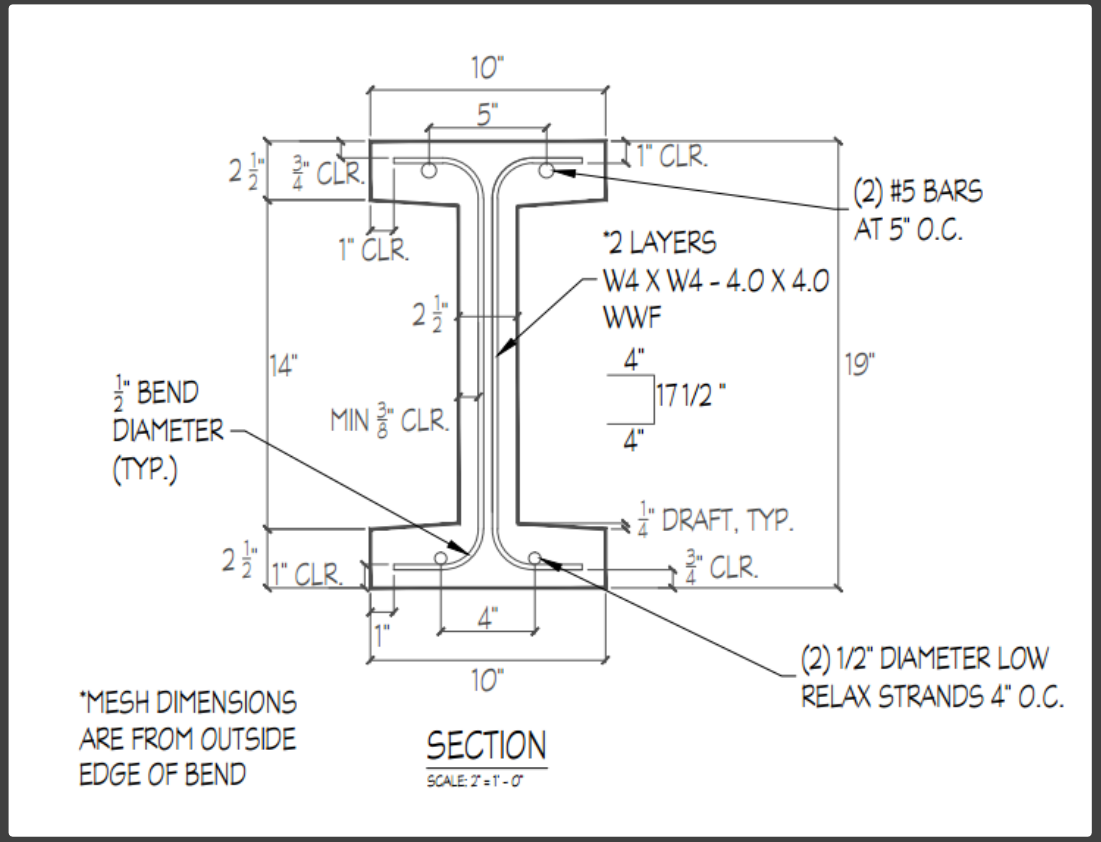
Decision Matrix

Table 1: "Decision Matrix"

Design	Weight (lb)	Score	Cost ($)	Score	Deflection (in)	Score	Total
Lowest Weight	1257	10	62.57	6	1.87	1	***17***
Lowest Cost	1430	6	41.85	10	1.60	0	***16***
Highest Deflection	1735	0	96.07	0	5.20	10	***10***

$$\text{Score} = 10 * \frac{(\text{Value in Entry} - \text{Worst Value})}{(\text{Best Value} - \text{Worst Value})}$$

Final Design



Picture Credit:
Brian Bloom in AutoCad 2013

Figure 8: "Final Design Cross Section"

