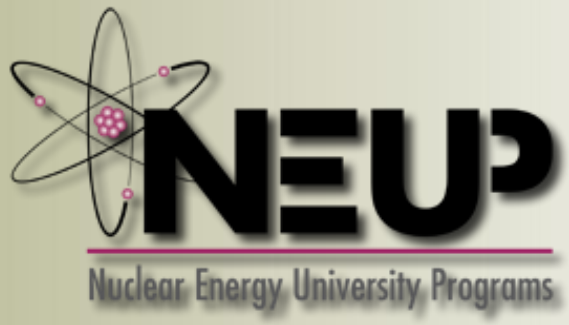
Prefabricated High-Strength Rebar Systems with High-Performance Concrete for Accelerated Construction of Nuclear Concrete Structures



Primary Objective

Reduce field construction times and fabrication costs of reinforced concrete nuclear structures through:

1) High-strength reinforcing steel (rebar)

2) Prefabricated rebar assemblies, including headed anchorages

3) High-strength concrete

Collaboration

UNIVERSITY OF NOTRE DAME

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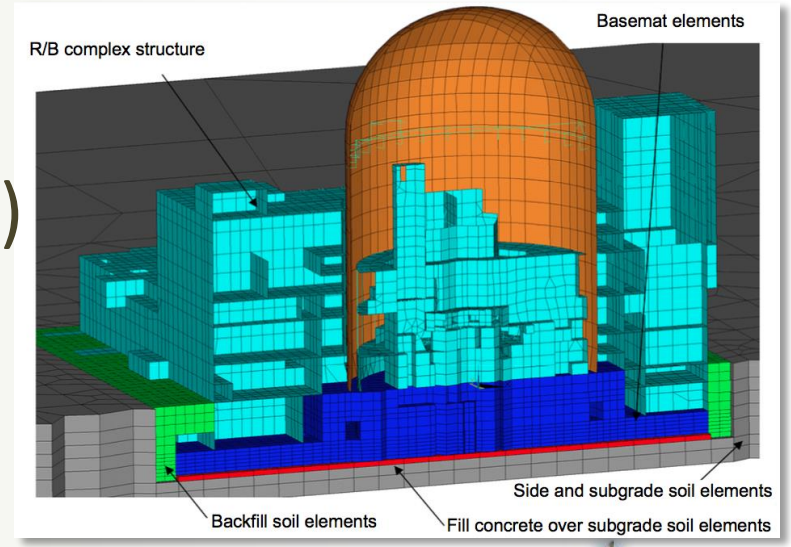
Scope

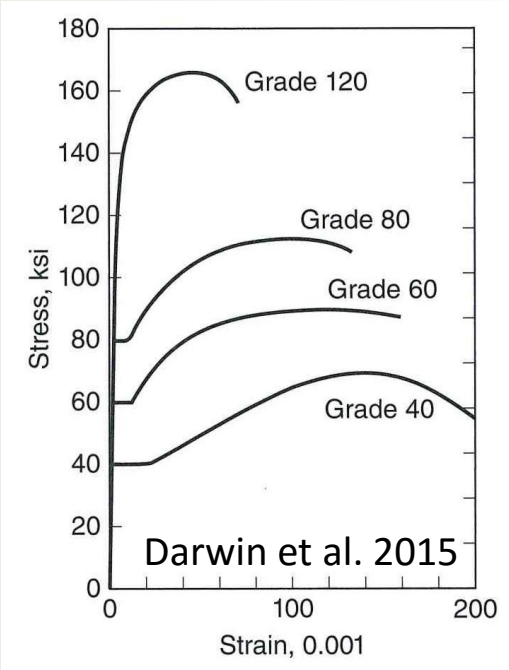
- Explore effectiveness, code conformity, and viability of existing high-strength materials
- Aim to reduce complexities in rebar to improve construction quality and ease of inspection
- Focus on shear walls (ACI 349) – most common lateral load resisting members in nuclear structures (pressure vessels not in scope)

