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

NEUP
Nuclear Energy University Programs

UNIVERSITY OF NOTRE DAME
HIGH STRENGTH MATERIALS PREFABRICATION
Sandia National Laboratories
AECOM

Primary Objective

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

1) High-strength reinforcing steel bars (rebar)

2) Prefabricated rebar assemblies, including headed anchorages

3) High-strength concrete

Collaboration

UNIVERSITY OF NOTRE DAME

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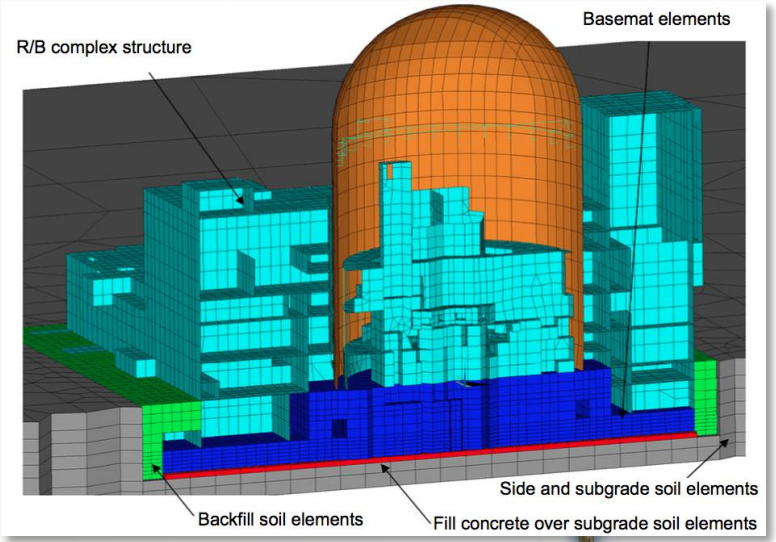
Scope

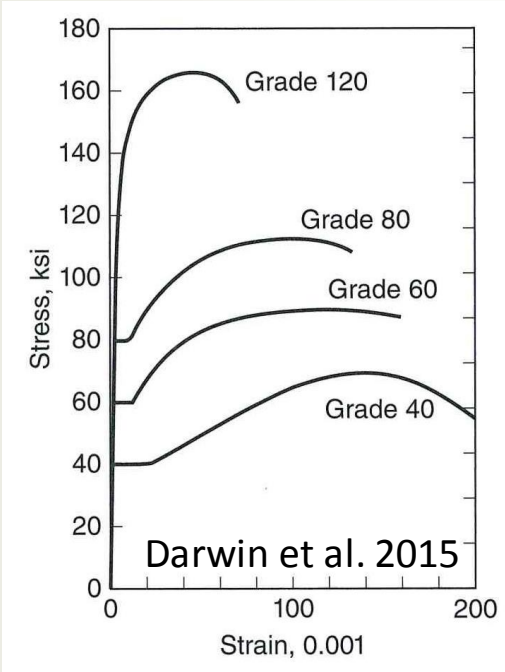
- Explore effectiveness, code conformity, and viability of existing high-strength materials
- Focus on shear walls (ACI 349) – most common lateral load resisting members in nuclear structures (pressure vessels not in scope)
- Aim to reduce complexities in rebar to improve construction quality and ease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

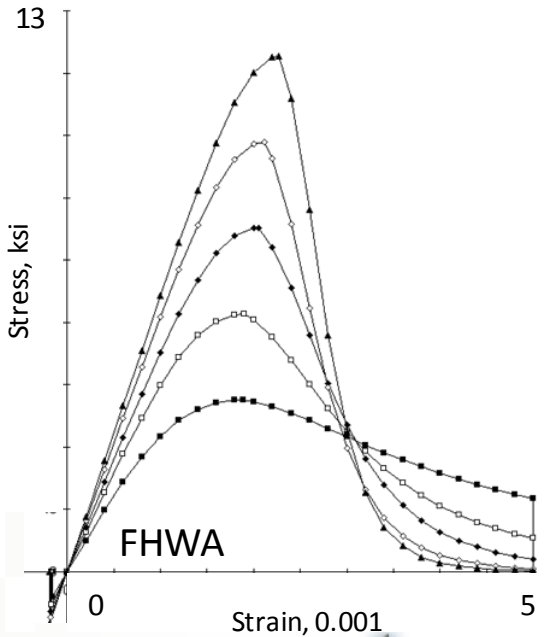


US-APWR Design Control Doc.

