Architectural Forms and Structural Design

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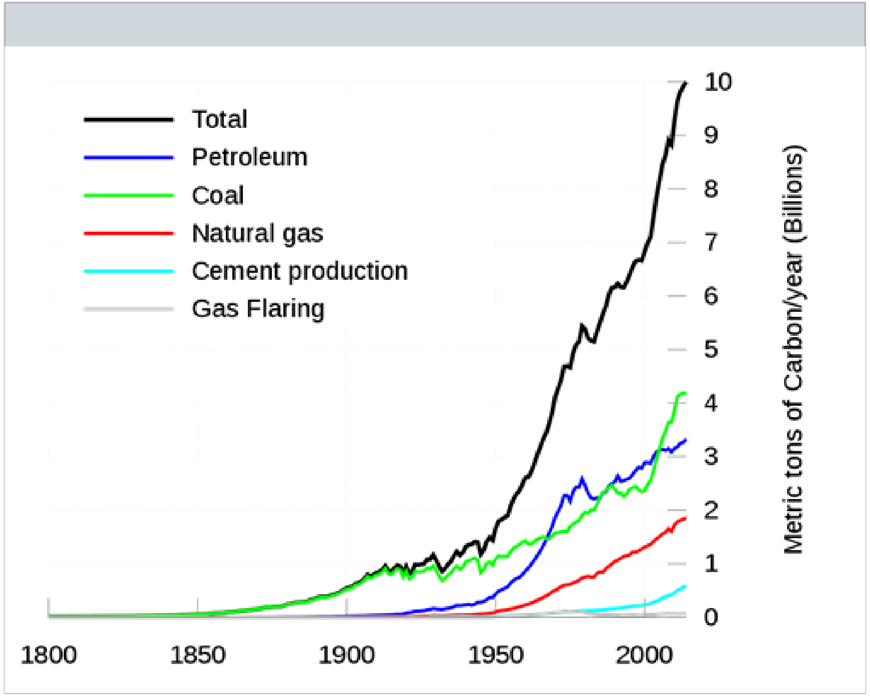
Carbon Emissions

- Cement production makes up nearly 9% of global carbon emission
- Ways to reduce emissions
  - **Use material efficient**
  - The use of OPC clinker
  - Improve kiln efficiency
  - Improve fuel mixtures
  - Improve energy use
  - Carbon Capture and Storage



