

# Historic Concrete Structures

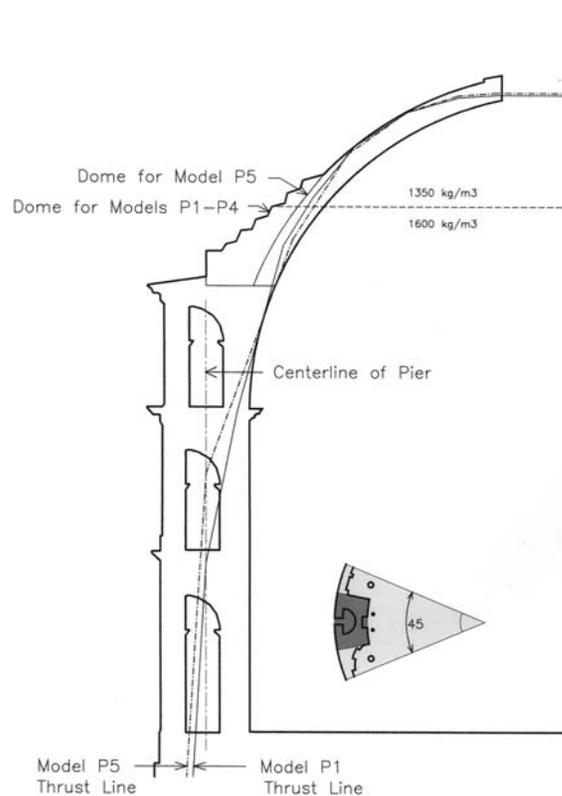
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# Historic Concrete Structures

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- **History**
- **Types of concrete structures**
- **Non-destructive testing (NDT)**
- **Analysis Methods**