Scope:
High Strength Materials

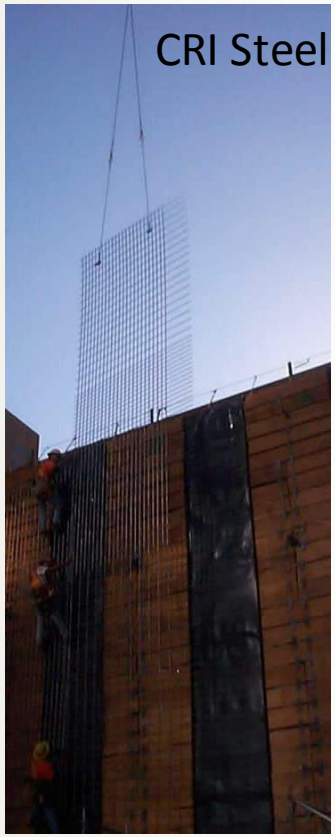
- High-strength rebar (up to grade 120) with high-strength, high durability concrete (around 15 ksi)
- Concrete strength of 5 ksi typical in current practice
- ACI 349 limits headed bars and shear reinforcement to grade 60

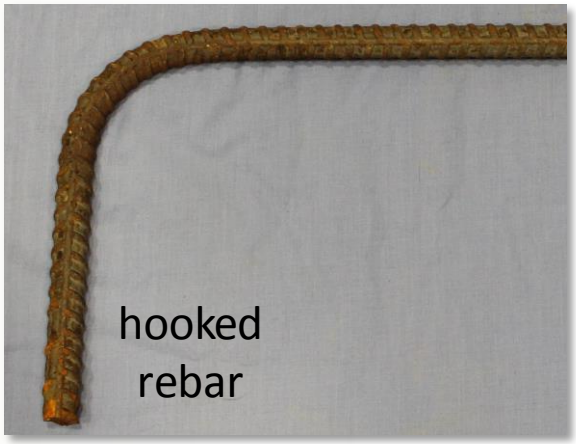




