

Overview of 2008 REU Research Project 3: “Parametric Flexural Evaluation of Concrete Members Reinforced with High-Strength Reinforcement”

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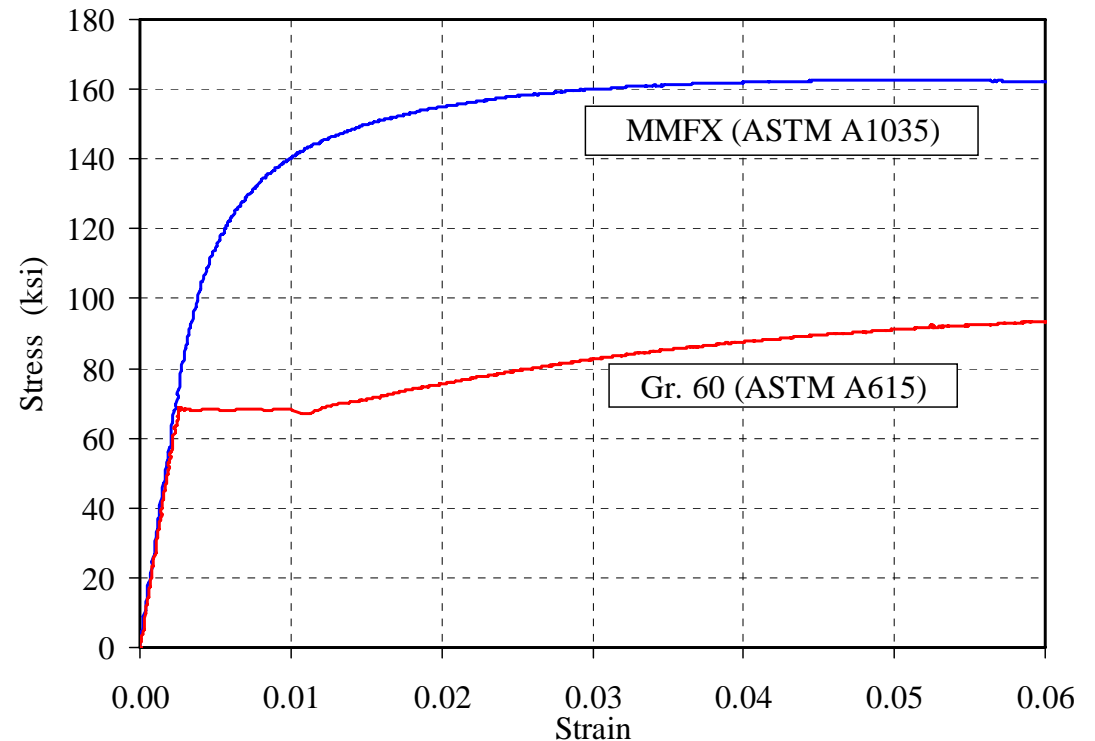
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Use of High-Strength Reinforcement in
Reinforced Concrete

BACKGROUND INFORMATION

- ASTM A1035 steel does not have a well-defined yield plateau
- AASHTO limits steel yield strength to 75 ksi



PROJECT OBJECTIVE

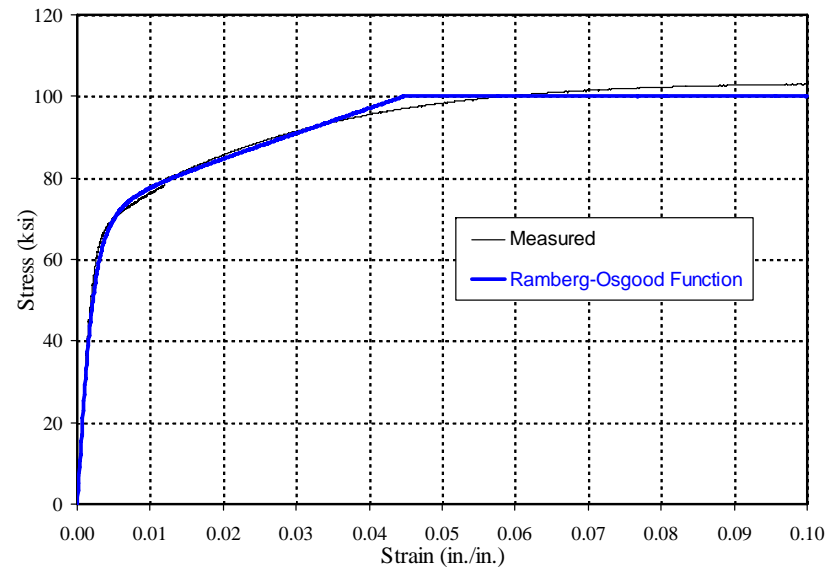
- Develop recommended revisions to the AASHTO LRFD Bridge Design Specifications providing the safe and economic use of high-strength steel reinforcement in structural concrete members

