

ANALYTICAL AND EXPERIMENTAL STUDY OF UNREINFORCED CONCRETE BEAM-COLUMN JOINTS

Part of NEES Grand Challenge Project

Principal Investigator: Khalid M. Mosalam, Professor and Vice Chair, UC Berkeley

Student Investigator: Sangjoon Park, Ph.D Candidate, UC Berkeley

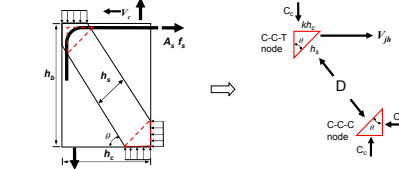
nees@berkeley Laboratory, University of California Berkeley

Motivation

- Effect of joint deformation
 - Significant change of response due to joint deformation
 - Collapse of building by joint shear failure
- Seismic performance of old existing RC building joints
 - No seismic design code prior to 1970's
 - No transverse reinforcement in the joint region
- Existing joint strength models
 - Inappropriate application from reinforced joints to unreinforced joints
 - Overly simplified failure mechanism
 - Underestimation of shear strength (FEMA 273/ ASCE 41)
- Dependency of joint shear strengths on beam reinforcement

Develop Equations of Parameters

1. Parameter of Joint Aspect Ratio

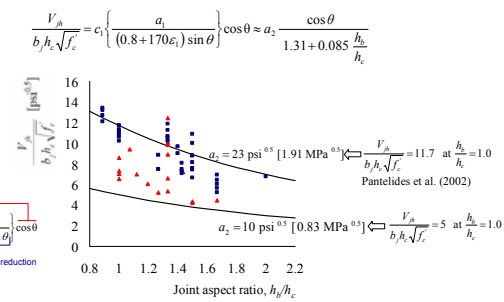


➤ Equilibrium $V_{jb} = c_1 (\sigma_c b_j h_j) \cos \theta$, where $\theta = \tan^{-1}(h_c/h_j)$

➤ C-C-T node zone $\frac{h_c}{h_j} = \frac{a_1}{\sin \theta}$ where $\sin \theta = \frac{1}{\sqrt{1+(h_c/h_j)^2}}$ $\sigma_c = \frac{V_{jb}}{b_j h_c \sqrt{f_c}} = c_1 \left\{ \frac{a_1}{(0.8+170\epsilon_1) \sin \theta} \right\} \cos \theta$

➤ Constitutive $\sigma_c = \frac{a_2 \sqrt{f_c}}{0.8+170\epsilon_1}$ Vollum (1998)

➤ Proposed equation for joint aspect ratio



2. Parameter of Beam Reinforcement

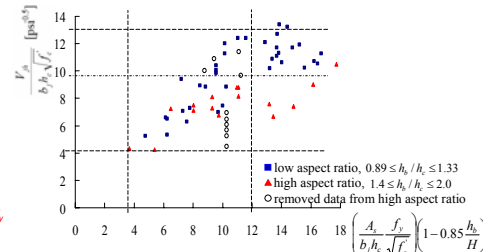
➤ Equilibrium $V_{jb} = A_s f_s - V_c = A_s f_s \left(1 - \frac{L+h_c/2}{H} \frac{jd}{L} \right)$

$jd = 0.8h_c$

$\frac{L+h_c/2}{H} \frac{jd}{L} = \frac{L+h_c/2}{H} \frac{0.8h_c}{L} \approx 0.85 \frac{h_c}{H}$

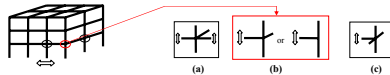
If beam reinforcement is yielding, $f_s = f_y$

➤ Normalized form $\frac{V_{jb}}{b_j h_c \sqrt{f_c}} \approx \left(\frac{A_s f_y}{b_j h_c \sqrt{f_c}} \right) \left(1 - 0.85 \frac{h_c}{H} \right)$: Beam reinforcement index = Joint shear demand at $f_s = f_y$

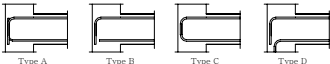


Database of Literature Tests

➤ Unreinforced exterior joint tests without or one lateral beam



➤ Anchorage details of selected specimens



➤ Column width (b_c) \geq beam width (b_b)

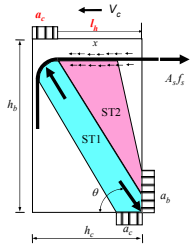
➤ 62 test data are collected

➤ Failure mode: J (joint shear failure without beam yielding)
 BJ (joint shear failure with beam yielding)