Scope: Prefabricated Rebar Assemblies

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





Potential Benefits

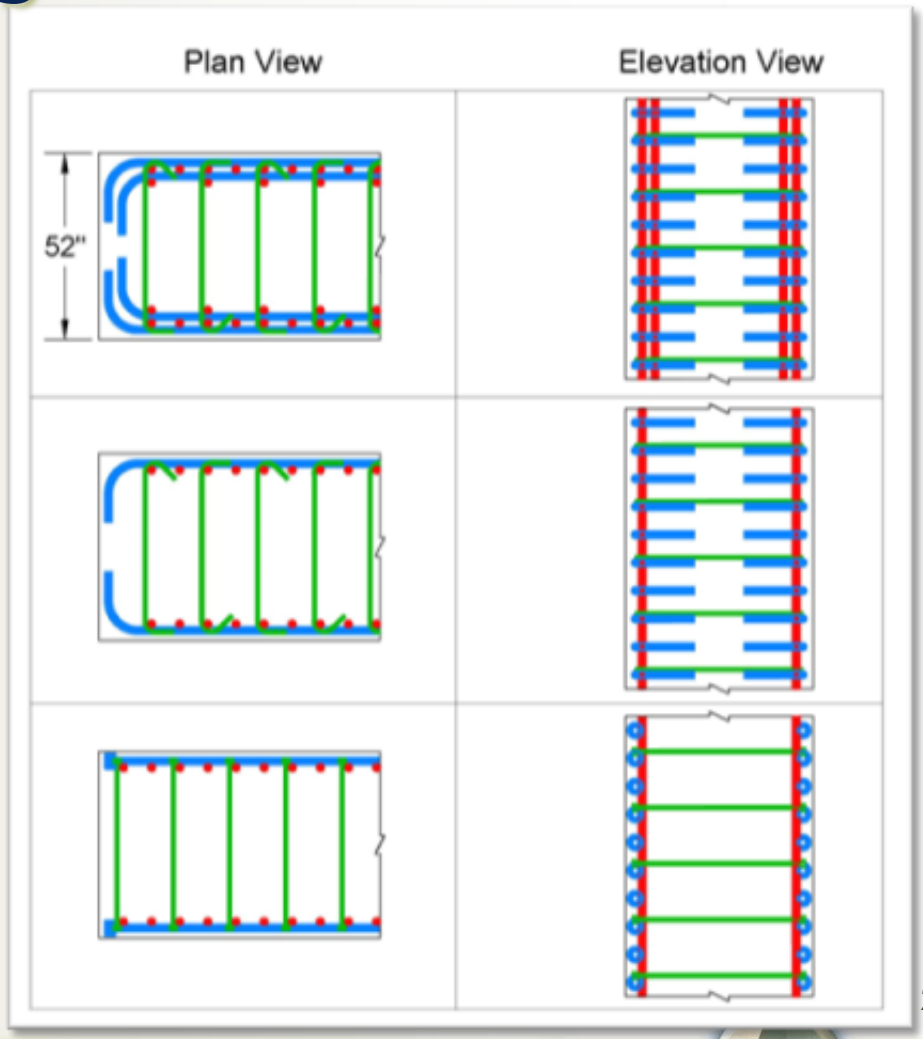
Most Congested (current)

Multiple layers of hooked Grade 60 bars

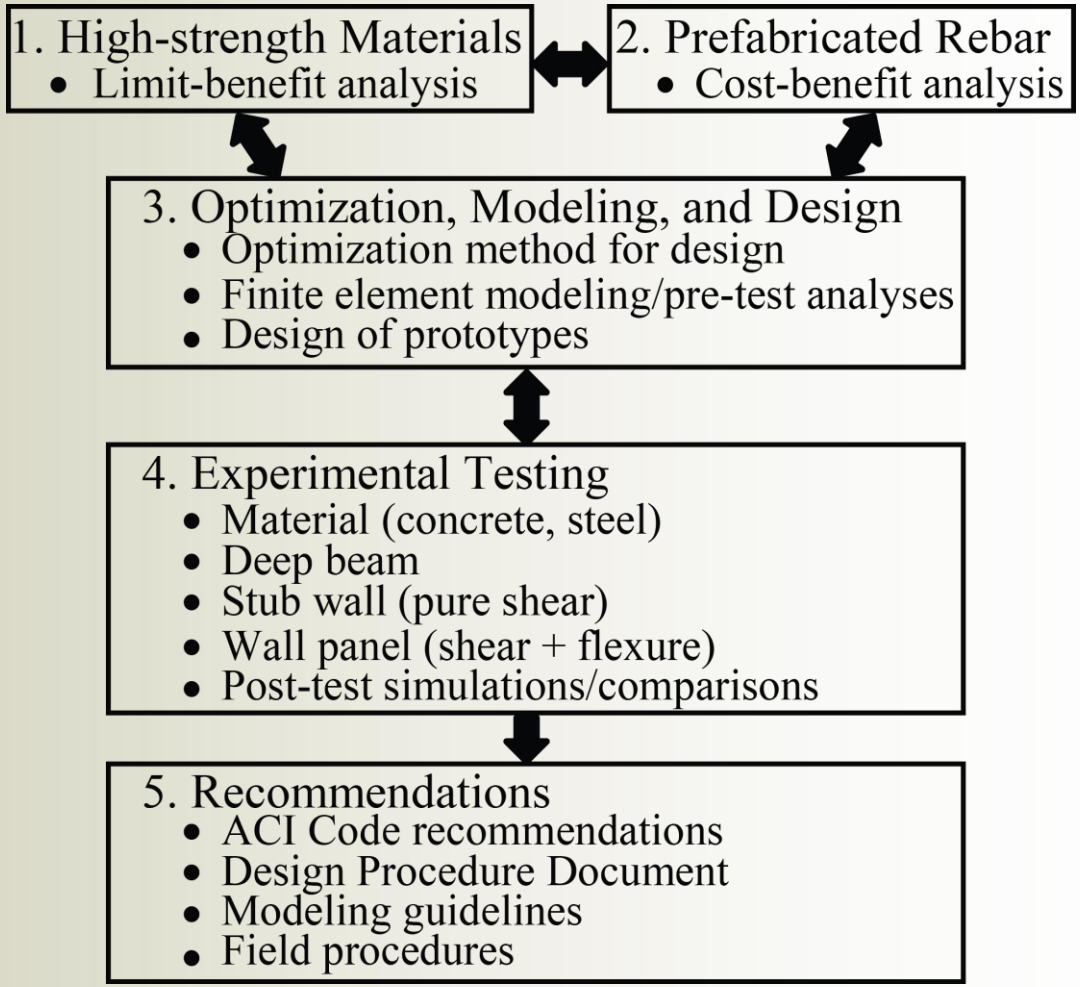
Fewer layers of hooked high-strength bars