PROJECT WORK PLAN

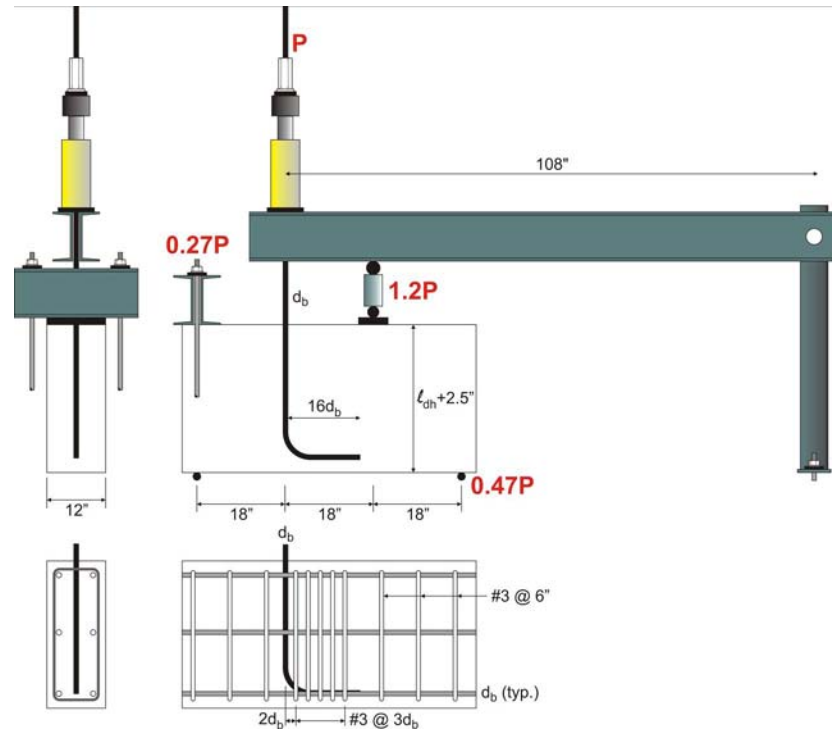
- Material testing and characterizations, analytical studies, component testing, and full-scale member testing
- Investigate strength and service behavior and detailing of high-strength reinforced member design

1. Material Testing & Characterization

- Perform a number of tension tests for multiple types of steel without a well defined yield plateau
- Obtain stress-strain data
- Fit functions such as Ramberg-Osgood to model stress-strain curves