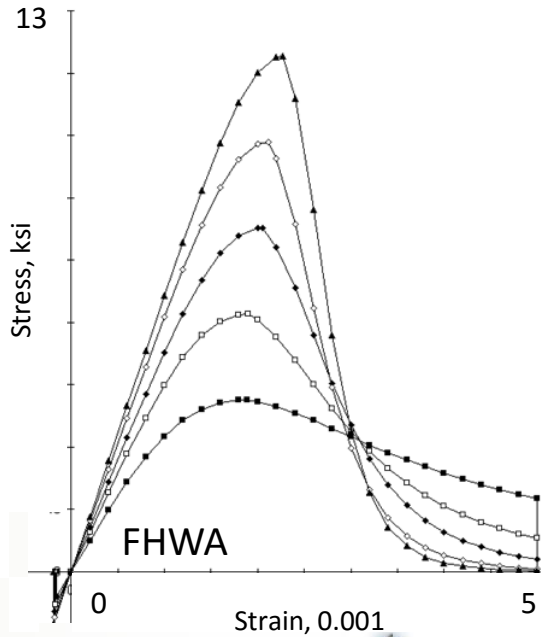


US-APWR Design Control Doc.

Scope:
High Strength Materials

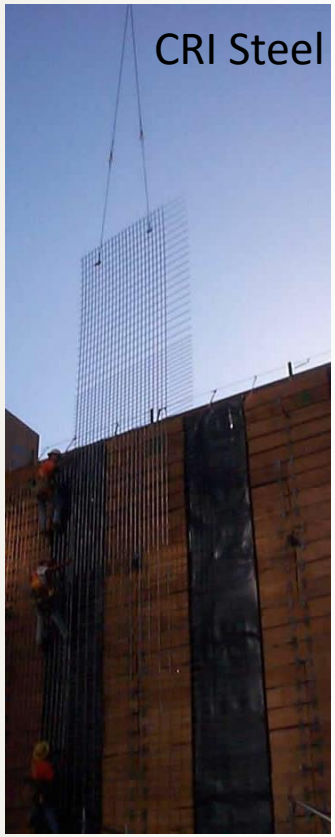
- High-strength rebar (up to grade 120) with high-strength, high durability concrete (around 15 ksi)
- Concrete strength of 5 ksi typical in current practice
- ACI 349 limits headed bars and shear reinforcement to grade 60

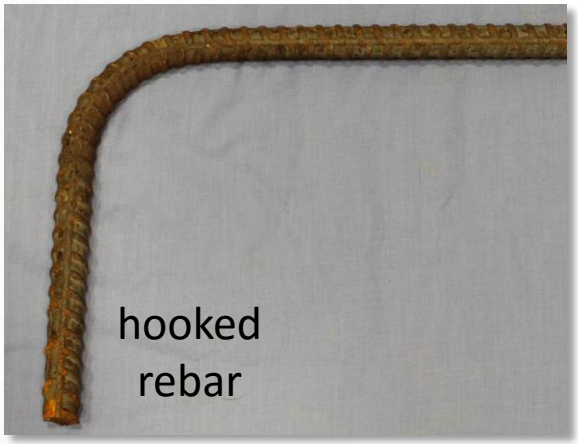




Scope: Prefabricated Rebar Assemblies

- Partially prefabricated cages for nuclear structural members (e.g., thick shear walls, slabs)
- Headed bars to reduce congestion (eliminates hooked bars)