# Roman Pantheon, 2<sup>nd</sup> C AD

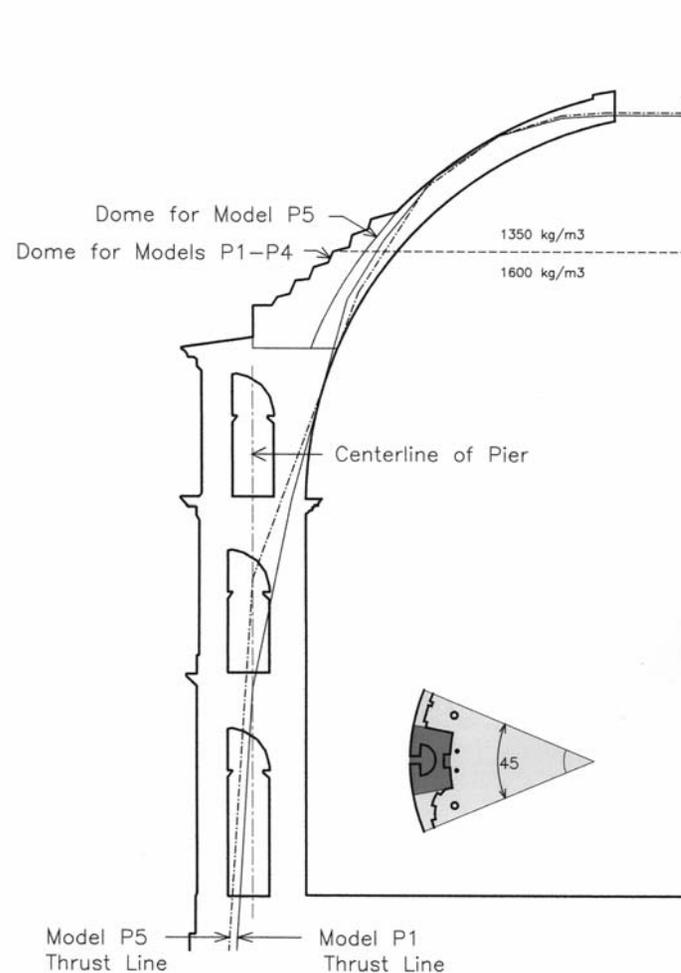


Unreinforced concrete

No tension, acts like masonry

New book on Roman  
Concrete from OUP  
by Lynn Lancaster

Analysis of Pantheon and  
other Roman structures  