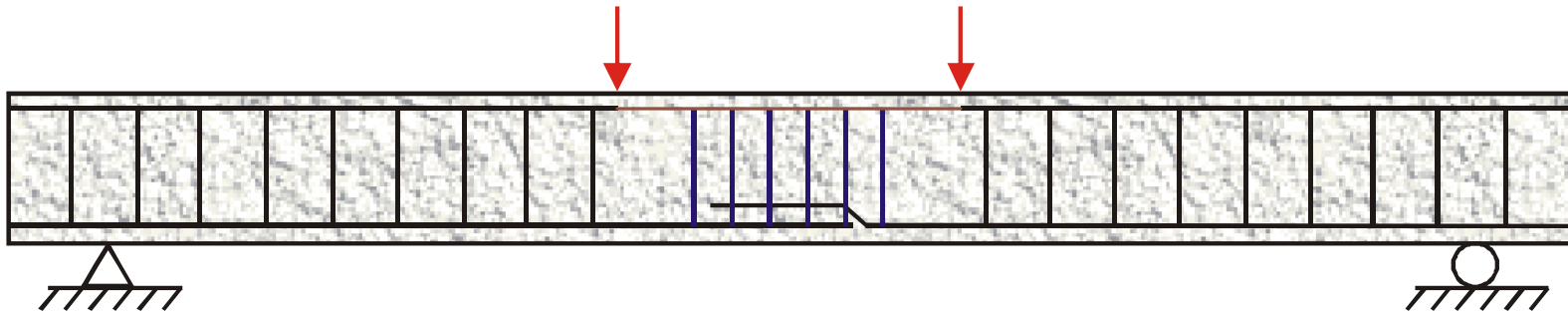


2. Experimental Evaluation of Bond Behavior of High-Strength Reinforcement



Schematic of hooked bar test set-up

2. Experimental Evaluation of Bond Behavior of High-Strength Reinforcement

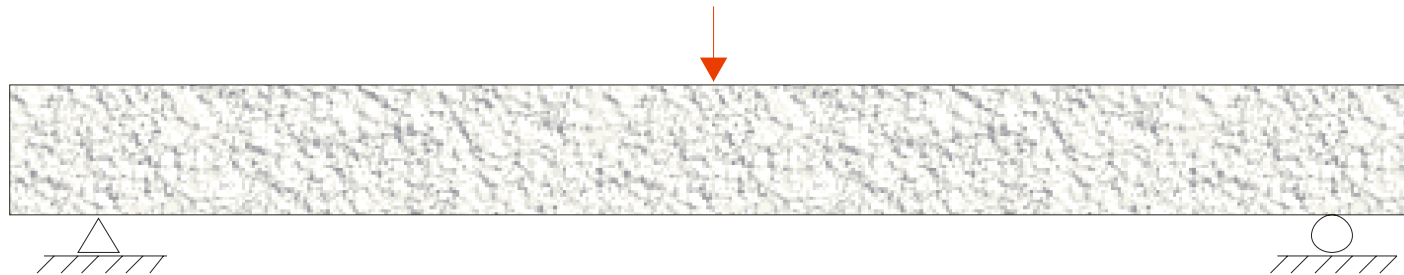


Schematics of Full-Scale Splice Beam Tests

3. Analytical and Experimental Evaluation of Flexural Resistance and Behavior

- Consider multiple methods to analyze flexural resistance
 - ◆ American Concrete Institute (ACI 318-05) method
 - ◆ Ramberg-Osgood model
 - ◆ Fiber Analysis using XTRACT
- Evaluate tension-controlled and compression-controlled strain limits for A 1035
- Examine existing design examples replacing A615 steel with A1035 steel

3. Analytical and Experimental Evaluation of Flexural Resistance and Behavior



Elevation View of Test Specimens

4. Analytical and Experimental Evaluation of Shear and Torsion Resistance and Behavior

The screenshot displays the Response 2000 software interface for a beam analysis. The main window is titled "Response-2000 - beam-1 a 1035".

Geometric Properties Table:

	Gross Conc.	Trans (n=5.80)
Area (in ²)	240.0	262.8
Inertia (in ⁴)	11520.0	13164.5
y _t (in)	12.0	12.8
y _b (in)	12.0	11.2
S _t (in ³)	960.0	1031.2
S _b (in ³)	960.0	1171.9

Crack Spacing: 2 x dist + 0.1 d_b / p

Loading (N,M,V + dN,dM,dV): 0.0, 0.0, 0.0 + 0.0, 1.7, 1.0

Concrete: f_c' = 10000 psi, a = 0.41 in, f_t = 355 psi (auto), ε_o' = 2.52 ms

Rebar: f_y = 183 ksi, f_t = 124, ε_s =

Member Crack Diagram: A diagram showing the distribution of cracks along the member length (0 to 60 inches). Crack widths are labeled at various points, such as 0.033, 0.083, 0.070, 0.011, 0.008, 0.014, 0.075, 0.082, 0.089, 0.082, 0.050, 0.028, 0.023, 0.003, 0.025, 0.053, 0.061, 0.068, 0.057, 0.034, 0.022, 0.007, 0.014, 0.019, 0.023, 0.027, 0.028, 0.032.

Control : M-V: A graph showing the relationship between Moment (M) and Shear Force (V). The peak moment is 185.6 and the peak shear force is 32.7.