Fabrication

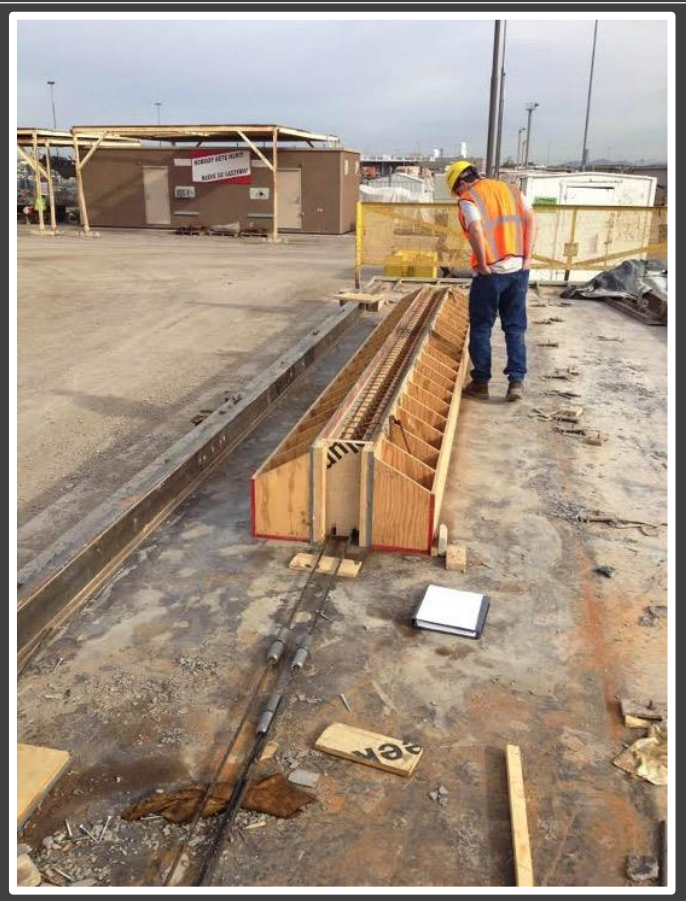


Figure 9: “Checking Formwork”

Figure 10: “Checking Measurements”

Picture Credit:
Brian Bloom

Fabrication

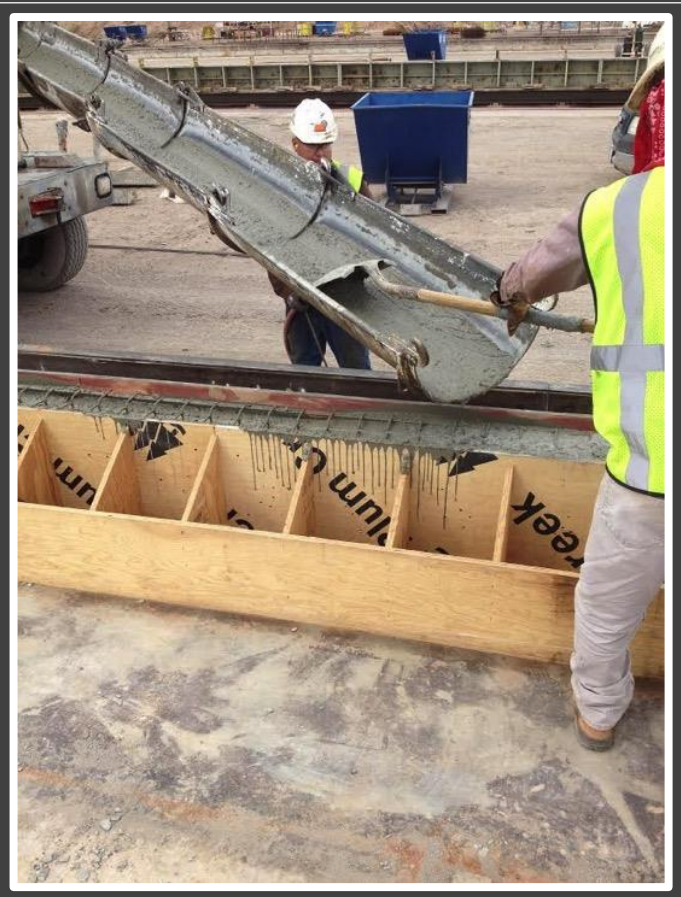


Figure 11: “Pouring Concrete”

Figure 12: “Fabrication Process”