using thrust lines



# Eddystone Lighthouse

## John Smeaton, 1759



English Engineer Smeaton experiments with cement mortars

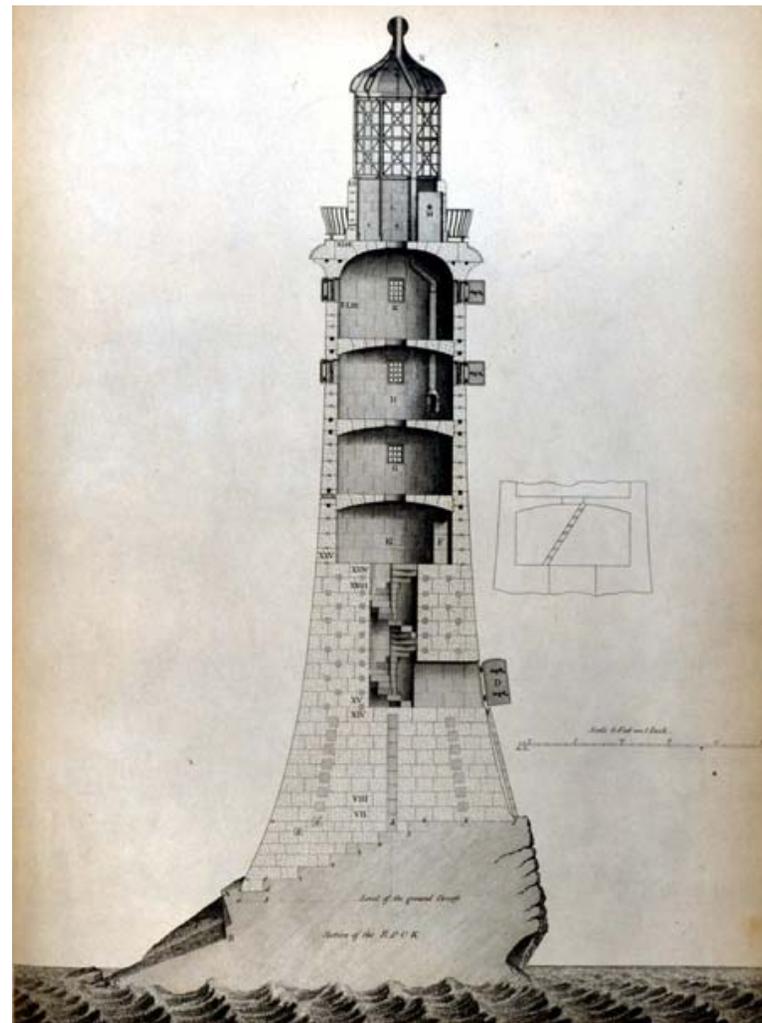
Finds mortar that can set underwater

Uses for lighthouse foundations

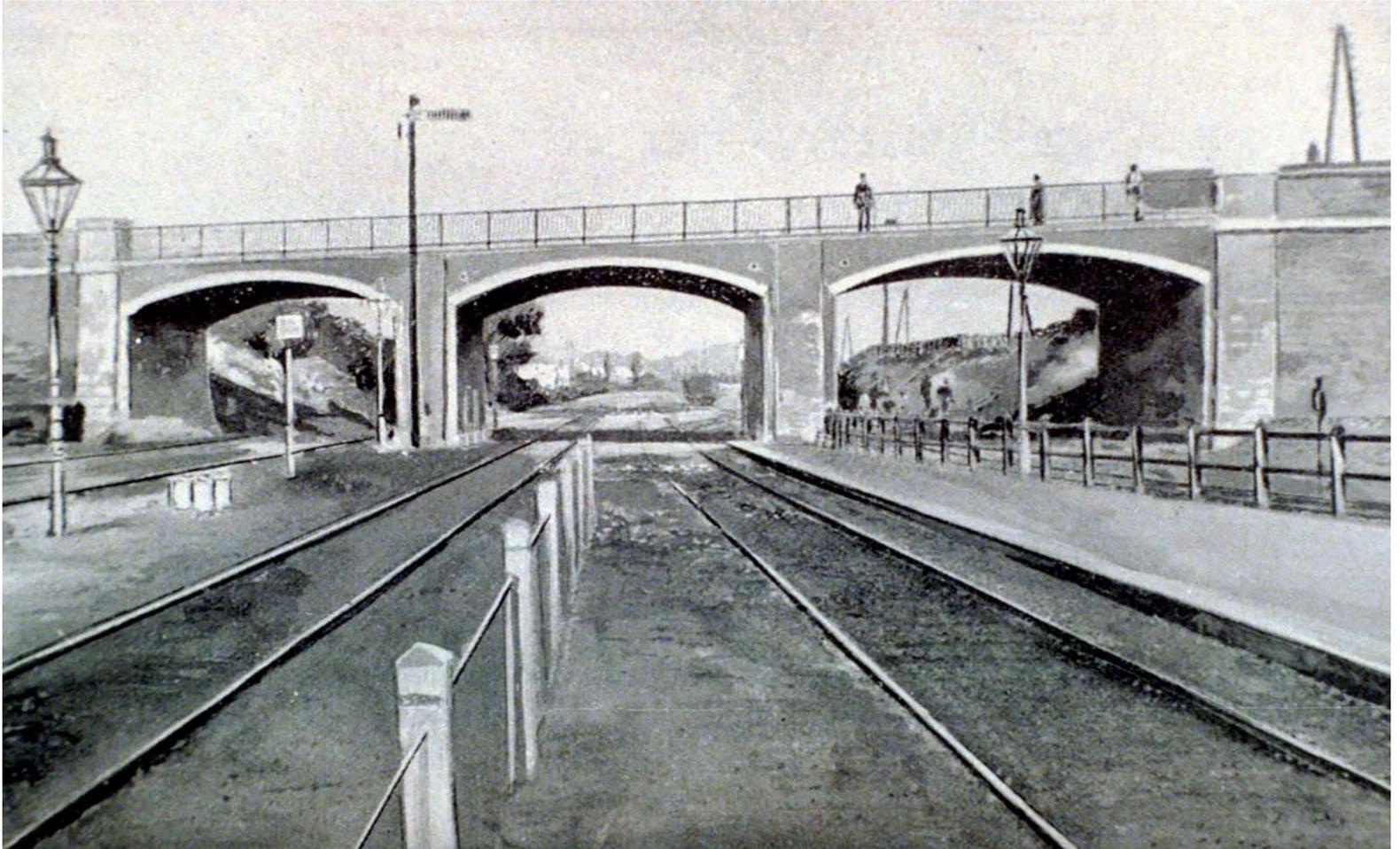