Control : P-Δ: A graph showing the relationship between Load (P) and Deflection (Δ). The peak load is 106.9 and the peak deflection is 0.16.

Curvature Distribution: A graph showing Curvature (rad/10⁶ in) versus Length along Member (in). The curvature increases from 0 at 0 inches to approximately 240 at 60 inches.

Shear Strain Distribution: A graph showing Shear Strain (ms) versus Length along Member (in). The shear strain increases from 0 at 0 inches to a peak of approximately 4.20 at 45 inches, then decreases.

Deflection: A graph showing Deflection (in) versus Length along Member (in). The deflection is negative, reaching a maximum of approximately -0.5 inches at 60 inches.

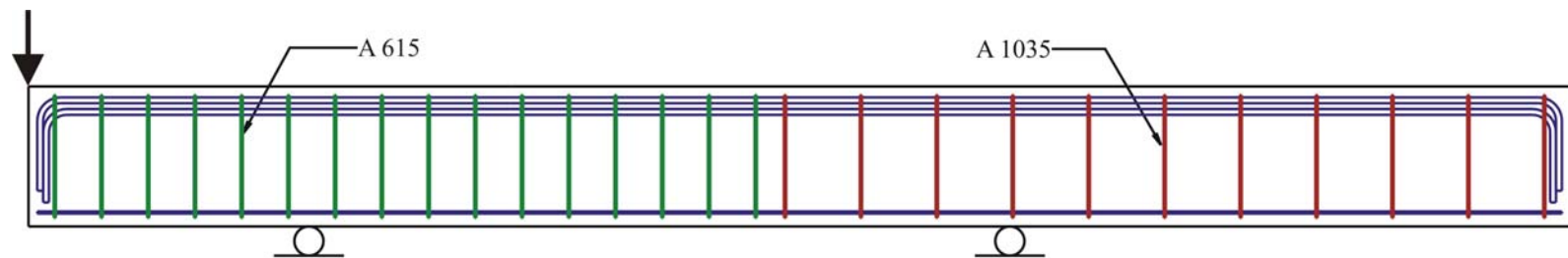
Load-Max Deflection: A graph showing Shear Force (kips) versus Maximum Deflection (in). The shear force increases from 0 at 0 inches to a peak of approximately 30.0 kips at 0.4 inches of maximum deflection.

Summary Values: V: 106.9 kips, Dy: 0.56 in, Dx: 0.046 in

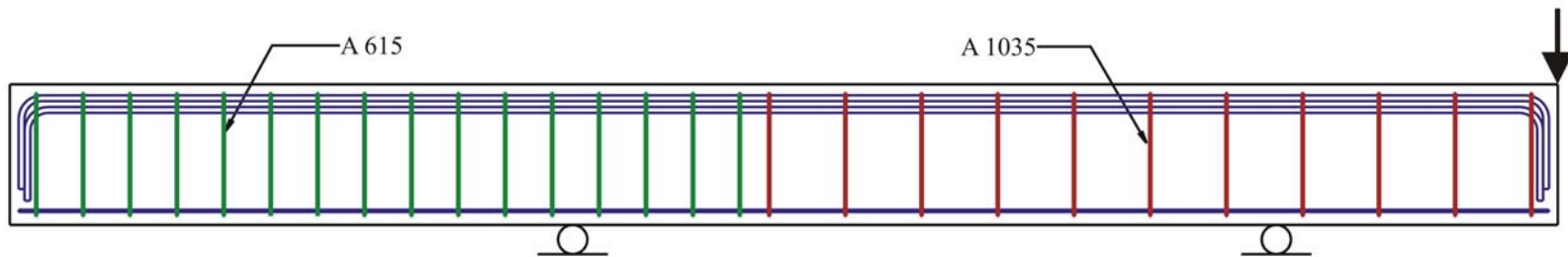
Response 2000

of High-Strength Reinforcement in Reinforced Concrete

4. Analytical and Experimental Evaluation of Shear and Torsion Resistance and Behavior



(a) First Test: Loading of the left end



(b) Second: Loading of the right end

Preliminary Specimen Details

5. Analytical Evaluation of Confinement and Column Resistance

- Perform parametric studies to develop moment-curvature & axial load-moment interaction diagrams