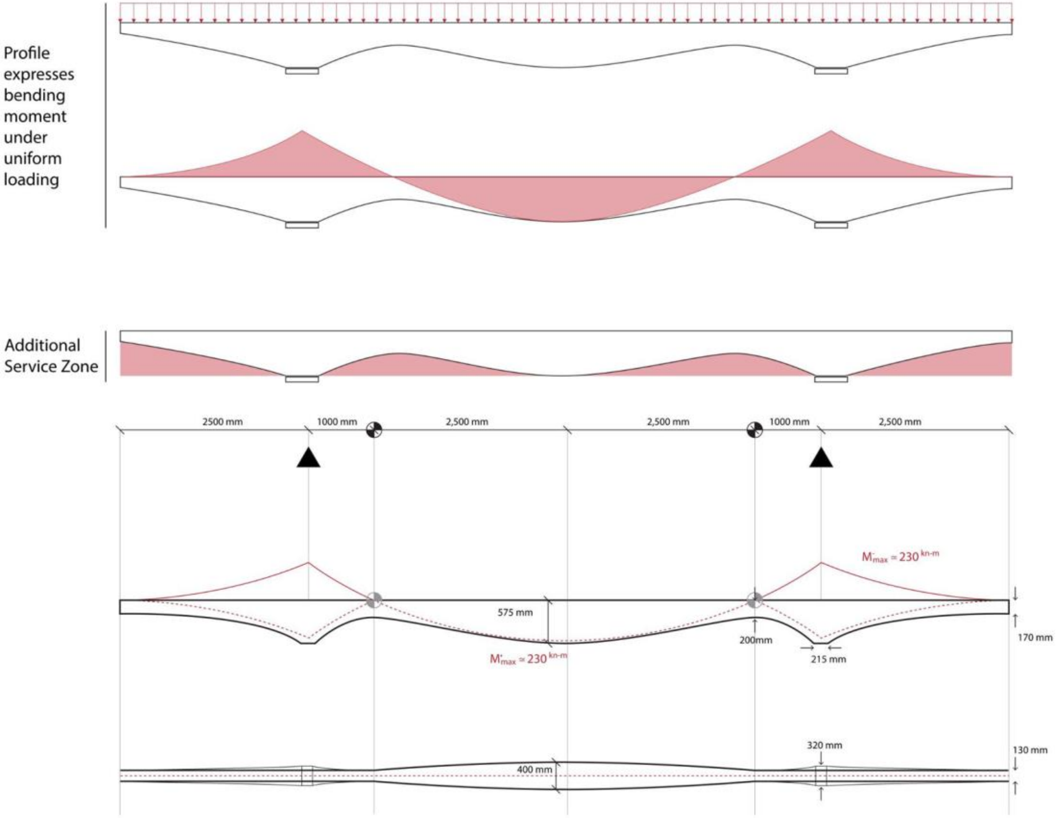
02. Construction techniques

1960

2016

Research Goals

- Define a new architectural language for concrete structures that will introduce the use of a coefficient of stiffness for concrete formwork. This will include the design and development of the new formwork system
- Explore the use of advanced cementitious materials that will minimize the use of reinforcement without sacrificing structural integrity; and
- Evaluate new design strategies and computational tools that seamlessly integrate architectural forms with structural needs.



Cross Section

Where xs, ys are coordinates along the curve, l is the fabric perimeter length.

F(θ,k) is the incomplete elliptical of the first kind, K(k) is the corresponding complete elliptic integral of the first kind

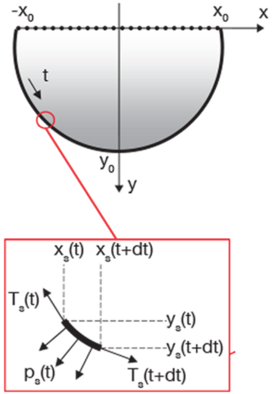
((k) = F(π/2,k)). E(θ,k) is the incomplete elliptic integral of the second kind.

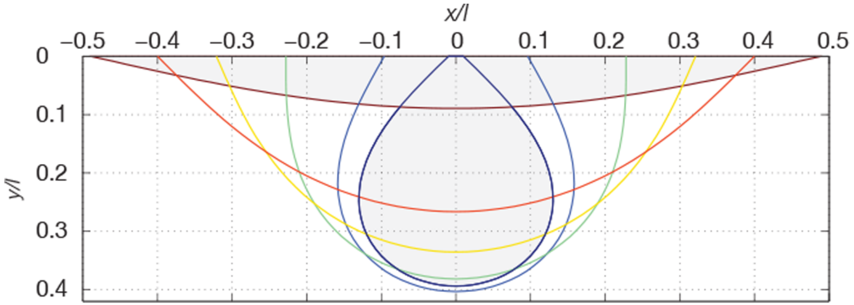
Equilibrium considerations (l); and cross section predictions (r) (after Iosilevski, 2010).

$$\frac{x_s}{l} = \frac{E(\theta_s,k)}{K(k)} - \frac{1}{2}\frac{F(\theta_s,k)}{K(k)}$$