Picture Credit:
Brian Bloom

Test Setup

Picture Credit: Catherine Irvine

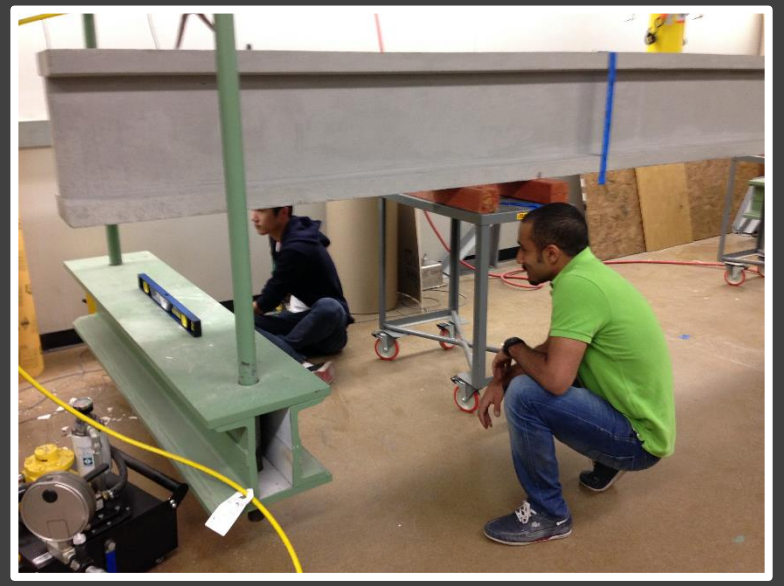


Figure 12: “Leveling Supports”

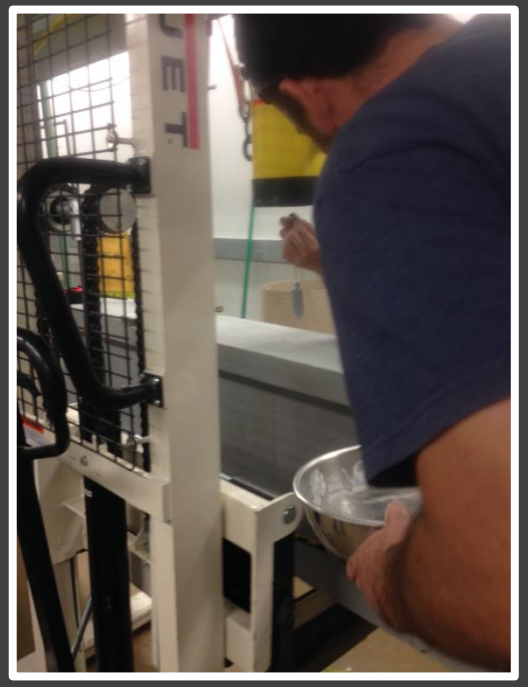


Figure 13: “Getting Ready To Drop Beam”

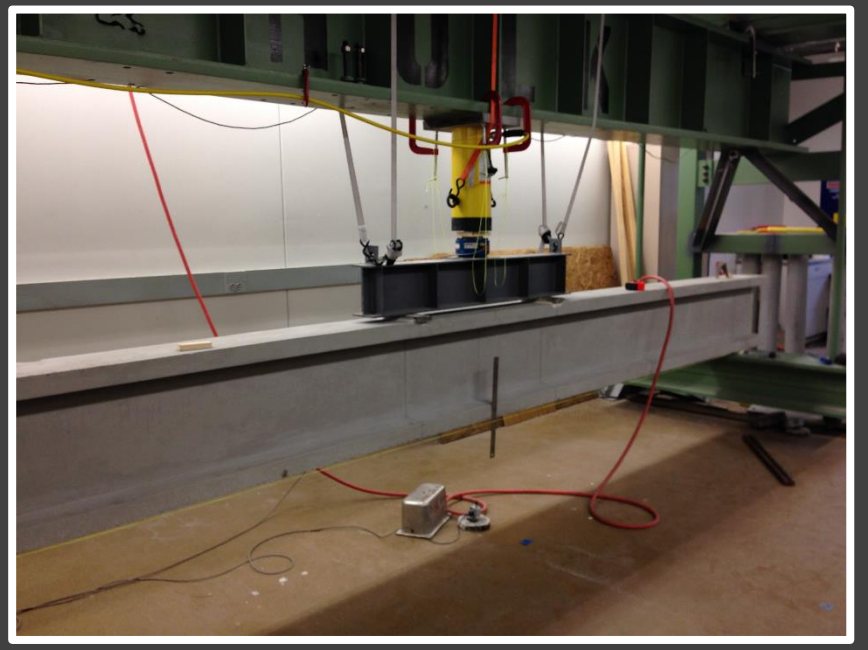


Figure 14: “Beam Ready To Test”

Test Setup

Picture Credit: Catherine Irvine

Figure 15: "Axial Compression Test"

Figure 16: "Concrete Cylinders"