Column Analysis Parameters

Design	Seismic Square, Seismic Spiral, Non-seismic Spiral
Steel Strength	120 ksi, 60 ksi
Concrete Compressive Strength	5 ksi, 10 ksi, 15 ksi
Column Dimension	18", 24", 36", 48", 60"
Transverse Reinforcement	#3, #4, #5

- To identify any unexpected behaviors of columns reinforced with high-strength steel

6. Experimental Evaluation of Fatigue Performance of Members Reinforced with High-Strength Reinforcement

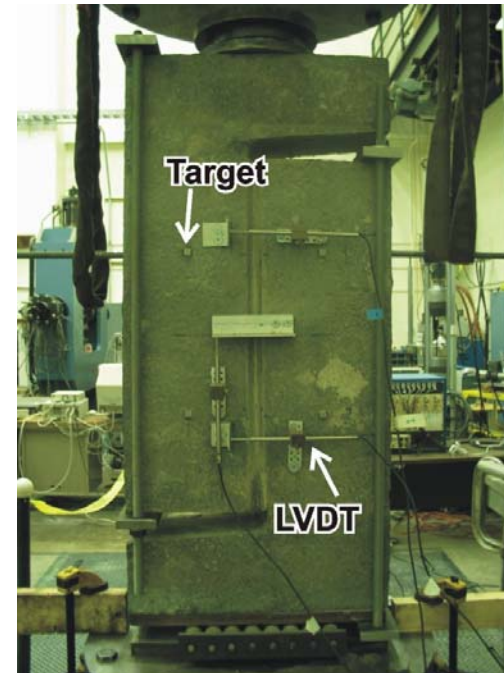
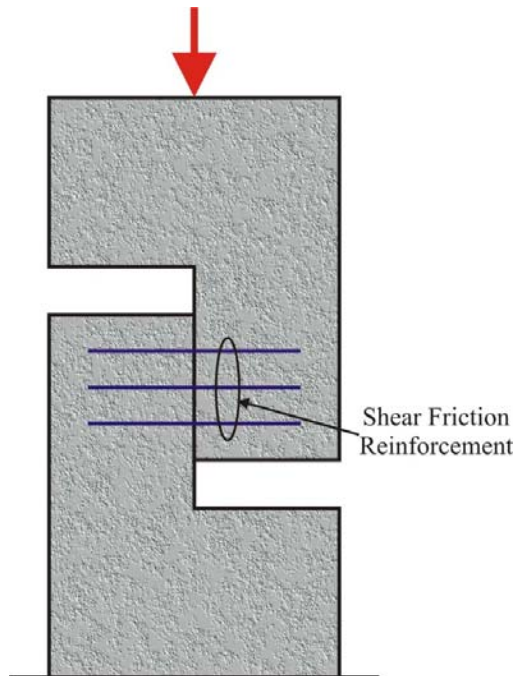
- Determine if current AASHTO Specs are applicable to members with high-strength reinforcement
- Similar to flexural test set-up
- Min. of 2 million fatigue cycles of loading
- Beam will be loaded to failure to compare the ultimate limit with previous tests and determine the effects of fatigue loading

7. Parametric Evaluation of Distribution of Reinforcement for Control of Cracking

- Parametric studies using several models will be performed
 - ◆ Gergley and Lutz (1968)
 - ◆ Frosch (2001)
 - ◆ Gilbert (2008)
- Determine whether it is possible to meet the current width requirements for A1035 bars subjected to typical service level loads
- Establish service level stresses for which ASTM A1035 bars can meet crack width requirements
- Determine a range of clear covers and crack widths for which ASTM A1035 bars can be placed at practical spacings

8. Interface Shear Transfer - Shear Friction

- Determine if a yield stress greater than 60 ksi can be used in design



Summary

- The analytical studies will provide a better understanding of the behavior of concrete members reinforced high-strength steel.
- Recommended revisions to the AASHTO specifications will be made when necessary, and preliminary design equations will be developed for experimental tests where appropriate.
- NCHRP Project Number 12-77 will provide analytical and experimental testing results to make appropriate revision recommendations to the AASHTO specifications incorporating the safe and economic use of high-strength steel reinforcement in structural concrete members.

Thank You