Develop Analytical Model

1. Assumptions

➤ Two inclined struts mechanism



2. Formulation

➤ Equilibrium $V_{jb} = V_{j,ST1} + V_{j,ST2}$

$V_{j,ST1} = A_s f_s - n \pi \phi_b \int_0^x \mu(f_s) dx$

$V_{j,ST2} = n \pi \phi_b \int_0^x \mu(f_s) dx - V_c$

μ : Bond strength

μ_b : 12√f_s [psi] - Lehman & Moehle (2000)

μ_b : 6√f_s [psi] - CEB-FIP (1990)

μ_b : 1.8√f_s [psi] - CEB-FIP (1990)

f_s : tensile stress of beam reinforcement

➤ Fraction factor α of ST1

$V_{jb} = V_{j,ST1} + V_{j,ST2} \approx A_s f_s \left(1 - 0.85 \frac{h_c}{H} \right)$

$V_{j,ST1} = \alpha V_{jb} = A_s f_s - n \pi \phi_b \int_0^x \mu(f_s) dx$

$V_{j,ST2} = (1-\alpha)V_{jb} = n \pi \phi_b \int_0^x \mu(f_s) dx - V_c$

$\alpha = \frac{H}{H-0.85h_c} \left(1 - \frac{4}{\phi_b} \frac{\int_0^x \mu(f_s) dx}{f_s} \right)$

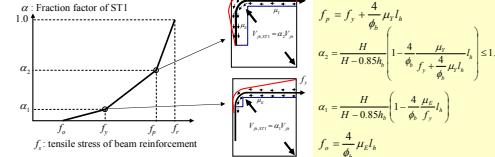
➤ Definition of joint shear failure

Joint shear failure is defined when the demand of ST1 reaches its capacity

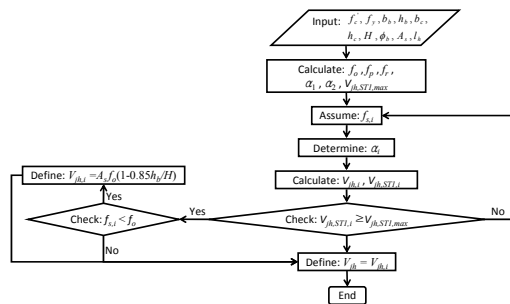
$V_{j,ST1,max} = c \frac{b_j h_c \sqrt{f_c} \cos \theta}{1.31+0.085 \frac{h_c}{h_j}}$

$c = 8.3 \frac{V_{j,ST1,max}}{b_j h_c \sqrt{f_c}} = 4$ at $\frac{h_c}{h_j} = 1.1$ from Hakuto et al. (2000)

➤ Fraction factor α curve

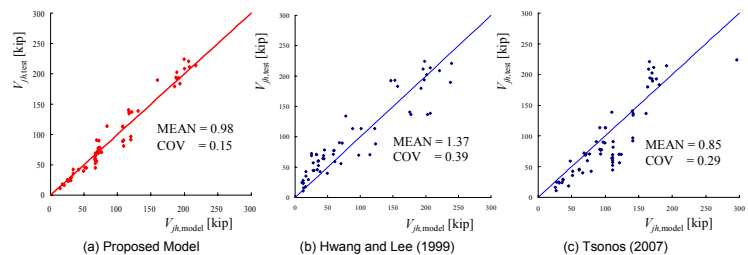


3. Solution algorithm



4. Evaluation

	$a_1 = 0.4h_c$	$a_1 = 0.35h_c$	$a_1 = 0.3h_c$	$a_1 = 0.25h_c$
Mean	1.016	0.985	0.955	0.927
COV	0.149	0.149	0.150	0.147



This project was made possible with support from:



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

UC Berkeley ■ Caltech ■ Stanford ■ UC Davis ■ UC Irvine ■ UC Los Angeles ■ UC San Diego ■ USC ■ U Washington