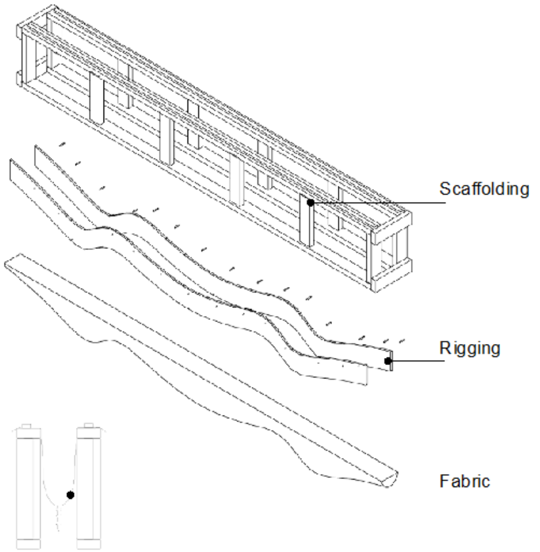
$$\frac{y_s}{l} = \frac{k}{K(k)}\cos\theta_s$$

$$A_c = l^2\,\frac{k\sqrt{1-k^2}}{K^2(k)}$$





Formwork Design



Casting

Concrete

Cylinder Diameter = 3”

<u>Control</u>

P = 61140 lbs | Peak Stress = 8649.64 psi

<u>Cylinder 1</u>

P = 60120 lbs | Peak Stress = 8505.24 psi

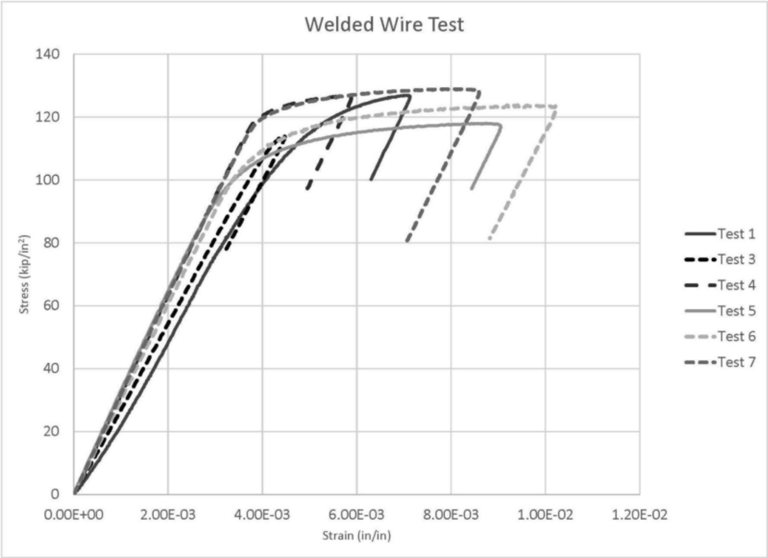
<u>Cylinder 2</u>

P = 57150 lbs | Peak Stress = 8085.07 psi

Testing

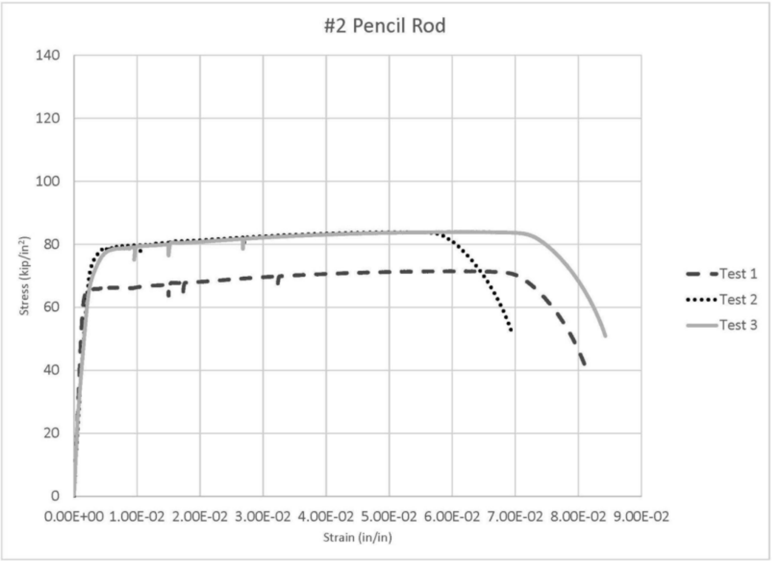
Steel Type 1

- Welded Wire Mesh Sections
- Pros
  - High maximum strength
  - Easy to bend
  - Easy to acquire in bulk
- Cons
  - High brittleness
  - Weak points at the welds
  - Small cross section