Potential Benefits

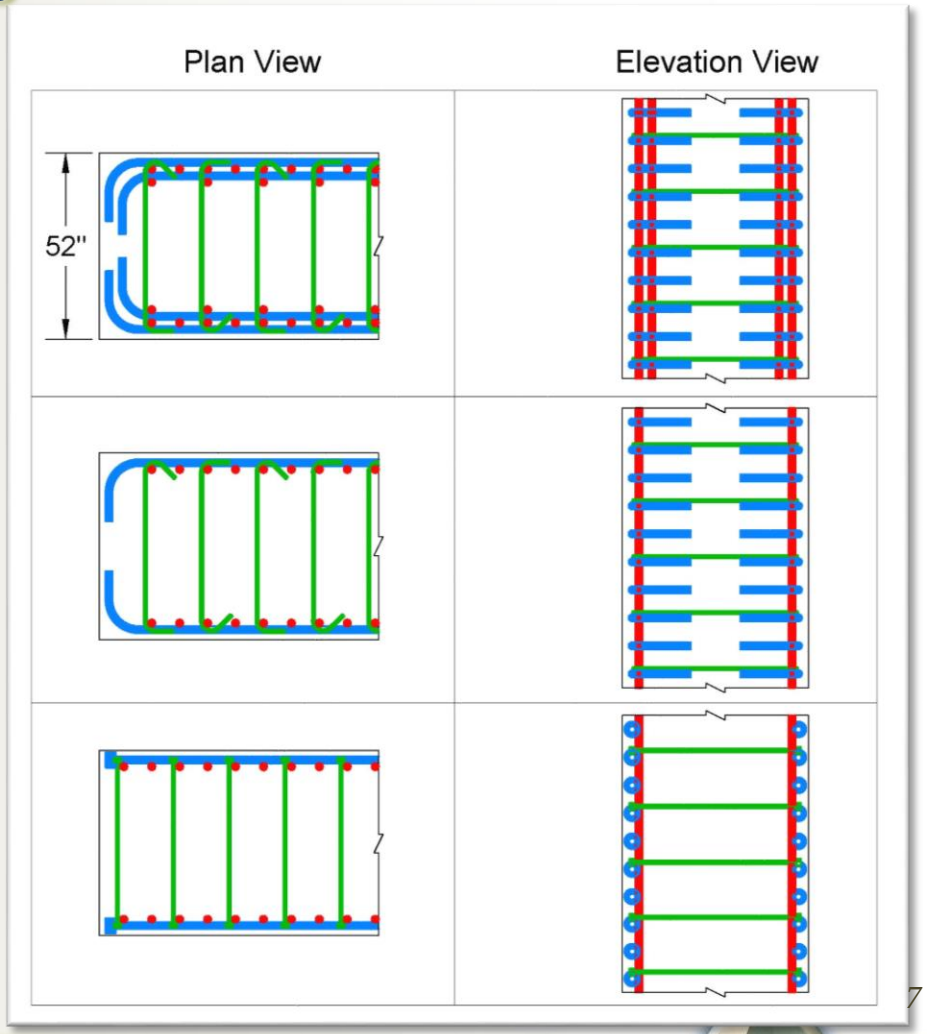
Most Congested (current)

Multiple layers of hooked Grade 60 bars

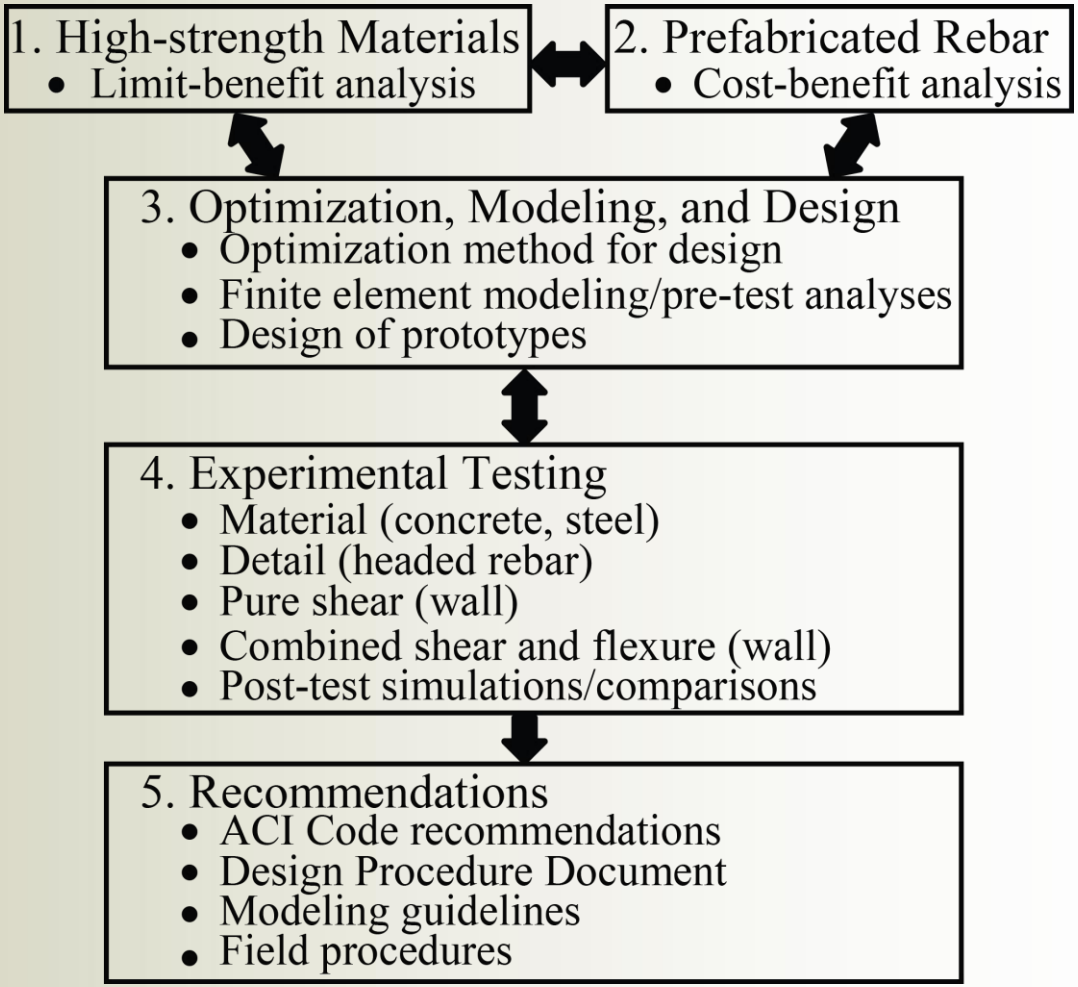
Fewer layers of hooked high-strength bars

