Procurement & Design of Composite Fender Piles to Meet MOTEMS

Courtesy: NC State University & Lancaster Composites

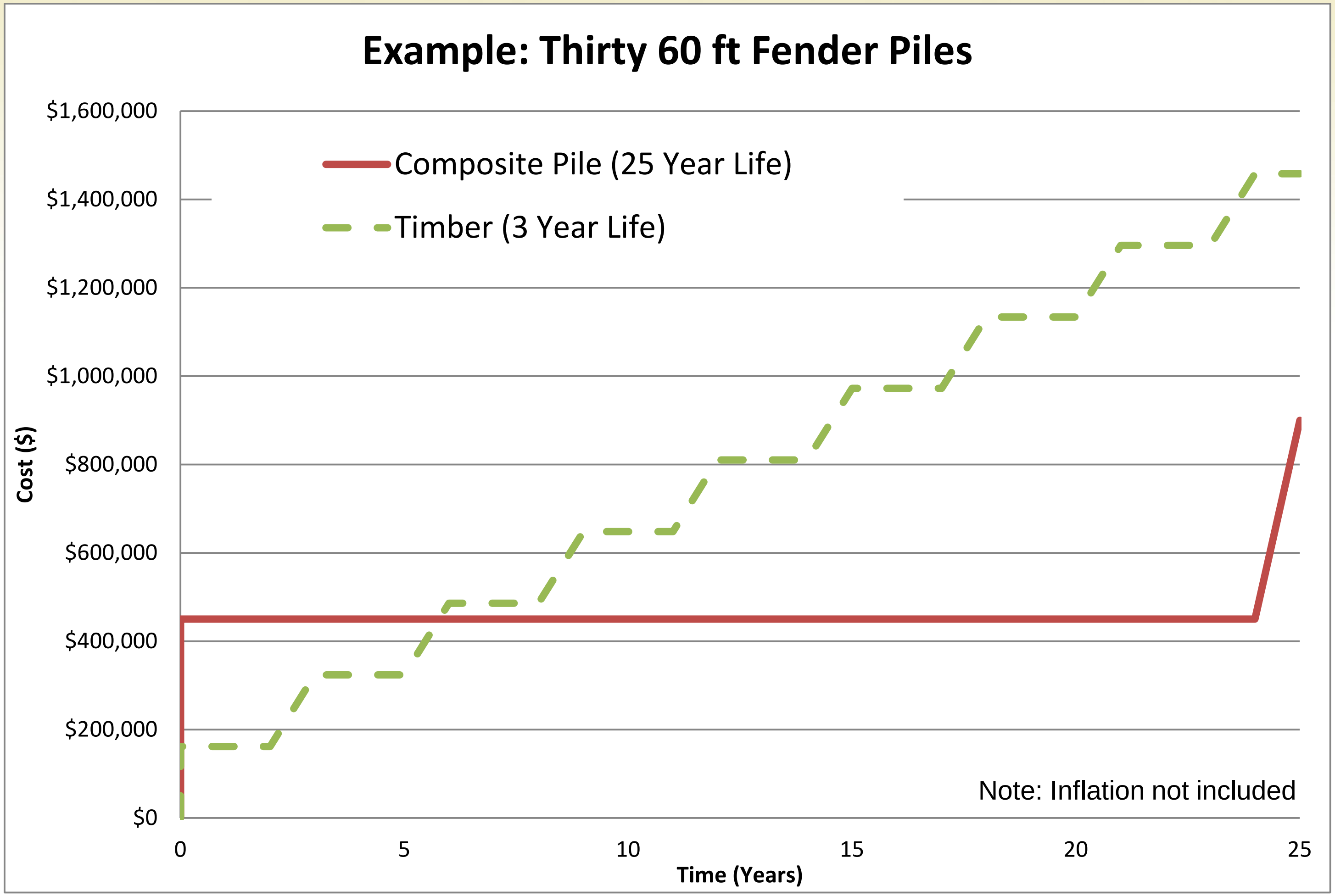
Presented by:

Marc Percher, P.E. – Moffatt & Nichol, Walnut Creek

Environmental Criteria for Piles

- Restricted Treatments of Timber Piles
  - Creosote – not allowed
  - ACZA – becoming restricted / prohibited
- Alternative Piles
  - Steel - $$$ and corrosion, driving windows
  - Concrete – also $$$, driving windows
  - Coated or wrapped timber
    - Increased cost over untreated
    - Abrasion can lead to accessible core
  - Greenheart or Ipe Wood - $$$ & lead time
  - FRP composite piles ← today's focus

