J. Basic. Appl. Sci. Res., 6(8)23-29, 2016

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Shear Behavior and Ductility Connections in Partial Prestressed Concrete Beam-Column Reinforced Concrete Frame Structure Story Building Due to Cyclic Lateral Loads

Made D Astawa[1*], IGPRaka[2], Tavio[2]

[1)]Doctoral Student Department of Civil Engineering(Structures) FTSP-ITS Surabaya & Lecturer Department of Civil Engineering (Structures) FTSP-UPN "Veteran" East Java.
[2)]Professor of Civil Engineering(Structures) Department at Institute of Technology Sepuluh Nopember Surabaya-Indonesia

Received: April 26, 2016
Accepted: June 9, 2016

ABSTRACT

This study specifically create a model specimen beam-column Interior connections using elements Partial Prestressed Concrete Beams with Reinforced Concrete Column. Dimensional cross section of the beam 250/400 mm and column section 400/400 mm. Shear on retaining structure beam-column connections using horizontal shear reinforcement in the form of stirrups ∅ 10-50 mm to fill the empty space bj = 288 mm. Shear load capacity plans on shear stirrups = 103.62 kN and shear force capable detained by the structure beam-column connections are Vjh = 409 kN. Using a parabolic arch 1 tendon with 2 Strand respectively D 12.7 mm. Experimental tests carried out in laboratory with cyclic loading (pseudo dynamic) lateral controlled by Drift Ratio, and static axial load of 640 kN on the top column as a stabilizer. The test results demonstrate the ability of specimen restrain force Ultimate Lateral Cyclic conditions: Load push (press) = 470.90 kN and Load pull = 465.80 kN. The result is very good in resisting shear press or Pull, namely above 409 kN. Structures ductility on drift ratio of 3.50% of all $\mu > 4.0$, are also eligible. Structures has the overall modeling good behavior and qualify as earthquake resistant buildings.
KEYWORDS: *Beam-Column Joint, shear Behavior, ductile, Earthquake Resistant.*

1. INTRODUCTION

Investigation of building collapse post- earthquake the region hit by an earthquake lately in Indonesia, such as the an earthquake in Aceh (2004), Yogyakarta (2006), West Sumatra (2009), largely due to a design fault of elements structure beam-column connection, because the principle of strong column -weak beam less attention design[(1)], namely the lack of transverse reinforcement at the core of the beam-column connections which serves as a barrier horizontal shear in the column, in accordance with SNI 2847: 2013 clause 21.7. 21.7.1 to 21.7.4[(2)], for the beam-column joint special moment frames forming part of the an earthquake force resisting system.

Some references on beam-column joint research among others: B Roger W G and Robert Park[(3)], research conducting Experimental prestressed concrete beam-columns joint Exterior resistance to earthquake loads. Magdi T E S, et al[(4)], examined an earthquake behavior and design of precast concrete frame post-tension without adhesions. Kashiwasaki T and Noguchi H[(5)] examined the model of prestressed concrete structures on the beam-column connections Interior. Murahidy et al[(6)] studied the construction and testing with dynamic wobble precast reinforced concrete building frame post-tension with ADAS element.

From some of these references, so in this study will examine the behavior of shear and ductility connection partial prestressed concrete beam-reinforced concrete column on the frame structure story building due to lateral cyclic loading.

2. THEORY

Beam-Column Joint

Test on joint and beams have shown that the shear strength is not sensitive to the shear reinforcement along the span. Then the ACI 318-08 Code [(7)] assumes joint force only as a function of the compressive strength of concrete that requires a minimum amount of transverse reinforcement in the joint. Tests on beam-column joint have shown that the shear strength is not sensitive to shear along the span. A force on joint only as a function of the strength of concrete which requires a minimum amount of reinforcement across the joint. Shear sectional area (Aj) should not be > gross cross section area (Ag) of the column. The minimum shear strength of the joint is determined not to be > Vn specified below-normal weight for concrete.

***Corresponding author:** Made D Astawa, Doctoral Student Department of Civil Engineering(Structures) FTSP-ITS Surabaya & Lecturer Department of Civil Engineering (Structures) FTSP-UPN "Veteran" East Java. email : masdawa@yahoo.com, mdastawa@upnjatim.ac.id

1). Restraint on all blocks that assemble into columns in front of the joint :

$$V_n \leq 20\sqrt{f'_c}\,.\,A_j \qquad \ldots\ldots\ldots (2.1)$$

2). Restraints in the three face or two faces opposite columns :

$$V_n \leq 15\sqrt{f'_c}.\,A_j \qquad \ldots\ldots\ldots (2.2)$$

3). All other cases :

$$V_n \leq 12\sqrt{f'_c}.\,A_j \qquad \ldots\ldots\ldots (2.3)$$

A framework of beams considered to provide confinement to the joint only if at least three quarters of the joint is covered by the beam. Vn value is allowed to be reduced by 25% if used in lightweight concrete. In addition, the test data shows that the value of equation (2.3) is not conservative when applied to the joint angles. Aj = effective cross-sectional area in the joint, the condition of flat parallel to the plane of shear reinforcement on the average produce joint. Assumes that the horizontal shear in the joint is determined on the basis that the flexural tensile stress in the steel fy = 1.25. Figure 1 shows the forces acting in the beam-column relations in the joint[8].