Least Congested (envisioned)

Fewer layers of headed high-strength bars



Project Tasks



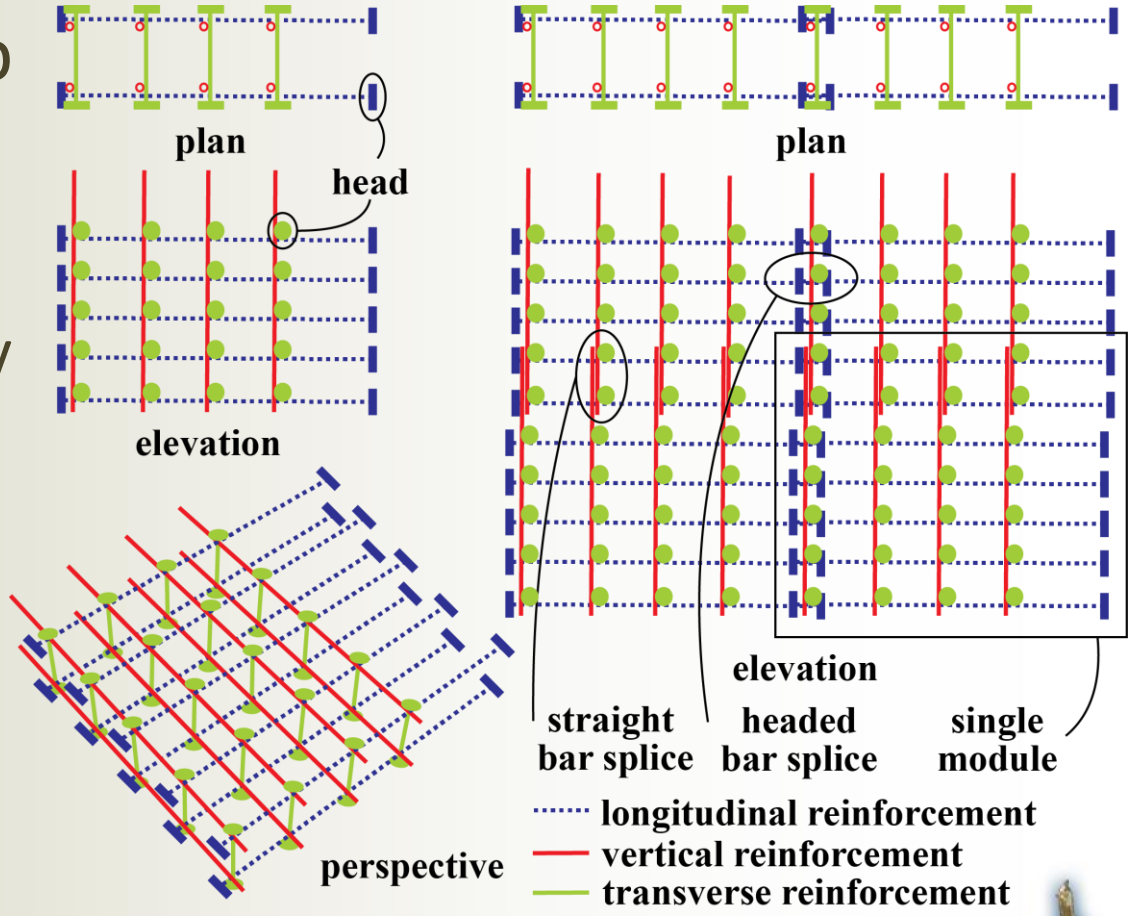
1- High-Strength Materials

Analytical study on limits/benefits, to:

