DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Seismic Behavior of Grade 80 RC Bridge Columns – Phase 1 and Critical Bending Strain of Longitudinal Reinforcement

Four Grade 80 scaled models of bridge columns were tested and compared to previously tested Grade 60 column.

Seismic

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Project Title:
Seismic Behavior of Grade 80 RC Bridge Columns – Phase 1 and Critical Bending Strain of Longitudinal Reinforcement

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WHAT IS THE NEED?

Modern seismic design relies on the principles of capacity design wherein certain structural members are chosen as plastic hinge members. In reinforced concrete, the choice of reinforcement is crucial for desirable performance of plastic hinge members. Current design codes specify a maximum yield strength of 60 ksi (Grade 60) for reinforcement used in plastic hinge members. However, using higher strength reinforcement (Grade 80) would reduce rebar congestion, construction cost, and building environmental footprint. Due to a lack of experimental evidence, engineers are hesitant to prescribe this rebar for use in plastic hinge members.

WHAT WAS OUR GOAL?

The goal of this project was to evaluate the seismic performance of the Grade 80 columns and to compare multiple design variables to current values used for Grade 60 columns. Of particular interest are:

1. plastic hinge lengths as well as bond slip and development.
2. einforcing bar strain limit states such as onset of transverse reinforcement yield, onset of bar buckling, and tensile fracture.
3. hysteretic energy dissipation.

WHAT DID WE DO?

Utilizing Grade 80 rebars donated from three producing mills (Nucor, Gerdau, and CMC), four circular columns were constructed, and tested at North Carolina State University, (NCSU). The columns were designed as scaled models of bridge columns with varying axial load and transverse steel ratios; each had a comparison Grade 60 column.

The seismic performance of the Grade 80 columns was evaluated and multiple design variables were compared to current values used for Grade 60 columns; including the equivalent viscus damping and the hysteretic energy dissipation at given ductility levels.

A unique optical measurement system was employed to measure strains in the longitudinal and transverse reinforcement well past the capacity of typical strain gages. This enabled the experimental plastic hinge length be calculated and the amount of strain penetration, or bond slip, was measured in each Grade 80 column test. The bending strain demand on the longitudinal reinforcement was quantified and a relationship between uniaxial tension strain and strain from bending was proposed.

WHAT WAS THE OUTCOME?

Results of the Grade 80 column tests indicated that the plastic hinge length, bond slip, strain-based limit states, and equivalent viscous damping were not significantly different to typical Grade 60 columns. Based off the results of these four column tests, Grade 80 rebar could be specified in place of Grade 60 rebar without major changes in design practice. However, the Grade 80 columns had slightly lower displacement capacities than the Grade 60 columns. This was due to differences in the critical bending strain, which were found to cause bar fracture after buckling.

A method to predict the tensile strain prior to longitudinal bar fracture was also developed from the relationship between uniaxial tension strain demand, the degree of longitudinal bar buckling and the newly identified critical bending strain. In addition, a simplified material test was developed to quantify the critical bending strain for any rebar. Rebar rib radius and manufacture process influenced the critical bending strain.

More column tests should be performed on Grade 80 rebar to:

- characterize plastic hinge lengths, equivalent viscous damping, and performance limit states.
- To test the hypothesis that critical bending strain corresponds to column displacement capacity.

More buckled bar tension tests can be performed in order to:

- Better identify the influence of rib radius, surface roughness, and chemical composition on the critical bending strain as well as to look for other factors that influence this parameter.
- Continue investigating bar buckling as a continuum process, and develop other mechanistic models for bar fracture.

WHAT IS THE BENEFIT?

Using higher strength reinforcement (Grade 80) would reduce rebar congestion, construction cost, and building environmental footprint. This will ensure reliability and structural integrity and balance performance, lifecycle cost, time, delivery, and risk to optimize total value. The benefit from this research is applicable to the public as well as the private sectors.