Structure of stone

# Eddystone Lighthouse

## John Smeaton, 1759

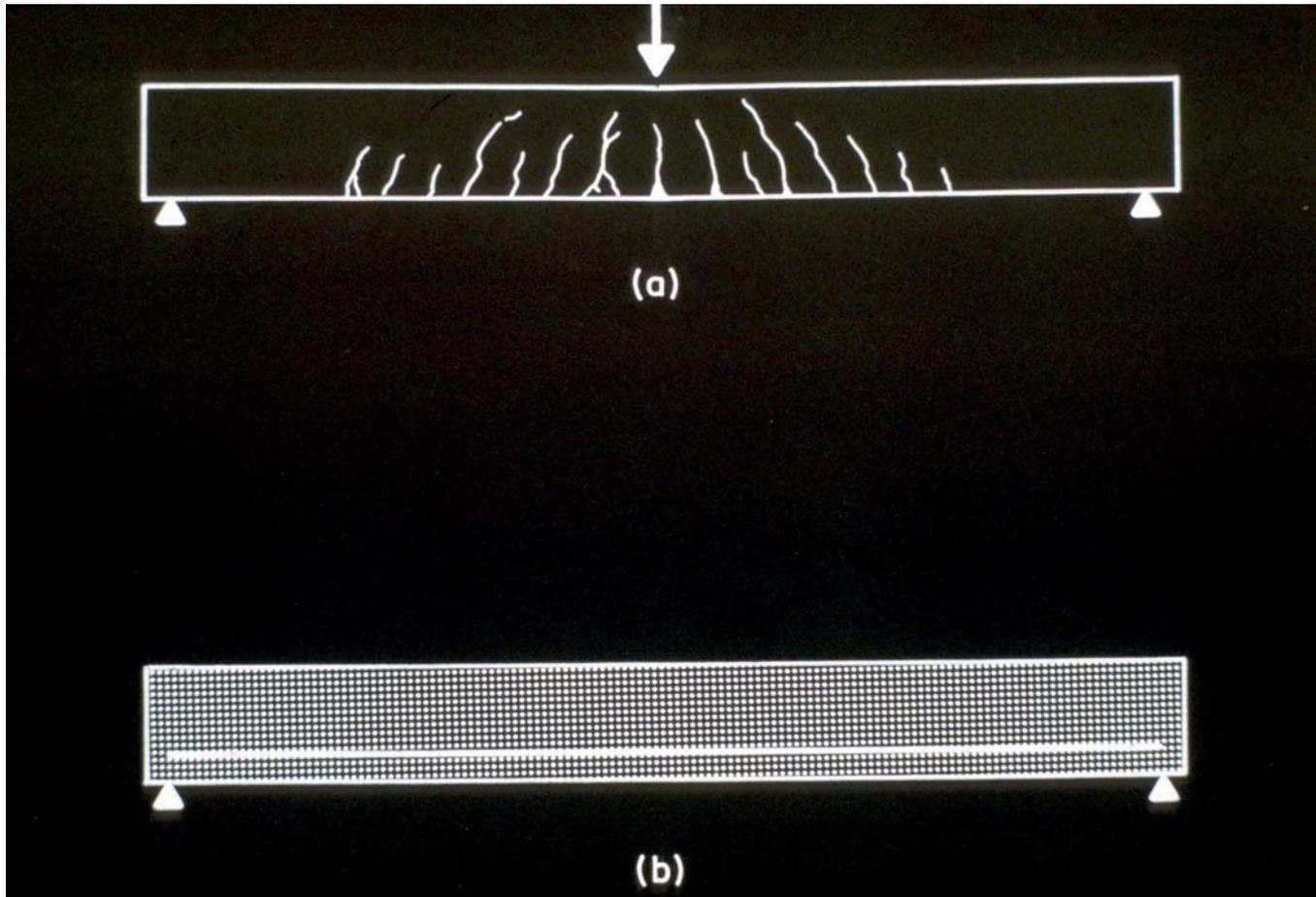


# Early 19<sup>th</sup> C Concrete Rail Bridge



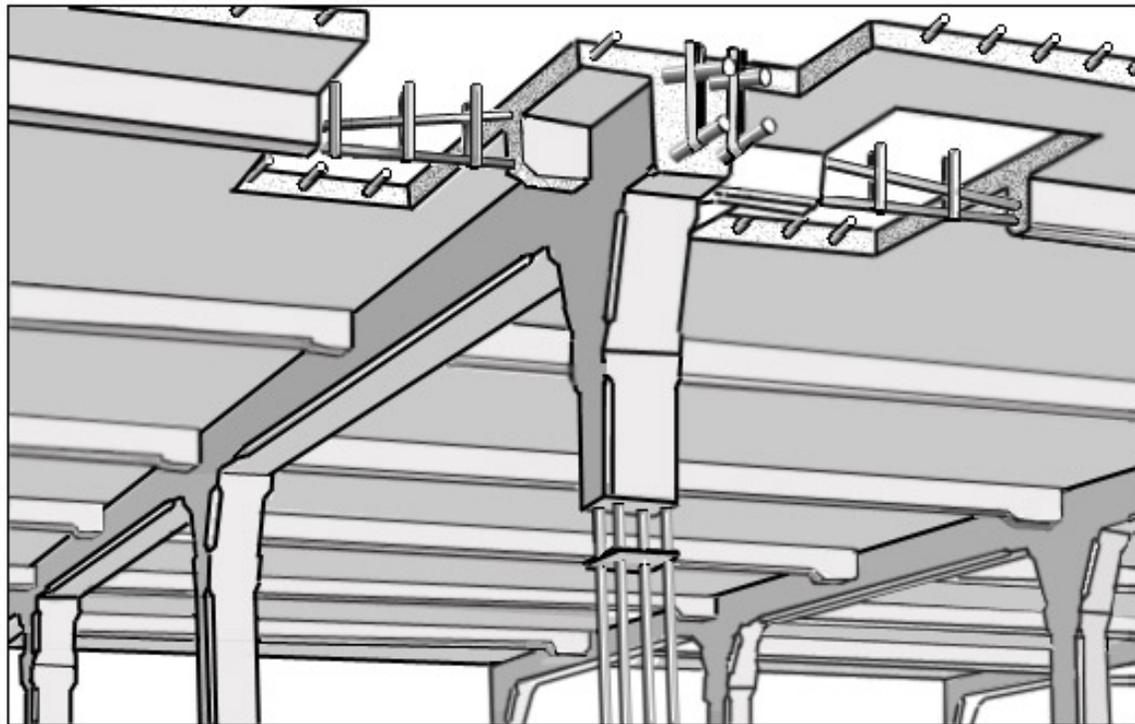
Unreinforced, used as “liquid masonry”