- Establish effects of high-strength materials on structural deformation capacities
- Establish required concrete strengths so that use of high-strength rebar does not cause poor concrete performance
- Determine reduction in steel volumes
- Inform subsequent tasks of research on ACI 349 requirements that have greatest impact on design

2- Prefab Rebar Cages

- Evaluate prefab headed rebar cages for:
  - transportability
  - liftability
  - modularity
- Develop field procedures



3- Optimization, Modeling, Design

- Develop optimization procedure to select materials and prefabrication solutions for:
  - minimum fabrication cost
  - minimum in-situ rebar cage assembly time
- Basic (design-level) and detailed (high-fidelity) numerical modeling
- Design of prototypes
- Pre-test design and analytical predictions

4- Experimental Evaluation

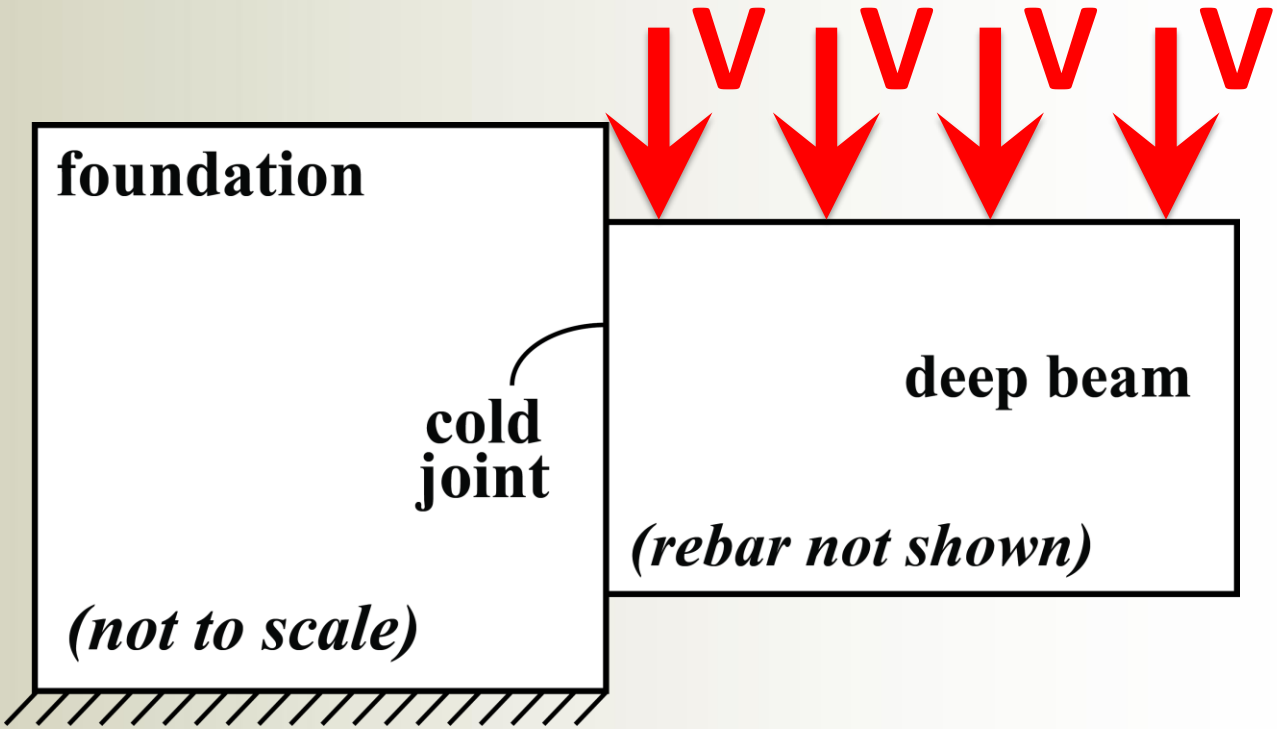
- Testing of:
  1) high-strength concrete and rebar materials
  2) deep beams to establish basic characteristics of shear-controlled behavior
  3) stub walls for pure shear strength of joints
  4) wall panels for combined shear+flexure behavior
- Validation of analytical modeling and design
- Post-test analyses to extend results