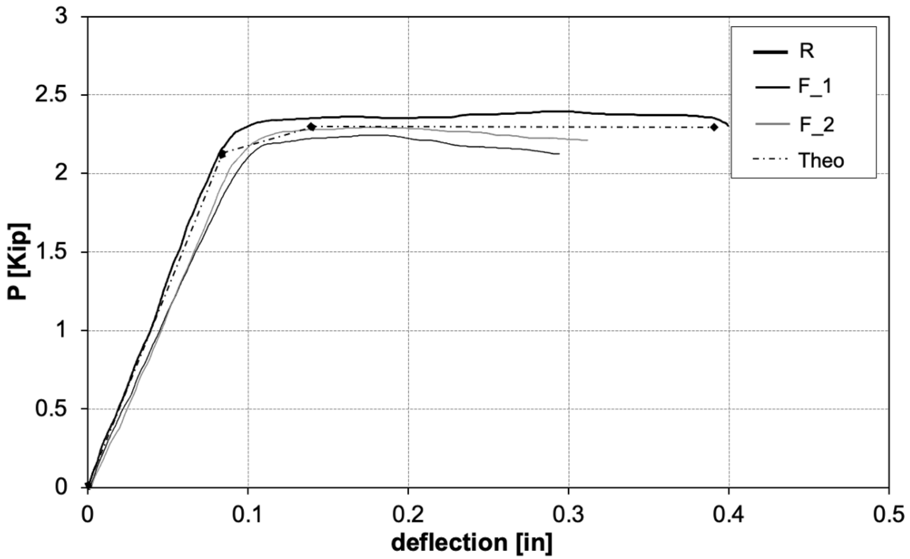
Steel Type 2

- #2 smooth bar (Pencil rod)
- Pros
  - Far less brittle
  - Consistent material
  - No weld points
  - Larger cross section
- Cons
  - Lower maximum strength
  - Difficult to bend
  - Lacks lugs and deformations