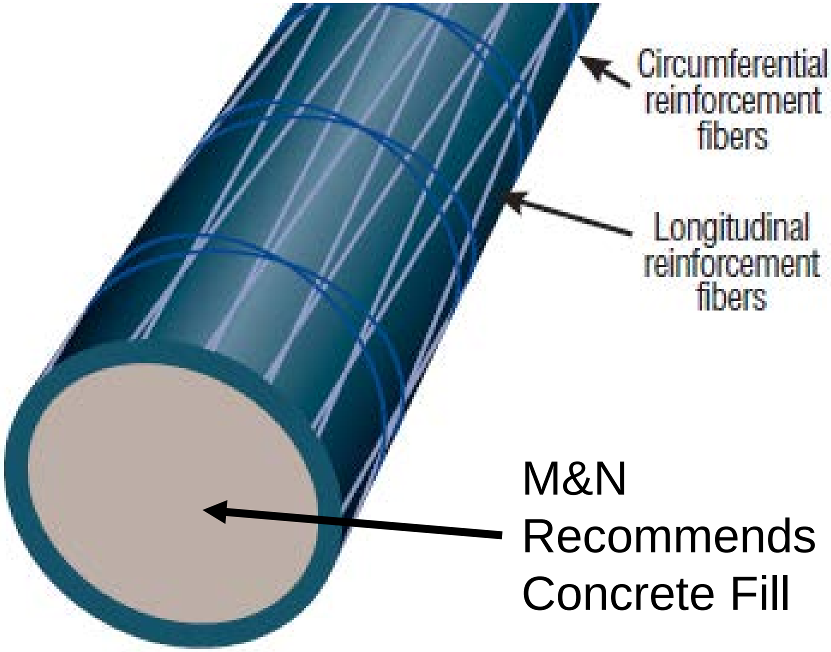
Why Composite Piles: Life Cycle Cost



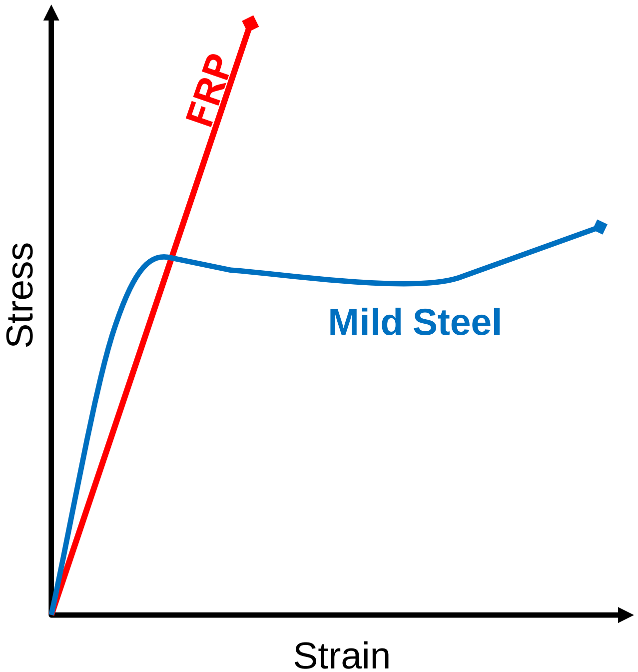
- ~$90 per LF for untreated pile every 1 to 3 years
- ~$250 per LF treated pile every 25+ years

What is a Composite Pile

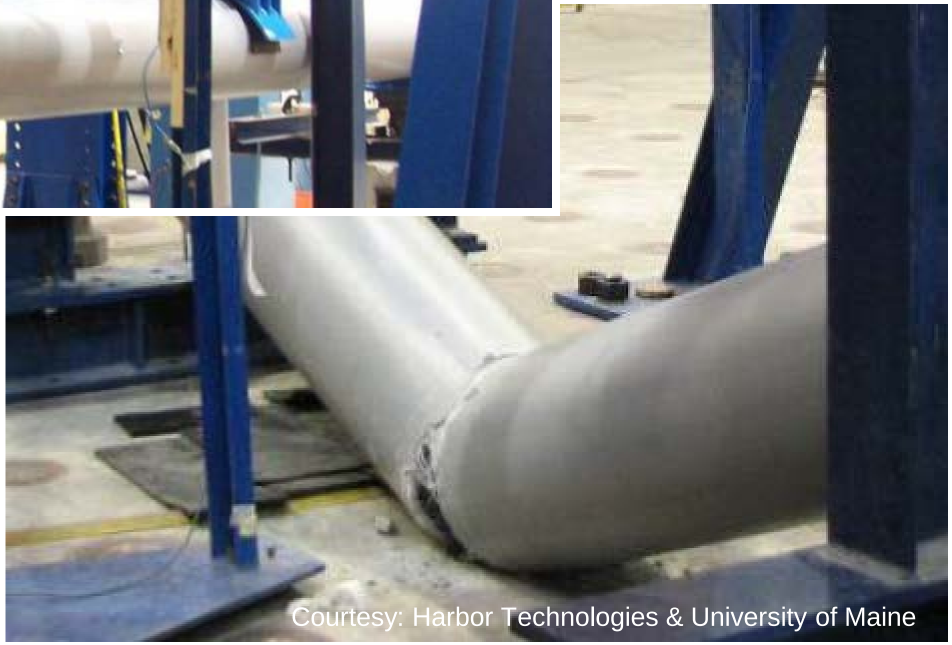
- Fiber Reinforced Plastic(FRP)
  - Fiberglass Layers } Composite
  - Epoxy Resin
- Fiberglass Layer Orientation