Least Congested (envisioned)

Fewer layers of headed high-strength bars



Project Tasks



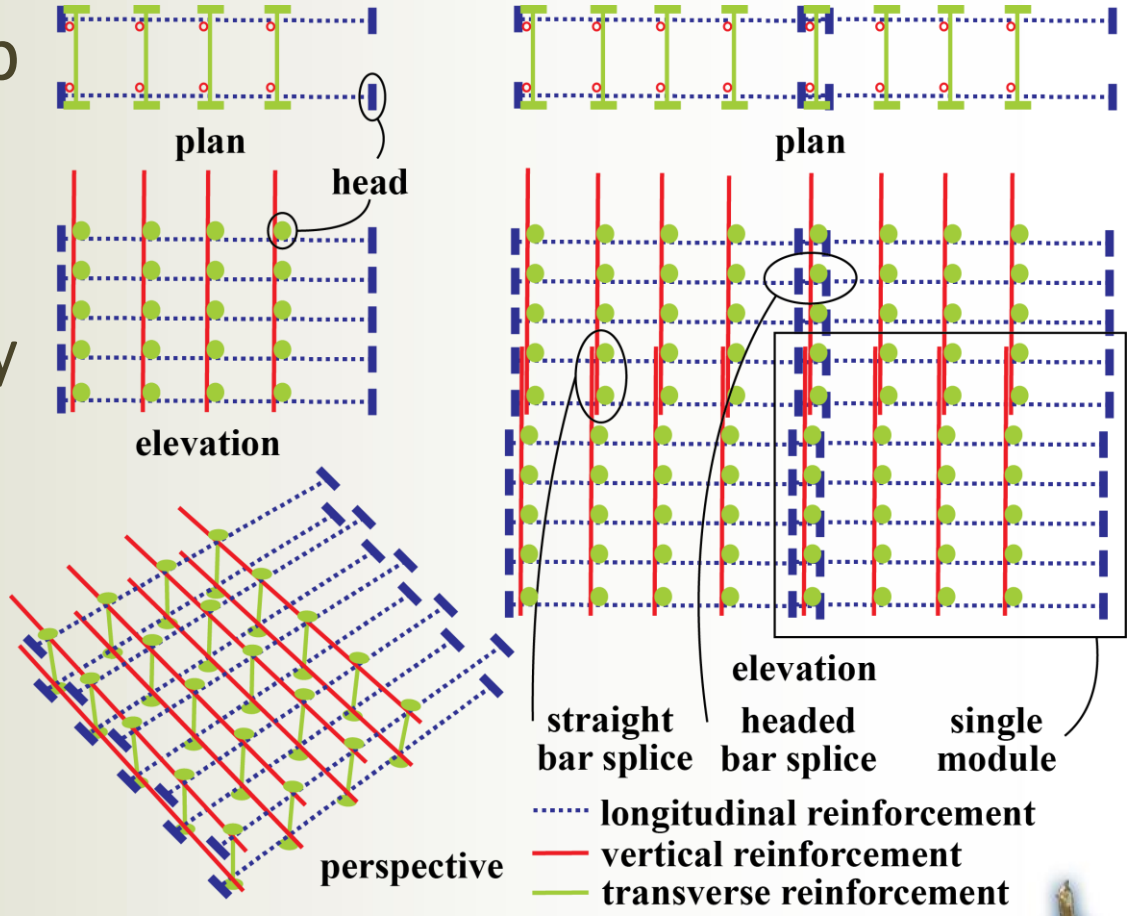
1- High-Strength Materials

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

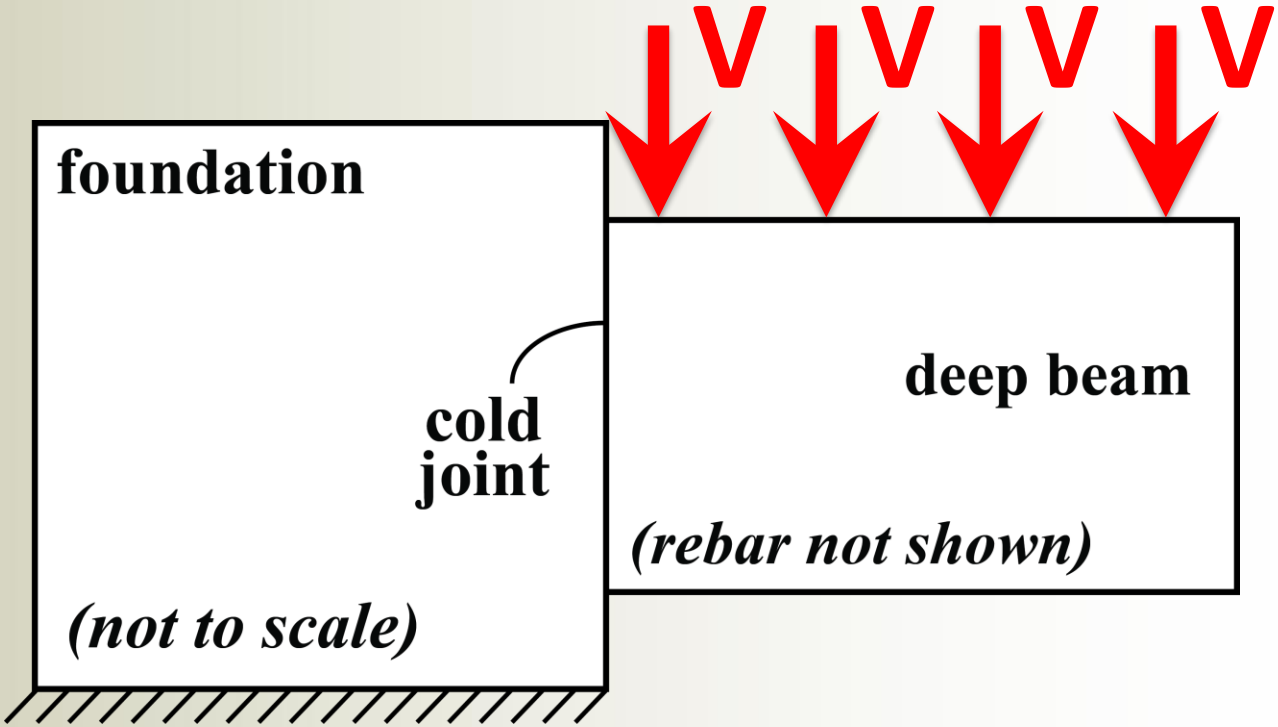
- Testing of:
  1) high-strength concrete and rebar materials
  2) deep beams to establish basic characteristics of shear-controlled behavior
  3) stub walls for pure shear strength of joints
  4) wall panels for combined shear+flexure behavior
- Validation of analytical modeling and design
- Post-test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