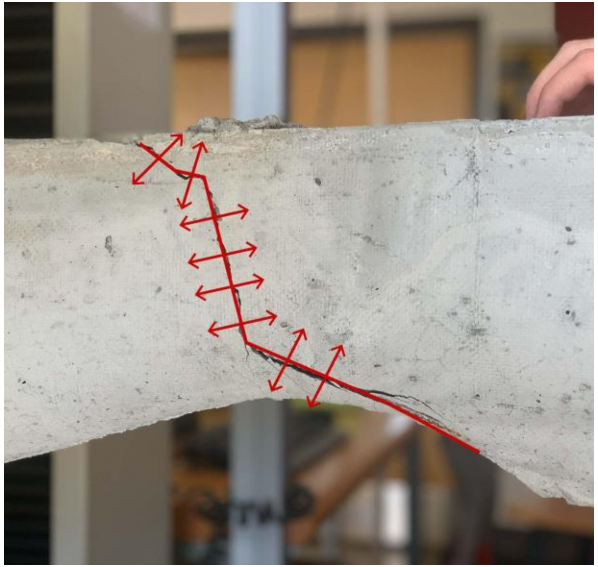


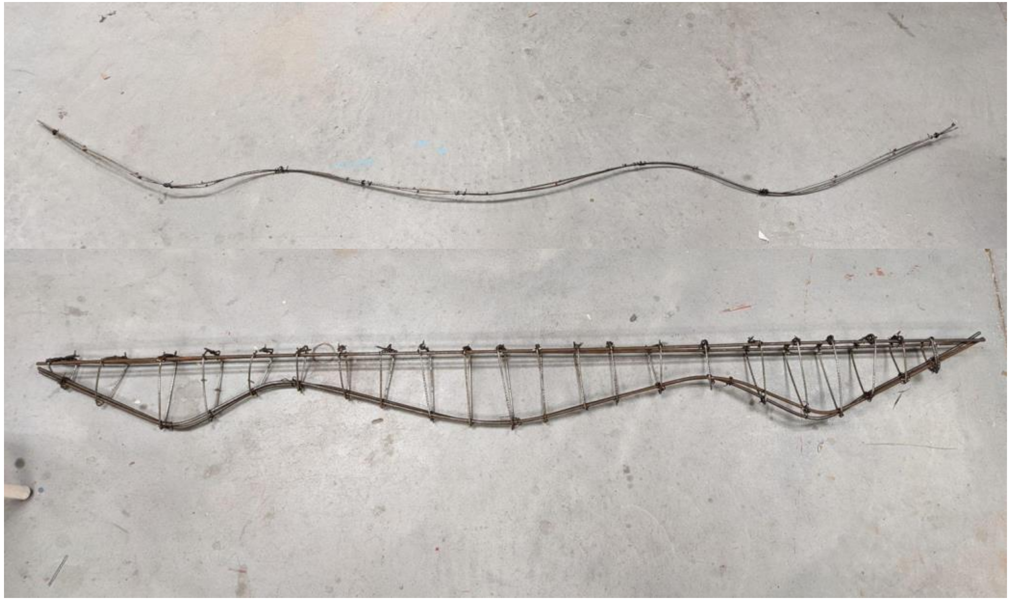
Beam Performance

- Fabric beam does not reach same maximum strength as prismatic
- Conclusions
  - Improper reinforcement is causing failure in the reinforcement before the concrete
  - While not being as strong it uses 40% less concrete by volume
  - Adjustment to the beam form to reduce stress concentration points



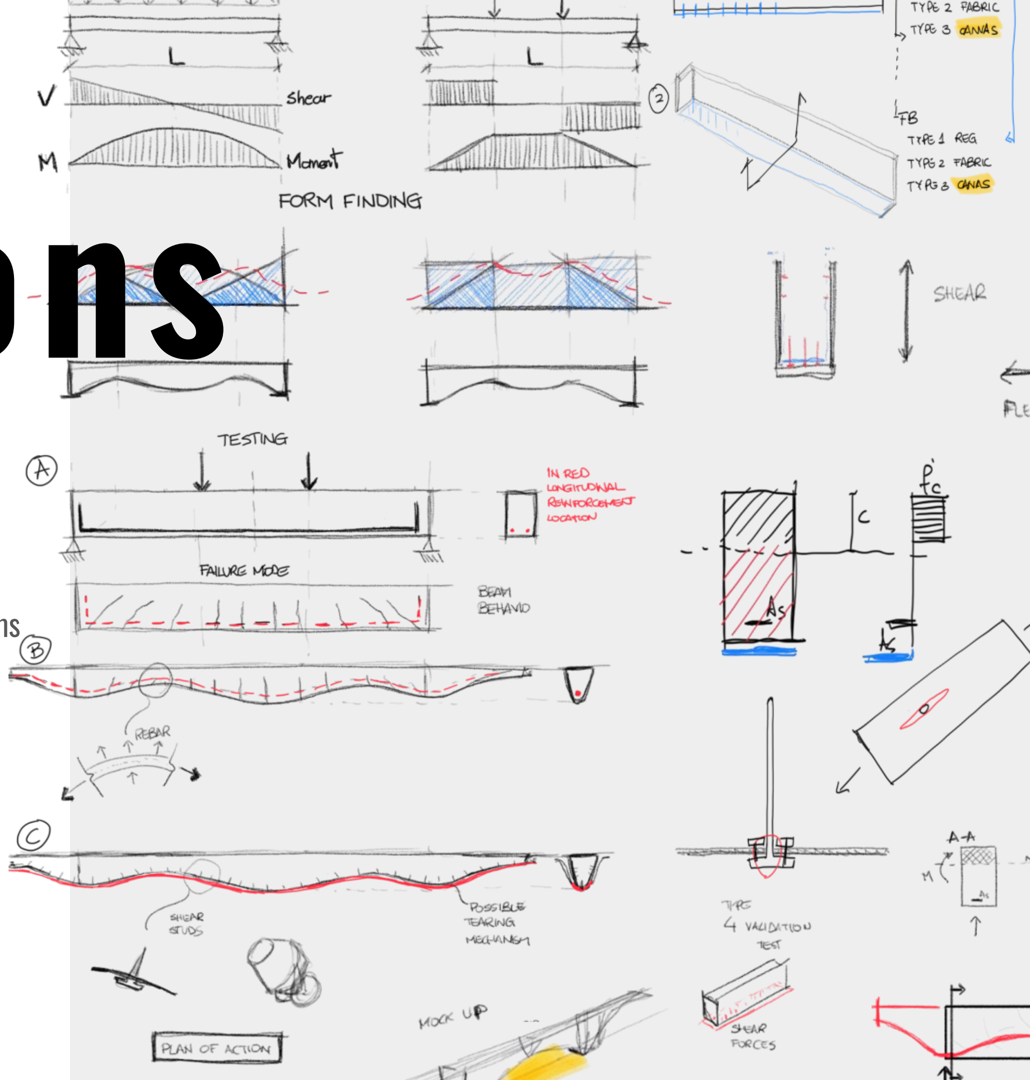
How to Reach Same Performance?