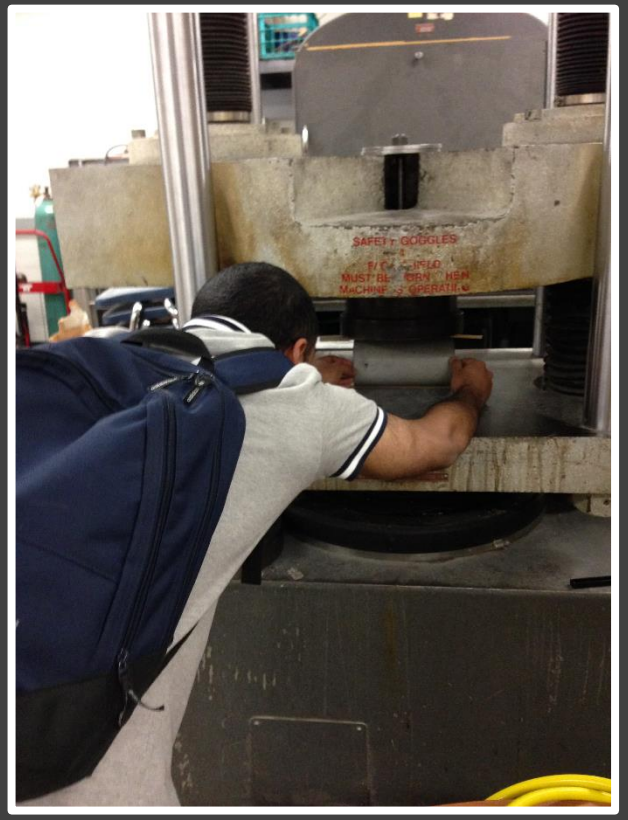


Figure 17: "Split Cylinder Test"

Pre-Test Analysis

Cylinder Tests

- Axial Compression
- Split Cylinder

Stress-Strain Curve

- From axial compression test data
- Average of max point on graph

Response2000

- Provides section response for beam design

Picture Credit: Catherine Irvine in Excel 2013

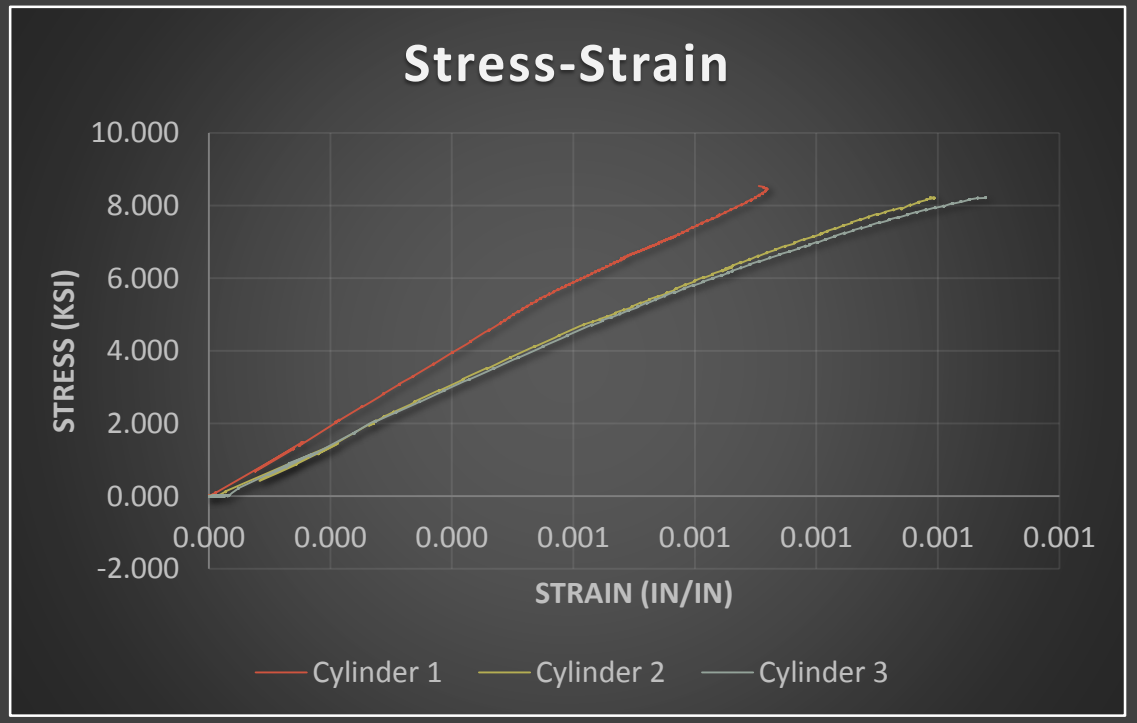


Figure 18: "Stress-Strain Curves"

