Emergency Repairs to the Jefferson Memorial Seawall

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Outline

- Original construction
- Issues
- Investigations
- Findings
- Design
- Seawall reconstruction
Introduction

- Tribute to 3rd President
- Groundbreaking 1938
- Dedicated April 12, 1943
- Original Statue was plaster, replaced by bronze 1947
- 2007: Fourth on the List of America’s Favorite Architecture by the AIA
Construction of the Memorial

- West Potomac Park on reclaimed land
- Bedrock is nearly 100 ft deep at the Memorial site
- Originally marshland and shoals
- Complex reclamation history throughout the 1800s
- Mostly intentional
- Reworked for construction of Memorial
Constructing the Memorial

Source: National Park Service Archives 1940
Constructing the Memorial

Source: National Park Service Archives 1941
Constructing the Memorial

Source: National Park Service Archives 1940
Constructing the Memorial

Source: National Park Service Archives 1941
Nomenclature

Perimeter Wall
Constructing the Memorial

- Memorial structure and steps supported on deep foundations
  - 443 cast-in-place Raymond piles
  - 88 24" caissons
  - 103 16" caissons
  - All bearing on rock
  - Detailed records of foundation work
Constructing the Memorial

- Seawall
  - No records on its construction
  - Original design was reinforced concrete wall on vertical and battered precast piles
  - Needed to investigate this further
- North Plaza, Perimeter Wall and Ring Road on Grade
Constructing the Memorial
Settlement issues

- Significant ground settlement was anticipated by designers
- “Let it happen then fix” approach
- Good historic monitoring data available
- Bench marks still accessible
Settlement issues

- By the 1960s, North Plaza had settled over 3 ft in places
- Perimeter walls sagged significantly
- Steps showed northward movement and structural damage
- Seawall settled but much less than North Plaza
- Memorial building not affected
Settlement issues

Source: National Park Service Archives
Settlement issues

- Study commissioned (Storch Report)
  - Reconstruction of North Plaza on piles
  - Buttressing of the steps
  - Repositioning of perimeter walls
  - No repair to seawall
  - Valuable information

- Repairs implemented by 1971
Settlement issues

Source: Storch report 1967
Settlement issues

Source: Storch report 1967
Time goes by so slowly...

... and time can do so much

(Righteous Brothers)
Its Happening Again…

- 2005-2006
  - “Sudden” noticeable seawall settlement
  - North Plaza pulling away from Steps

- October 2006, NPS commissions investigation of movements
Settlement issues
Investigation
Investigation
Questions that needed answers

- Was seawall on piles?
  - What type?
  - How deep?
- Were movements really sudden?
- If so, what was the cause?
- How much additional settlement? How much lateral movement?
- Was seawall safe?
- Was North Plaza safe?
- How about Memorial Building?
2006 Study

- Review historic information
- Exploration
- Instrumentation
- Survey
- Analyses
Findings
Was seawall on piles?

Source: National Park Service Archives 1939
Constructing the Memorial

Source: National Park Service Archives 1939
Findings
Findings
Findings
Findings
Remediation design

- Considered various alternatives
  - Deep Soil Mixing (DSM)
    - Treated root cause of problem
    - Spoils
  - Micropiles
    - Minimum disruption
    - Too flexible, required large number
  - Tied back diaphragm wall
    - Suitable stiffness
    - Conflict with North Plaza piles
Remediation design

- Selected caissons and battered pipe piles
  - Suitable stiffness
  - No conflicts with existing piles
  - Visitor’s experience
Remediation design
Remediation design
Lateral analyses
Lateral analyses of caisson and piles

- Apply soil movement profile
- Apply given displacement at top
- Determine shear at top
- For piles consider batter
Soil movement profile

- Scaled from inclinometers
- Maximum displacement at top
- Zero at about 65 ft
- Used settlement/lateral displacement ratio from Plaxis
Lateral Analyses
Lateral Analyses

- Iterative process
- Determine existing Plaza shear from Lpile analysis for various soil and head displacements
- Guess caisson and pipe pile sizes
- Use Lpile to determine shear forces, bending etc for zero head displacement
- Design caisson and piles
- Run structural analyses using framework or similar and determine head displacement
- Run next iteration
Remediation design
Remediation design
Seawall Reconstruction

- Contractor – Clark Construction
- Construction Management – Alpha
- CO/COR – NPS Denver
- Engineer – Schnabel Engineering
Seawall Reconstruction
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Transition Zone
North Plaza
North Plaza
Lessons learned

- Tidal Basin area around Jefferson Memorial may be subject to settlement over time
- Construction documentation is important
- Dewatering may have dramatic consequences even at considerable distance
- Current inclinometer data shows a change in direction and reduction of magnitude of movement
- Monitoring continues with periodic reporting to NPS
“thanks to a benevolent arrangement of things, the greater part of life is sunshine.”
Lateral Analyses

- Shear at top
- Caisson
- Pipe pile
- Plaza pile
- Max soil displacement
Seawall Reconstruction
Seawall Reconstruction
Seawall Reconstruction
Lateral Analyses

- Modeled caisson and pile separately in Lpile Plus
- Applied various magnitudes of soil movement around foundations
- Movement profile scaled from inclinometer data
- Maximum settlement estimated from present pore pressure distribution
- Maximum lateral movement scaled from settlement based on Plaxis analyses
Seawall Reconstruction