Courtesy: Lancaster Composites



Modes of Failure - Bending

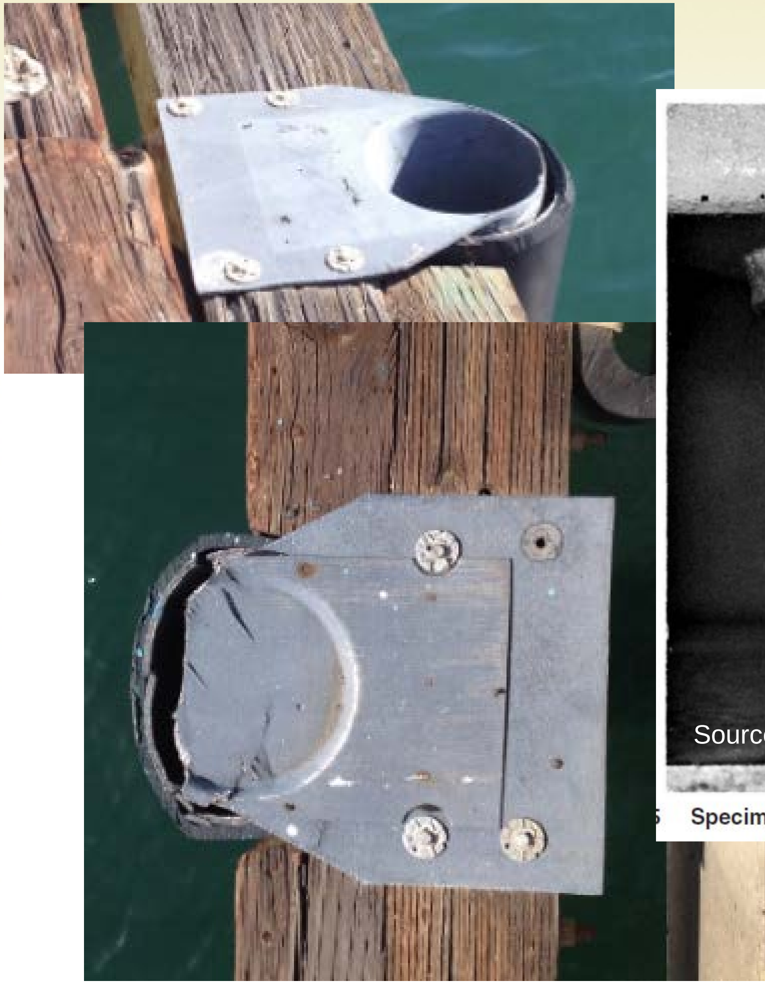


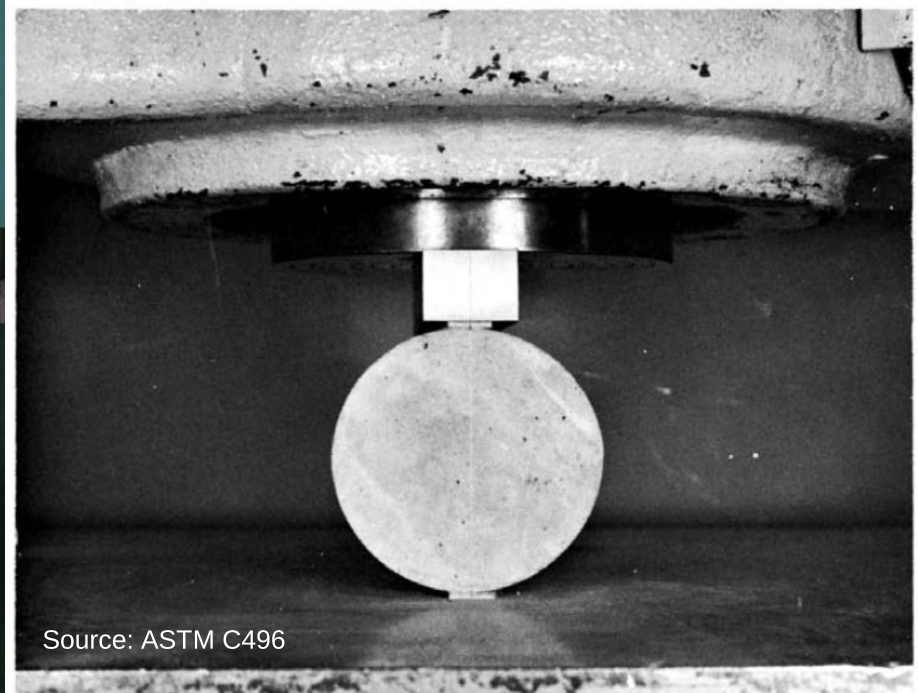
Courtesy: Harbor Technologies & University of Maine