# Historic Concrete Structures



# Hennibique System 1890's

Beginnings of Reinforced Concrete



*Hennebique system patented in France*

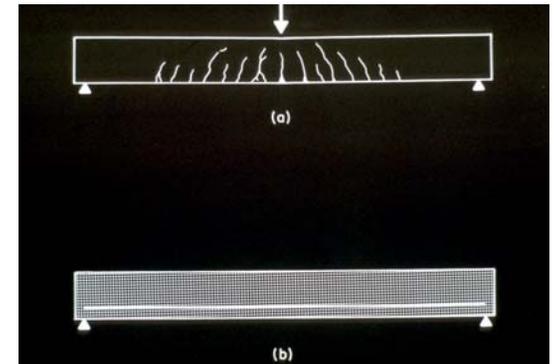
# Types of Concrete Structures

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- **Unreinforced (mass concrete)**
  - Roman Pantheon
  - Analyze like masonry
- **Early reinforced concrete**
  - 19<sup>th</sup> and early 20<sup>th</sup> C
  - Square, spiral, and round bars, non-standard
  - Often followed patents (like Hennebique system)
  - Analysis is difficult
- **Modern reinforced concrete**
  - Standardized rebar patterns and sizes
  - Use concrete codes to assess

# Analysis of RC Slab

- **Unreinforced (mass concrete)**
  - Arches within depth (flat arch)
  - Determine extent of horizontal forces
- **Early reinforced concrete**
  - Bond of bars
  - Shear reinforcement
- **Modern reinforced concrete**
  - Use a lower bound analysis to redistribute moments in different directions
  - Use yield line analysis for an upper bound approach



# NDT of Reinforced Concrete

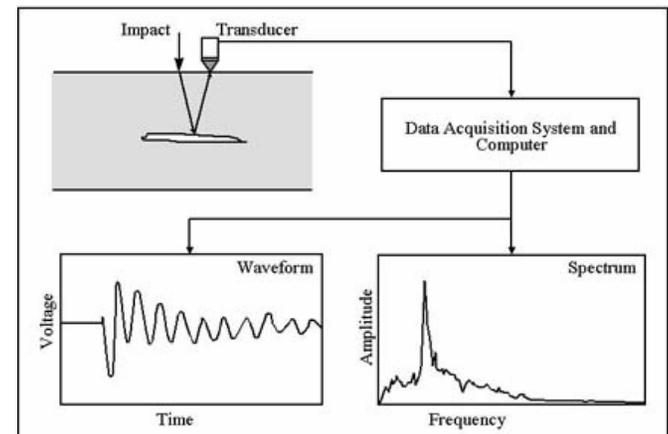
- Can use non-destructive testing (NDT) to find:

- Extent of corrosion
- Location and size of reinforcement
- Voids and areas of poor concrete
- Delamination of sections



- **Methods**

- Impact-Echo (sound waves)
- Radar
- Magnetometers
- Etc.



# Conclusions

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- **Material properties of concrete depend on the time period of construction**
- **Assessment methods are different from design methods**
  - **Use Upper Bound, such as yield line analysis for slabs**
- **In order to use plastic theory (Upper Bound Method) the structure must offer ductile behavior (lightly reinforced) rather than brittle behavior (shear failure or over-reinforced in bending)**