4.1- Material Testing

- ASTM tests for concrete and rebar materials
  - preliminary concrete mixes and rebar samples
  - materials from laboratory specimen construction

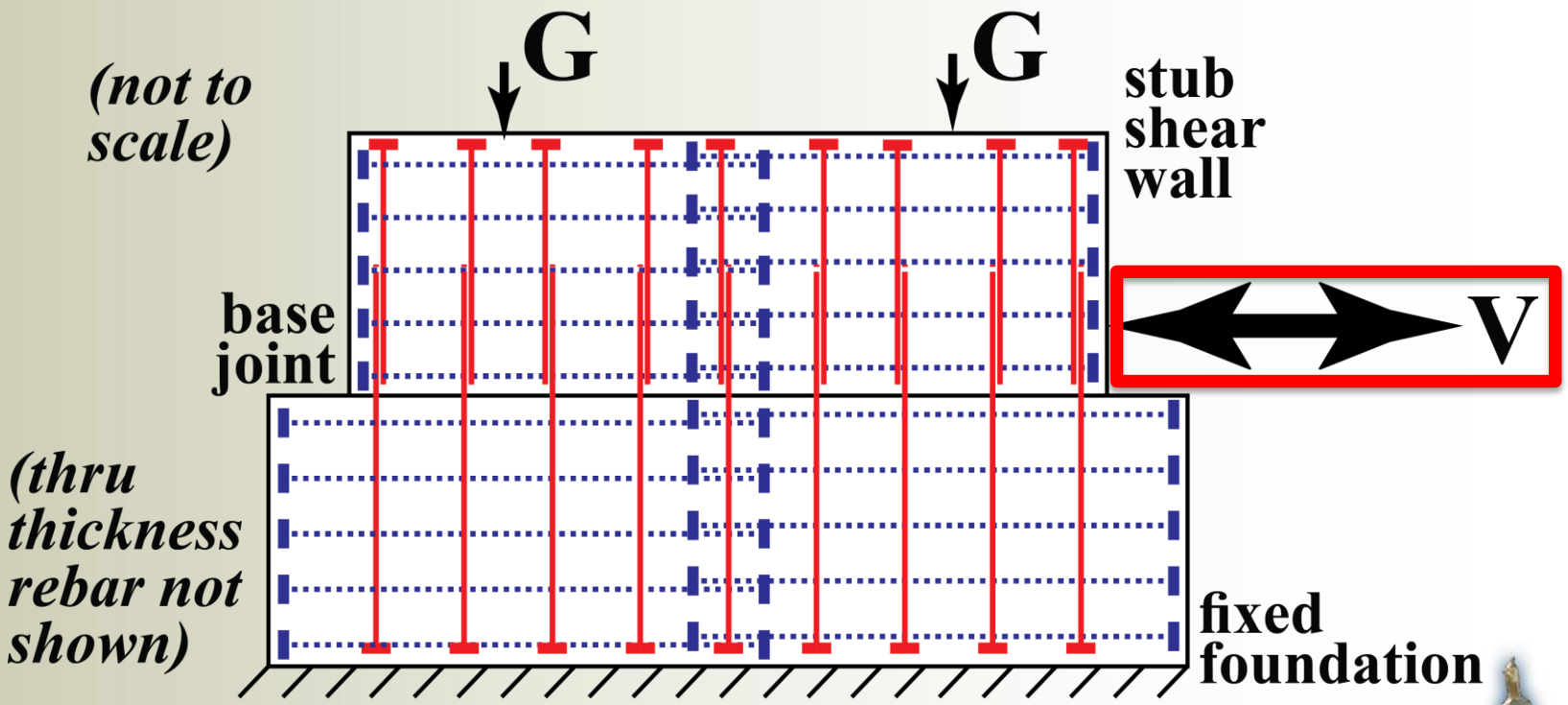
4.2- Deep Beam Tests

- Varying V/M ratios within shear span to establish basic characteristics of shear-controlled behavior