ASTM D6109

- 4 Point Bending
- 5 Samples
- cyclic and to failure
- Moment & Stiffness

Modes of Failure – Splitting/Crushing





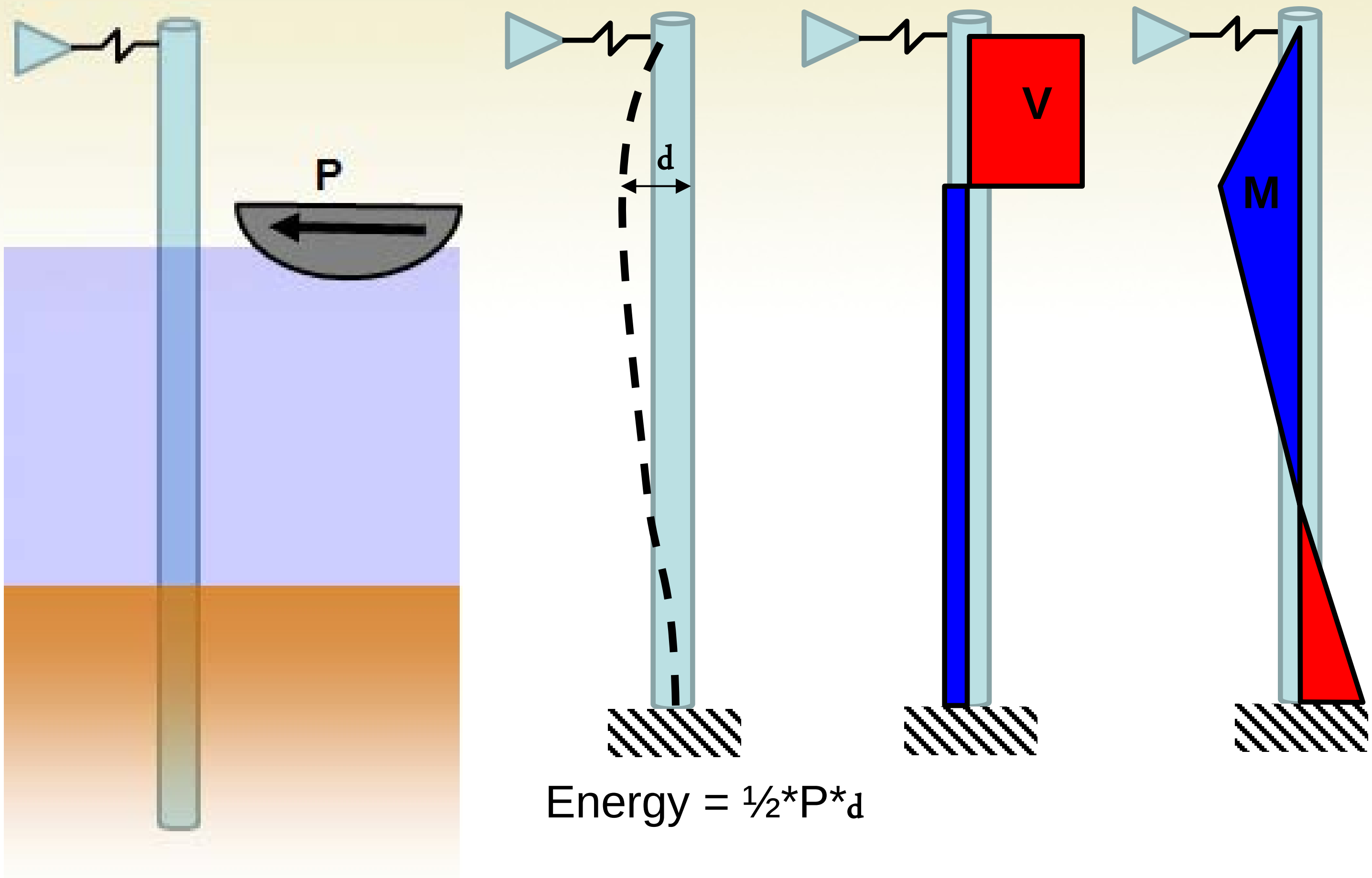
Specimen Positioned in a Testing Machine for Determination of Splitting Tensile Strength

- **Major concern is crushing of hollow FRP at top**
- **ASTM C496 – intended for concrete**

Modes of Failure – Connections

- **Concerned with abrasion, fatigue, etc.**
- **Optimally incorporate energy absorber at top**