Conclusions

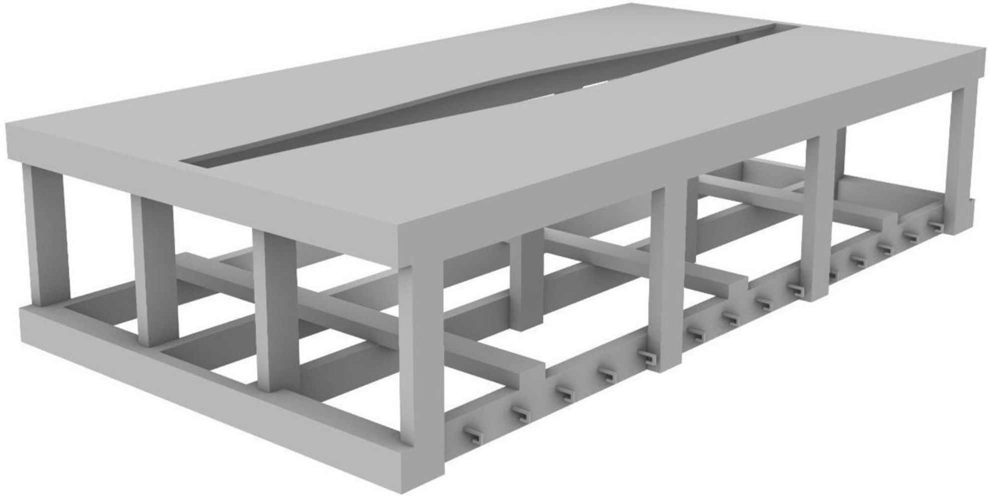
1. New formwork System
2. Developed SCC mixed design
3. New techniques to cast optimized shaped beams
4. Beams use 30% less concrete



Next Steps

- Develop and fabricate a new formwork that will allow for better control of the tension on the fabric.
  - More control over the cross-section
  - Control over the depth
  - Consistent bearing surfaces
  - Beam symmetry
  - Fabric re-use

- Investigate the use of post-tension reinforcement within the beam



Questions?