Predicted Values

Deflection

- Virtual Work Method in Excel
- **2.5 in**

Cracking Load

- Based on stress
- **22.1 kips**

Ultimate Load

- Based on ultimate moment, strength of prestressing strand
- **32.3 kips**

Figure 19: "Broken Cylinder"

Picture Credit: Catherine Irvine

Final Results

Table 3: "Predicted vs Actual Results"

	Predicted	Actual	%Difference
Cracking Load	22.1 kips	21.2 kips	4
Ultimate Load	32.3 kips	43.5 kips	-30
Ultimate Deflection	2.5 in	4 in	-46

Higher material strength than expected
- Factored into design, but not predictions
- Contest vs Application

Ultimate deflection
- Hard to predict
- Virtual Work is an approximate method

Failure

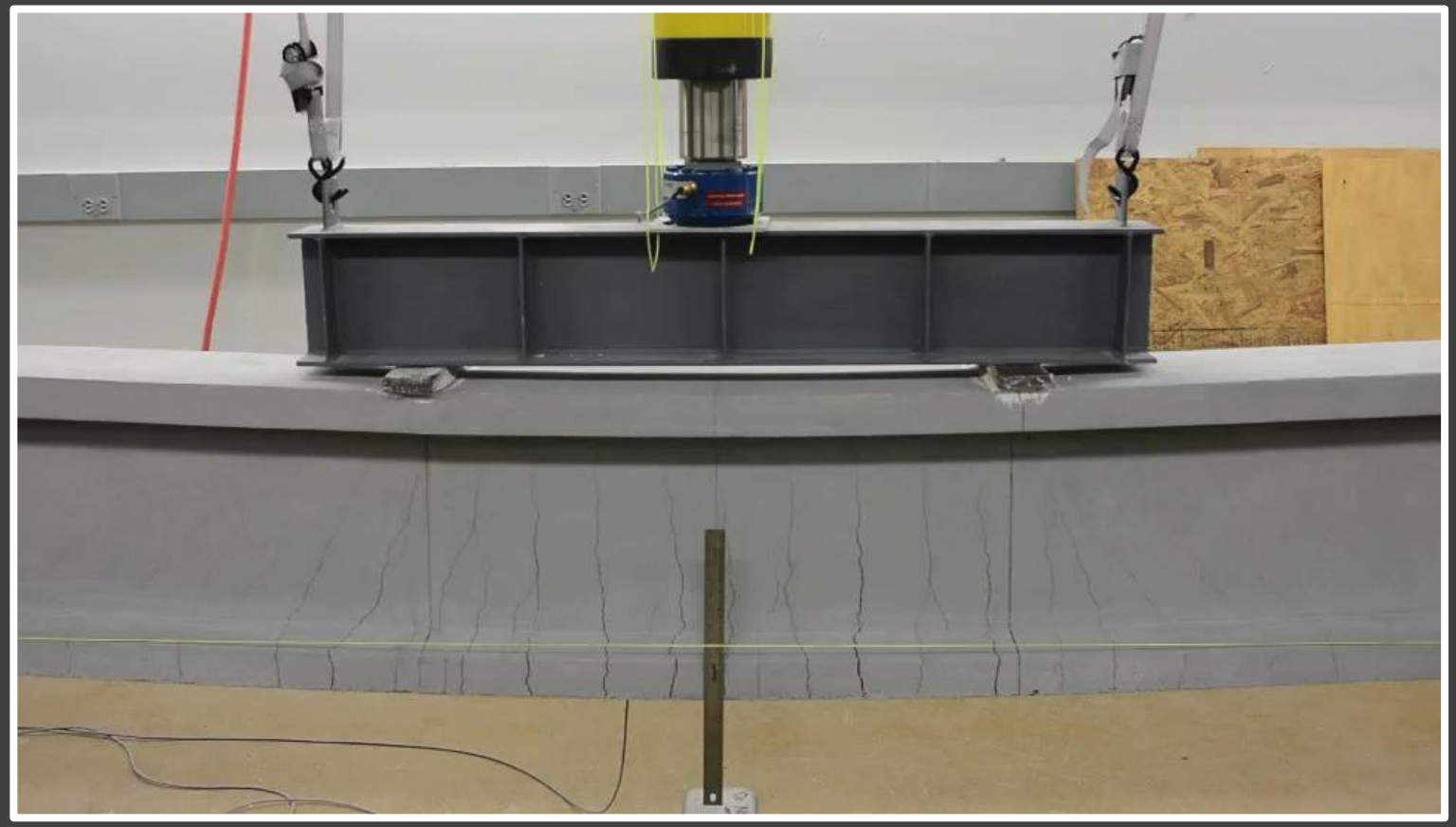
Picture Credit: Catherine Irvine

Figure 20: “Broken Strand”