Fender Piles



- Want Flexibility and Strength
- High Hits → Low Energy → High Shears

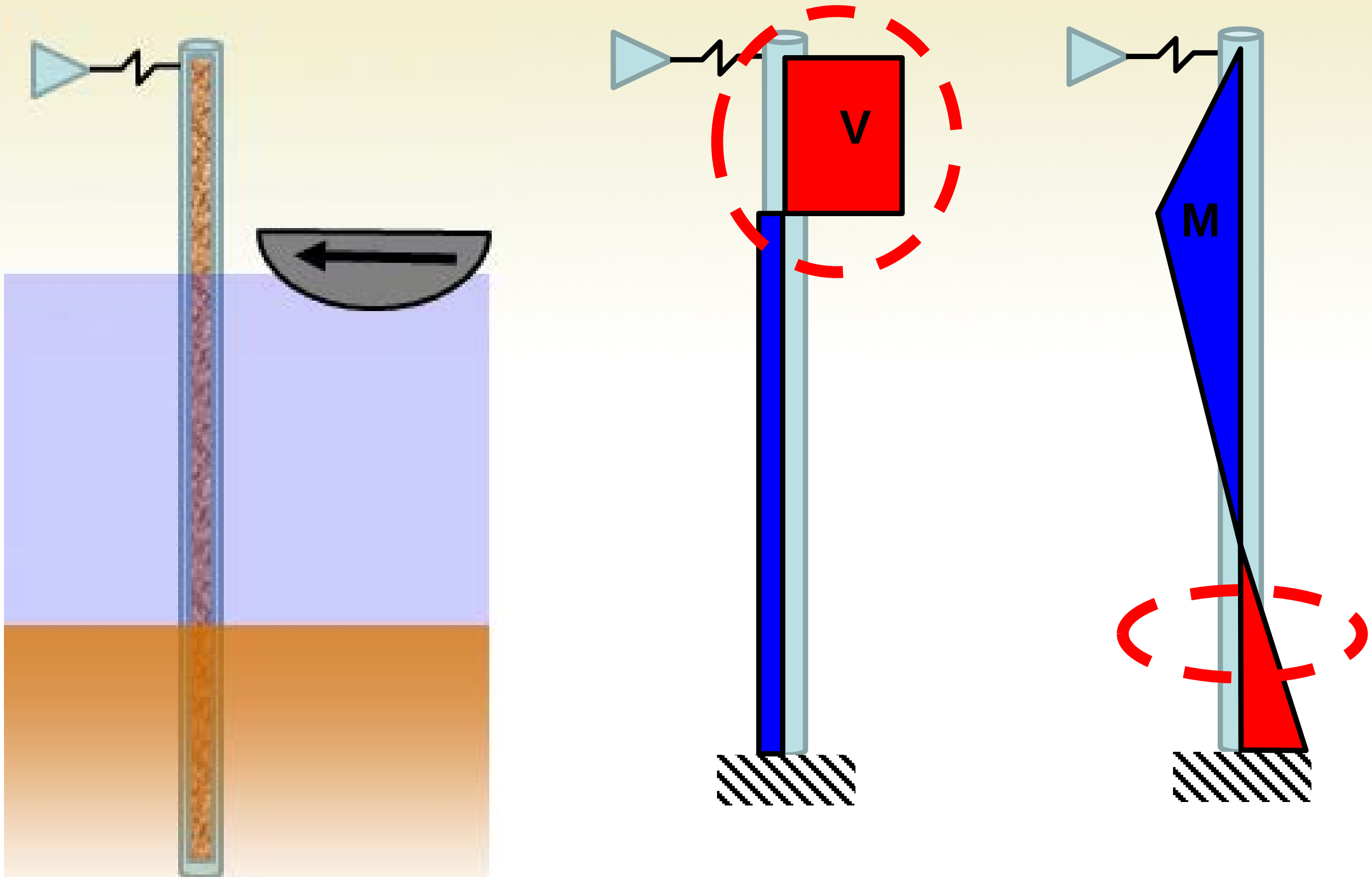
MOTEMS Compliance

- Based on Elastic Response:

$$E_{fender} = F_A \cdot C_b \cdot C_m \cdot E_{vessel} \quad (3\text{-}16)$$

- Use tested values for strength & stiffness
- Verify for full range of vessel impact elevation
- Connection design per AISC, NDS, ACI depending on materials
- In many ways, similar to other methods