IMAGES

FIGURE 1: column and footing rebar

FIGURE 2: actual test setup

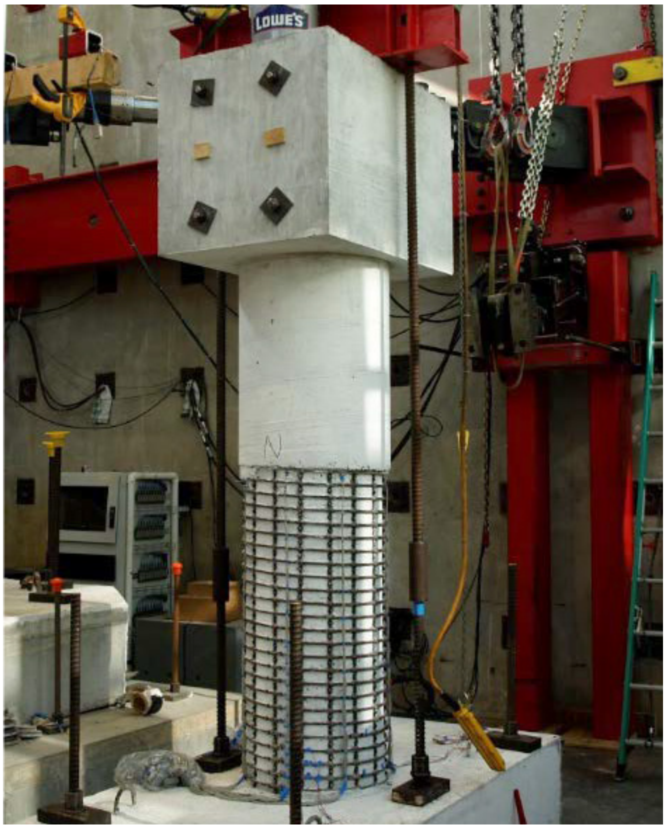

FIGURE 3: completed test specimen

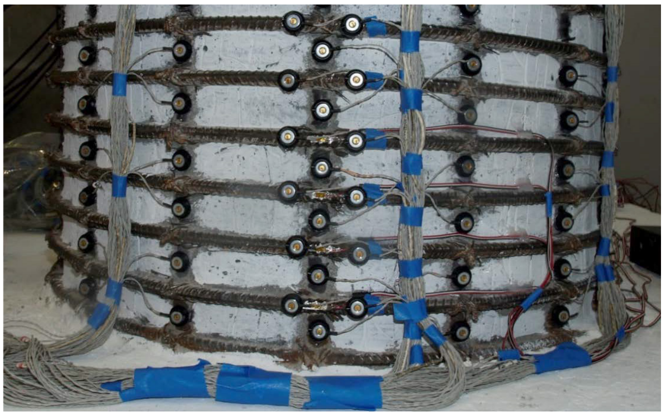

FIGURE 4: Optotrak markers in block-out regiofinal damage state

FIGURE 5: final damage state

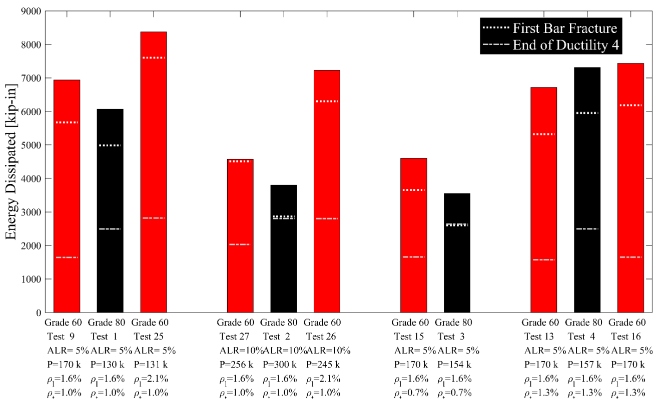

FIGURE 6: Comparison of total dissipated energy

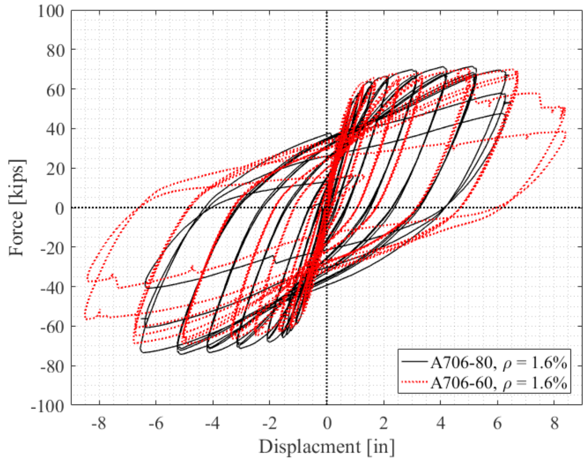

FIGURE 7: Hysteretic response of Grade 80 Test 1 and comparison Grade 60 columnswith similar steel content

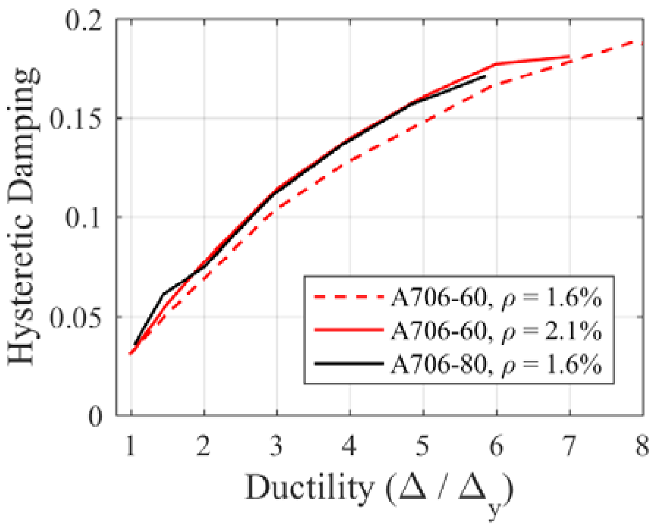

FIGURE 8: Damping vs ductility for Grade 80