peer.berkeley.edu

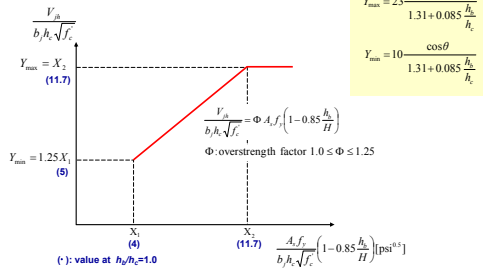
ANALYTICAL AND EXPERIMENTAL STUDY OF UNREINFORCED CONCRETE BEAM-COLUMN JOINTS

Part of NEES Grand Challenge Project

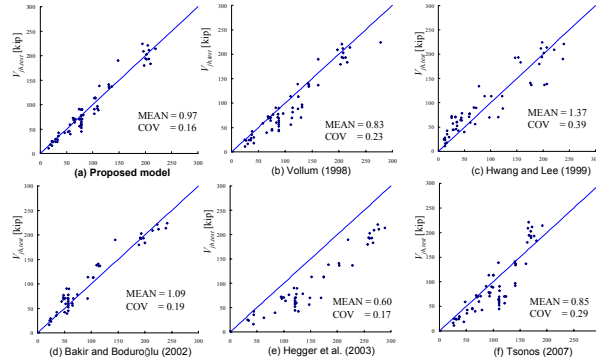
Principal Investigator: Khalid M. Mosalam, Professor and Vice Chair, UC Berkeley
 Student Investigator: Sangjoon Park, Ph.D Candidate, UC Berkeley
 nees@berkeley Laboratory, University of California Berkeley

Develop Semi-Empirical Model

1. Proposed Model

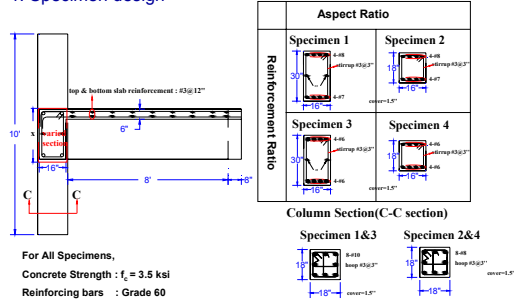


2. Evaluation



Ongoing Experimental Program

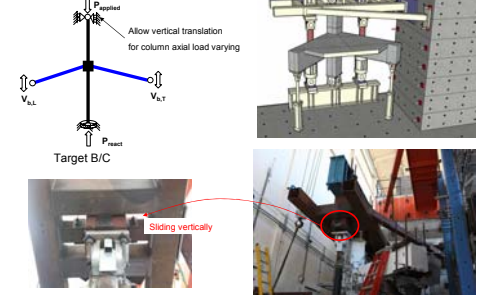
1. Specimen design



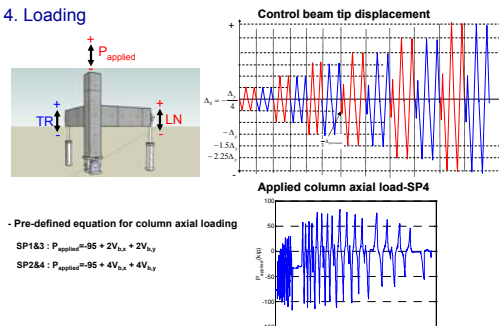
2. Construction



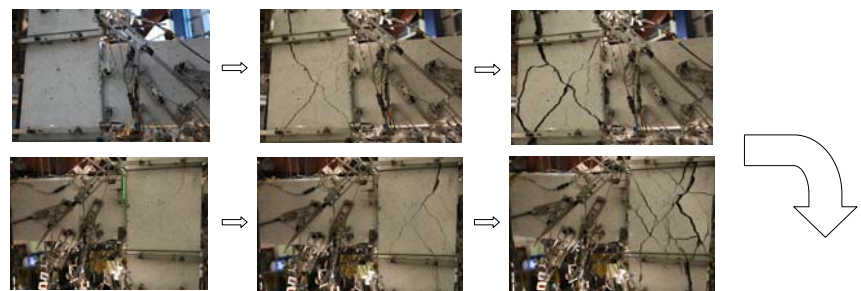
3. Setup



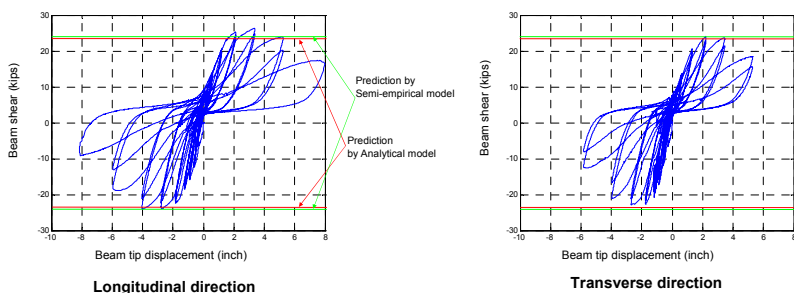
4. Loading



5. Test-SP4: Beam yielding \Leftrightarrow Joint shear failure



6. Comparison of test results with predictions by proposed two models



This project was made possible with support from:



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

UC Berkeley ■ Caltech ■ Stanford ■ UC Davis ■ UC Irvine ■ UC Los Angeles ■ UC San Diego ■ USC ■ U Washington

peer.berkeley.edu