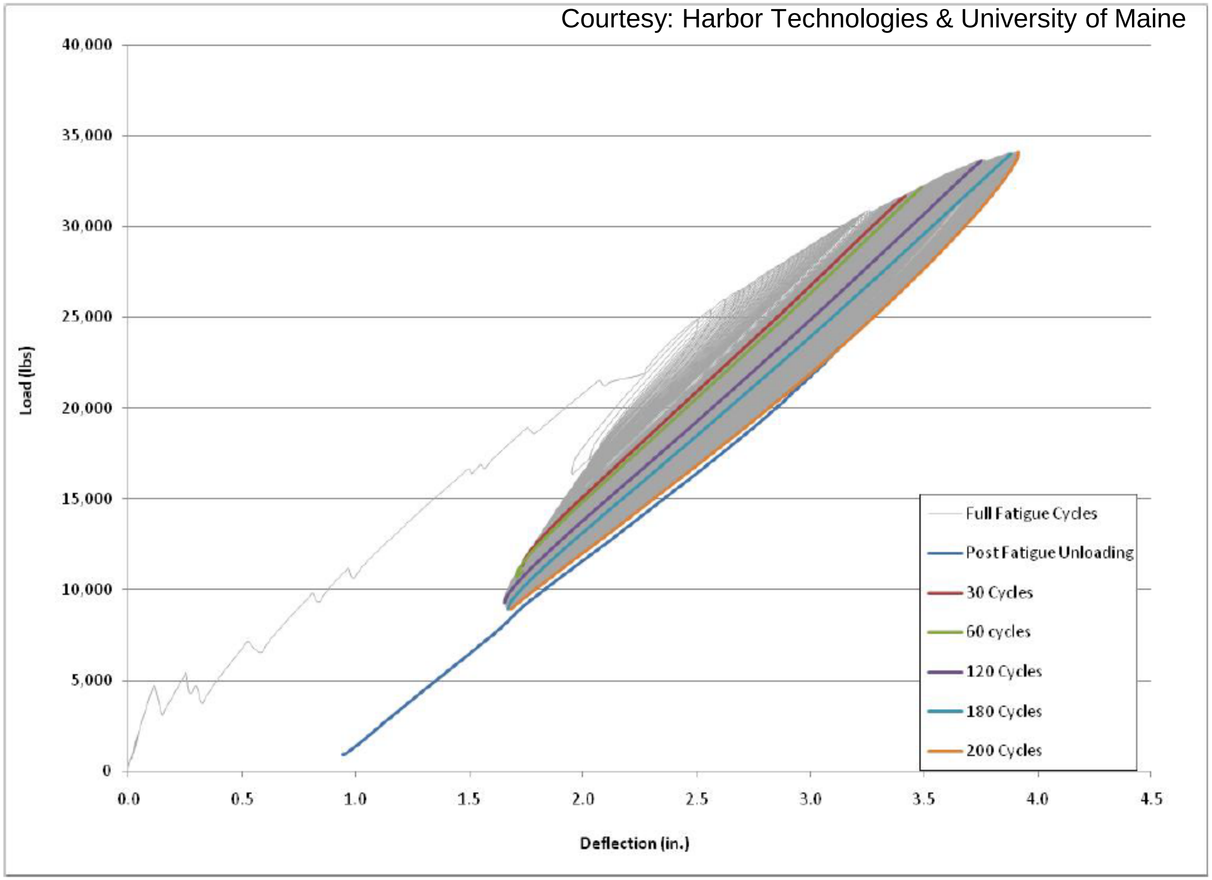
Concrete fill

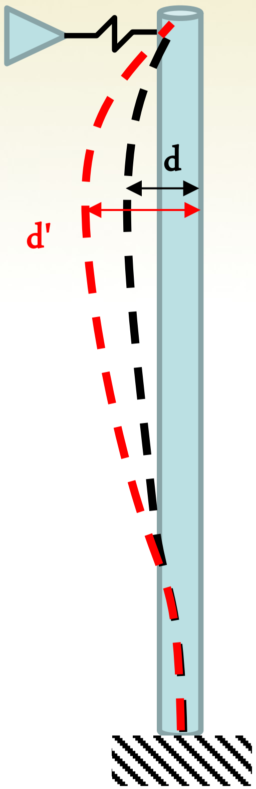


Concrete fill full height of pile because:

- Top of Pile Shear
- In-Soil Interface (no stiffness change)