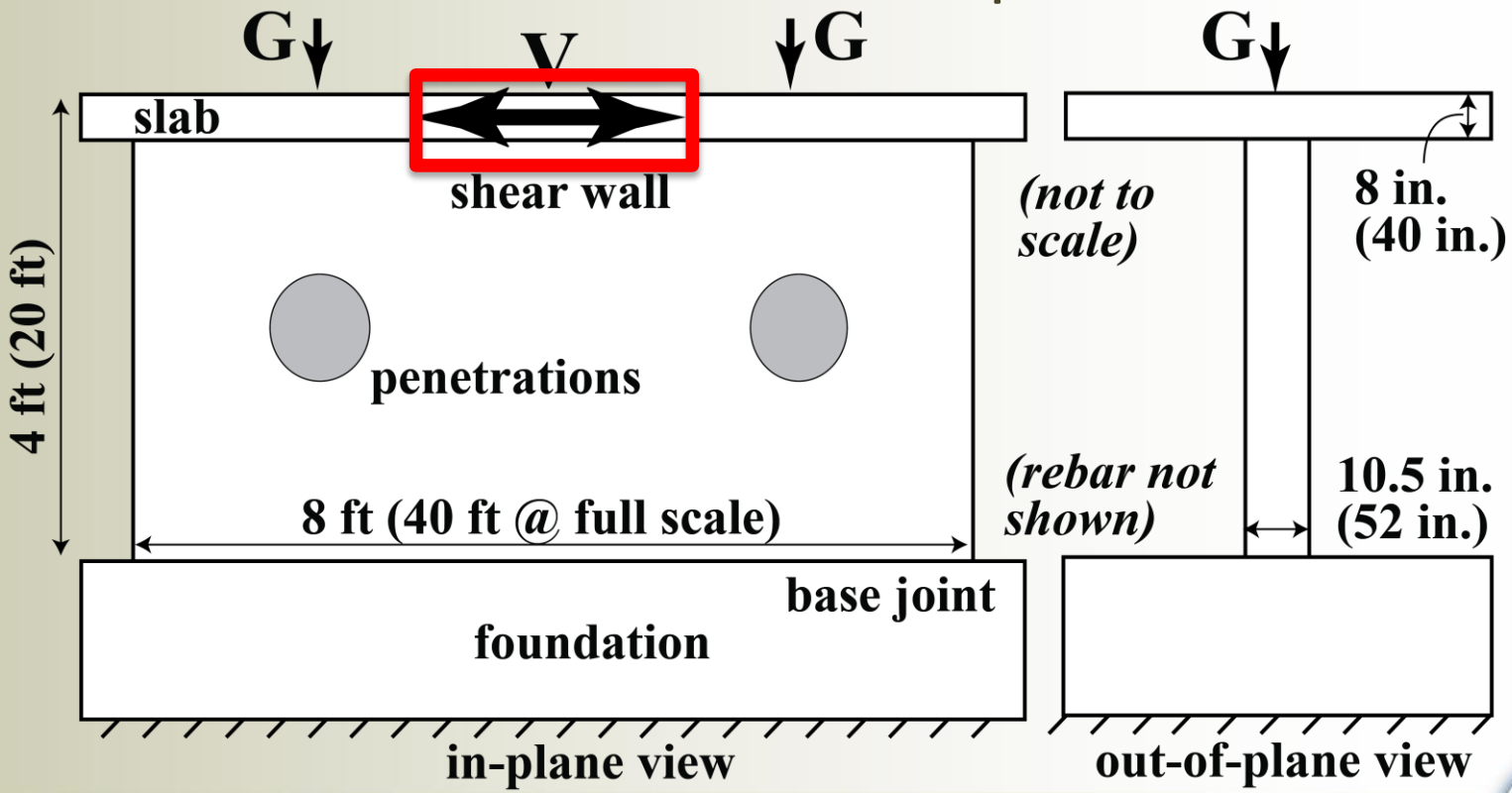
4.3- Stub Wall Tests

- Shear-wall-to-foundation joints under pure shear to establish shear friction strength