Figure 21: “Failure Crack”

Figure 22: “Crushing”

Video



Project Cost

Table 2: "Cost Analysis"

	Classification	Hours/Quantity	Billing Rate ($/hr)	Cost
I. Personnel	Senior Engineer	156	110	$17,160
	Information Engineer	156	86	$13,416
	Design Engineer	156	100	$15,600
	Engineering Analyst	156	100	$15,600
	TOTAL HOURS	624	***SUBTOTAL***	$61,776
II. Travel	Trips to Phoenix @ 286 mi/trip	3	$0.56/mi	$481
III. Subcontract*	Lightweight Concrete	0.42 cu. yd	$110/cu. yd	$46
(Tpac)	½" Prestressing Strand	38 ft	$0.30/ft	$11
	Compression Steel	40 lb	$0.45/lb	$18
	Mesh	0.027 lb	$0.50/lb	$1
	Formwork	46 sq. ft	$1.25/sq. ft	$57
			SUBTOTAL	$133
TOTAL PROJECT COST: $62,400				

*Subcontract cost based on PCI contest rules, not typical cost of prestressed concrete projects

Project Impacts

Educational

- Students learn hands-on design prior to graduation
- Other interested parties learn about pre-stressed concrete

Environmental

- Concrete production releases greenhouse gases

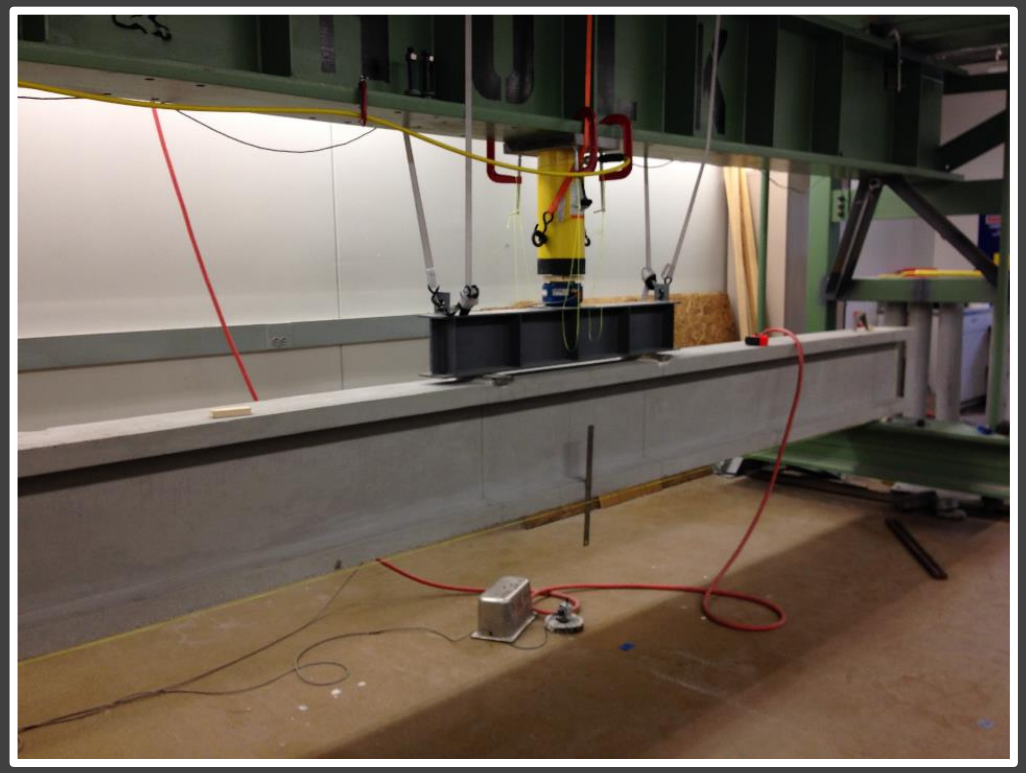
Economic

- Inexpensive building material (compared to steel structures)
- Pre-stressing extends life of structure under typical service loads

Social

- Alternative (to steel) for aesthetic/architectural design

Thank You



Acknowledgements

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