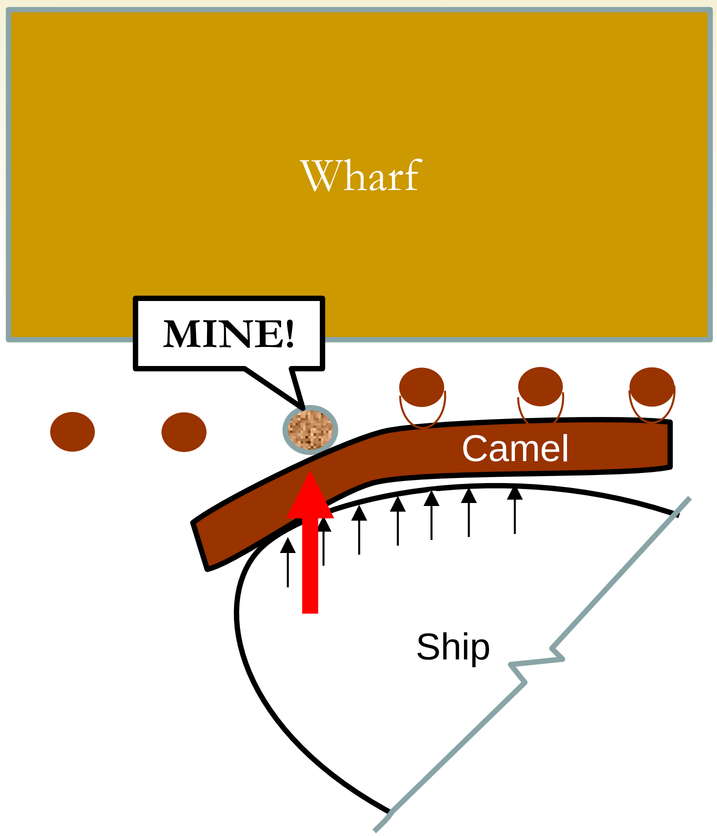
Fatigue and Softening

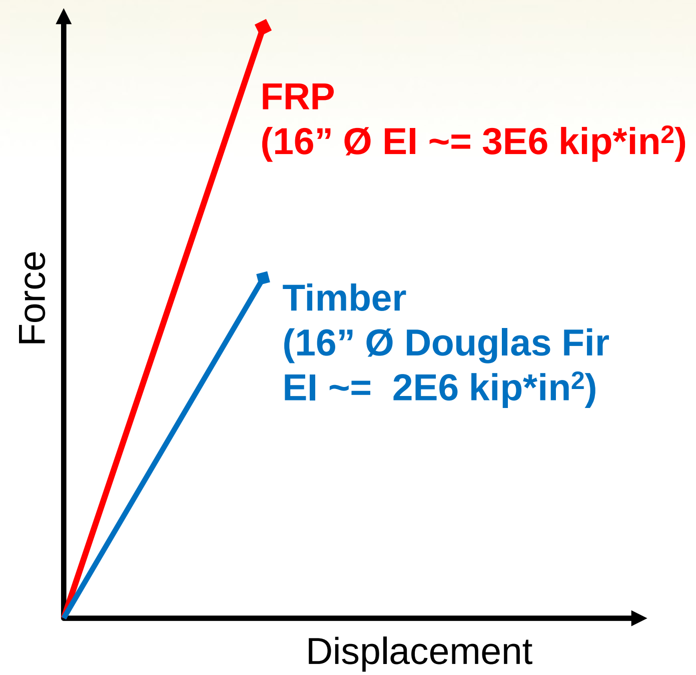




- Fatigue may limit life
- Softening = more energy absorption

Don’t Mix with Timber Piles





- Stiffer pile steals all the load

Specs & Testing

From UFGS 35 59 13.14 Type 5 (old, not perfect)

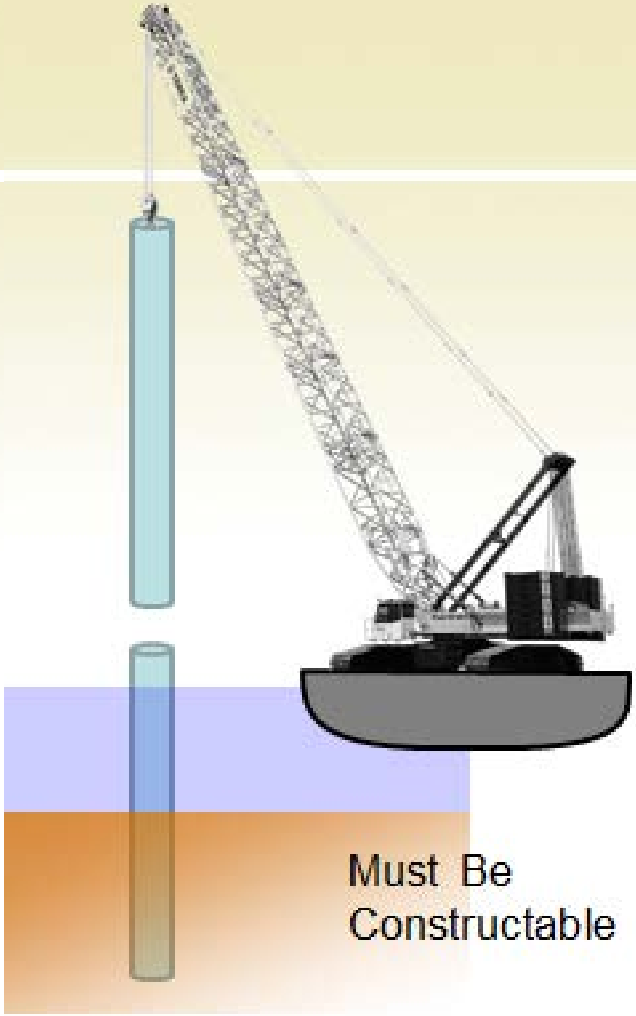
- Stiffness & Flexure (D6109)
- Crushing (ASTM C496)
- Density (D792)
- Water Absorption (D570)
- Brittleness (D746)
- Weatherability (D6662)
- Flame Spread (E84)
- Compressive Mod (D695)
- Tensile props (D638)
- Circumferential (D1599)
- Chemical Resistance (D543)
- Fiber percent by volume or weight
- Laminate void content