4.4- Wall Panel Tests

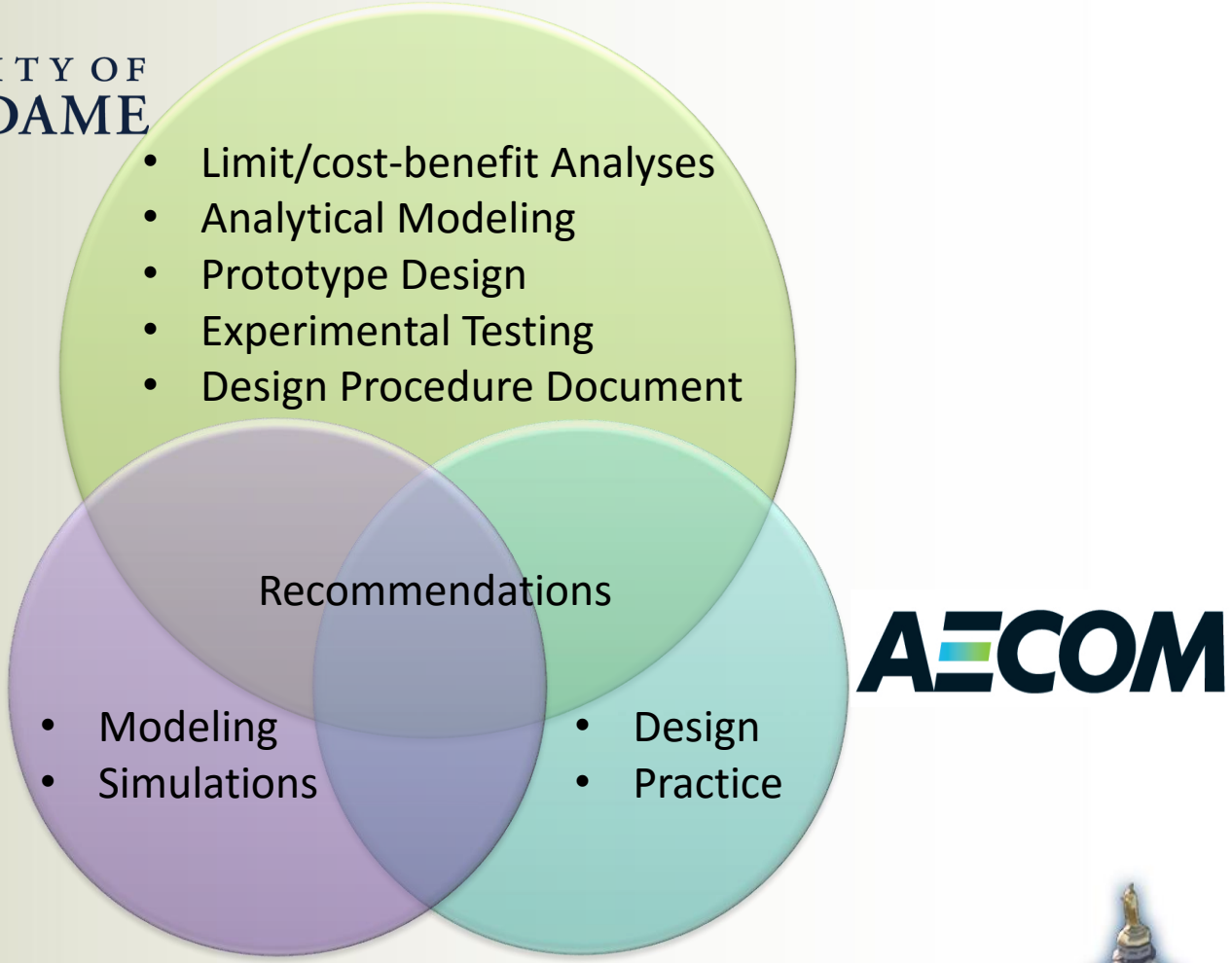
- Representative wall panels under moment+shear
- Includes thermal loads to explore thermal cracking



5- Recommendations

- Design, modeling, and construction recommendations on:
  - Appropriate high-strength materials
  - Prefabricated headed rebar assemblies
  - Basic (design-level) and detailed (high-fidelity) models
  - Optimization for minimum cost/construction time
  - Assumptions/approximations for design and analysis
  - Effective field methods for concrete/rebar placement
- Design Procedure Document

Roles of Collaborators



Questions?

http://phsrc-nuclearwalls.nd.edu