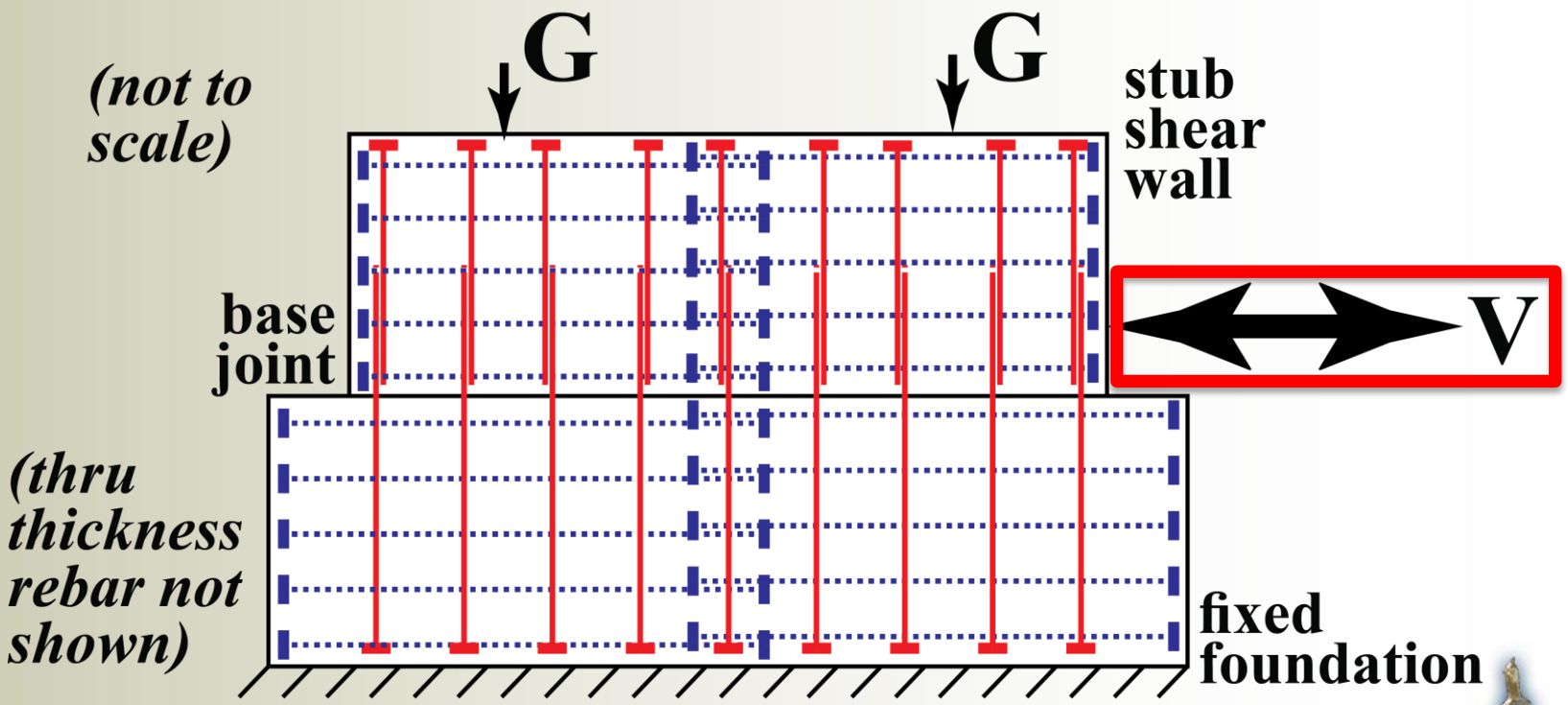
4.2- Deep Beam Tests

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



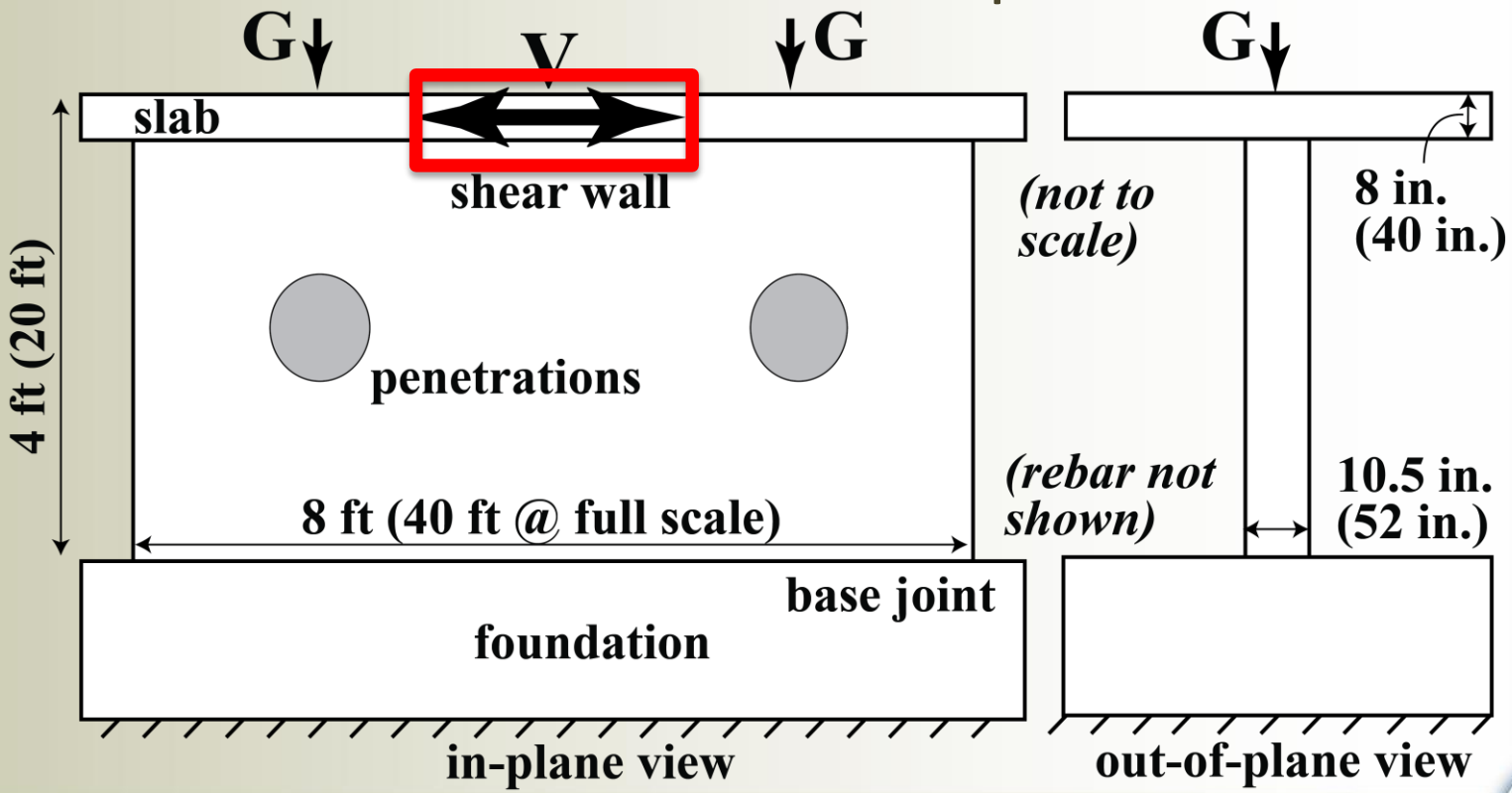
4.3- Stub Wall Tests

- 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

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- Limit/cost-benefit Analyses
- Analytical Modeling
- Prototype Design
- Experimental Testing
- Design Procedure Document

Sandia National Laboratories

- Modeling
- Simulations

Recommendations

AECOM

- Design
- Practice

Questions?

http://phsrc-nuclearwalls.nd.edu