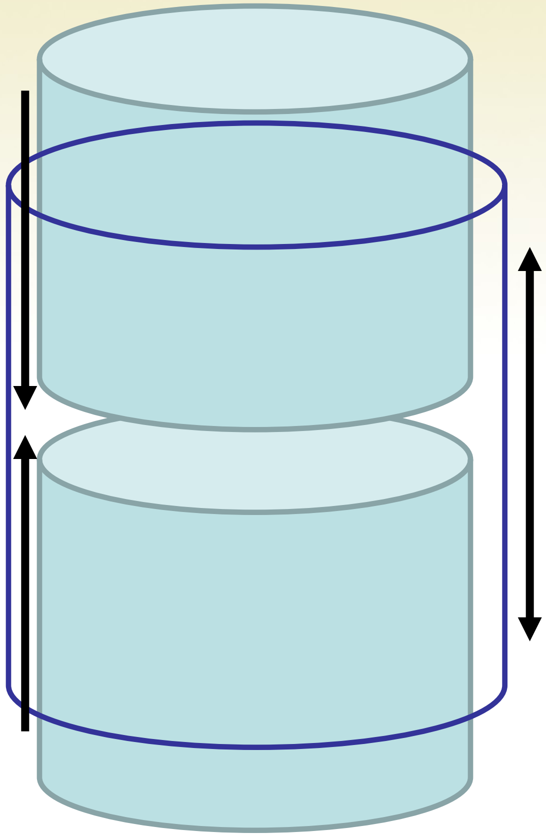
- Also need: HDPE sleeve, concrete fill, tolerance, and driving specs, etc.

Driving

- **Drives similar to concrete or timber**
- **Drive pile, cut, place HDPE sleeve, connect**
- **Can also use driving shoes to close section at tip**

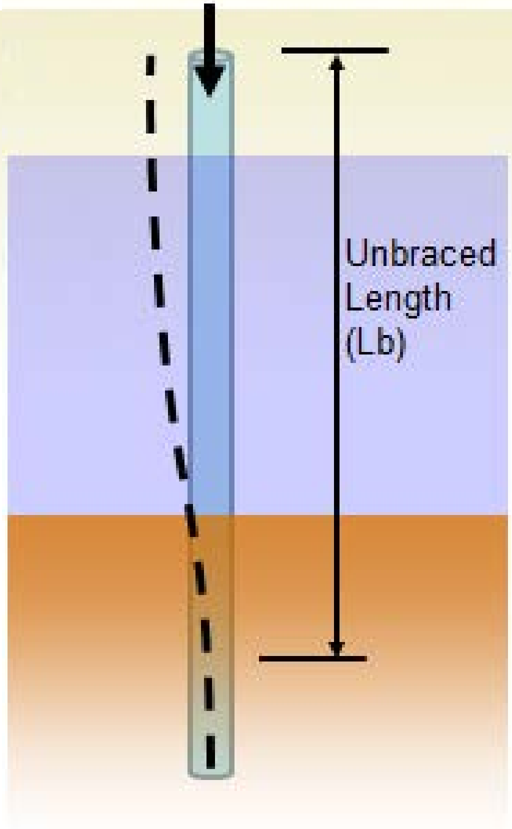
Splices

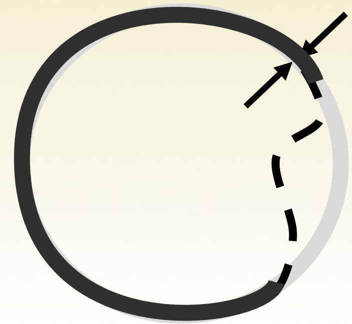


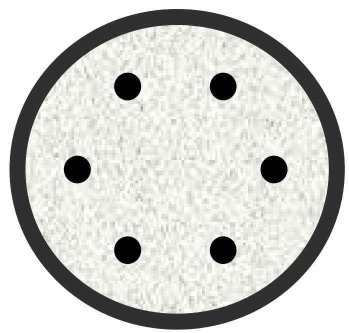


- **Piles available up to 115 ft in length**
- **Creates discontinuity in response, must be tested**
- **M&N recommends against using them**

Possible as Bearing Pile







Performing pile driving analysis (PDA)

Courtesy Lancaster Composites & University of Manitoba

Axial failure mode

- Hollow: Global and local buckling
- As reinforced concrete section – is there a cost advantage?
- Connections – concrete plug or steel
- Lack of ductility (need to detail like timber)

Conclusions

- Composite Piles are cost effective vs timber over their lifespans
- Meet environmental requirements
- Require close coordination with manufacturer
- Can be MOTEMS compliant

Questions?

Courtesy: NC State University & Lancaster Composites