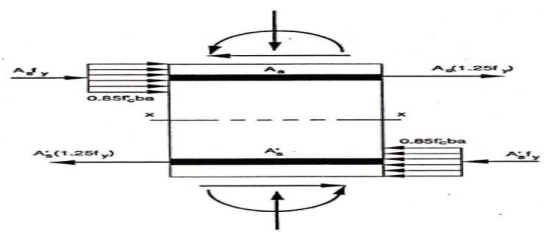


Figure 1. Horizontal shear force on the Beam-Column Joint (Fanella David A, Munshi Javeed. A, 1998)

Reinforcement distribution on the Joint

For reinforcement bar sizes 3 to No. 11 ends in a joint exterior with standard hooks 90 ° on the normal concrete, length delivery outside face of the column l_{dh}, as required by ACI 318-2008() regulations, shall not be less than the value of the largest of the equation (2.4), (2.5) and (2.6) the following :

$$l_{dh} \geq \frac{f_y.d_b}{\left(65\sqrt{f'_c}\right)} \qquad \ldots\ldots\ldots (2.4)$$

$$l_{dh} \geq 8\,d_b \qquad \ldots\ldots\ldots (2.5)$$

where db = bar diameter.

$$l_{dh} \geq 6 \text{ inch} \qquad \ldots\ldots\ldots (2.6)$$

Length distribution given out advance column should not be less than ld = 2.5 l_{dh} when the depth of the concrete cast in one ride down the slope reinforcement exceeds 12 " All straight bar ends on the joint reinforcement required for confinement passes through the core of a column or shear wall boundary rods. Every part, no longer restrained planting in the core must be increased by a factor of 1.6.

State of the Art Shear ductility of Beam-Column Joint

Uma and Prasad[9] conducts research on the seismic behavior of beam-column connections reinforced concrete skeleton. Aspects examined included: the force on beam-column connection, shear forces on the contribution mechanisms of connection, bonding requirements, factors affecting the strength of the bond, the requirements of sliding joints. Analysis of sliding on the connection, more details are described as follows:

1).Shear force at beam-column joint Interior.

Horizontal shear force across the joint can be obtained based on the criteria of balance. See arch bending moments, moments Ms and Mh work on the advance with the opposing forces on the joint between the beams are stringing. Assuming symmetrical reinforced beams, tensile force Tb and compressive force Cb done in reinforcement beams. Slide the vertical beam on the face of the joint is Vb. Assuming the shear force Cb = Tb, slide on the columns = Vcol, from forces above is calculated as the equilibrium criterion.

$$V_{col} = \frac{2T_b.Z_b+V_b.h_c}{l_c} \qquad \ldots\ldots\ldots (2.7)$$

wherein:

lc = height of the floor (the Fig. 2.2(a); hc = height of the column; Zb = the lever arm

Given the slope of the moment in the joint core, horizontal shear force,vjh can be written:

$$V_{jh} = V_{col}\left(\frac{l_c}{Z_b} - 1\right) - V_b\left(\frac{h_c}{Z_b}\right) \quad \ldots\ldots\ldots (2.8)$$

2).The Joint Shear strength

Joint shear strength is strongly influenced by the parameters that influence the two principles against sliding mechanism. Total force contributed by each mechanism can be considered as the shear strength of the joint in the horizontal direction is calculated by:

$$V_{jh} = V_{ch} + V_{sh} \quad \ldots\ldots\ldots (2.9)$$

where Vch is the contribution of the concrete strut and Vsh is a contribution of the truss mechanism. Contribution of each mechanism is influenced significantly by the prevailing conditions of the bond as discussed in the previous section (Figure 2, 3, 4)

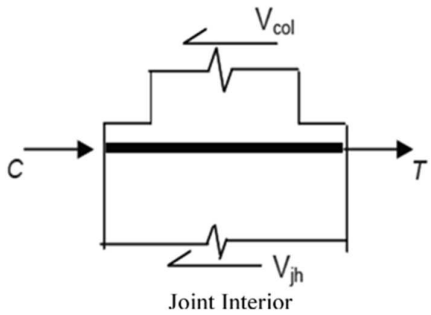
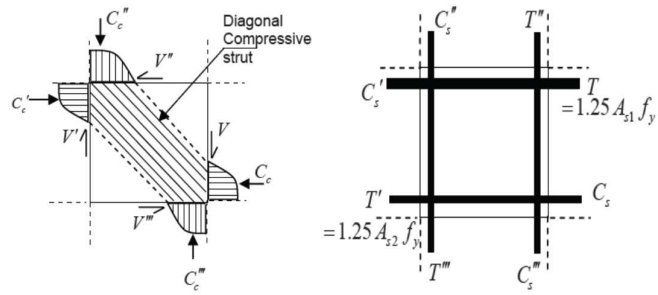
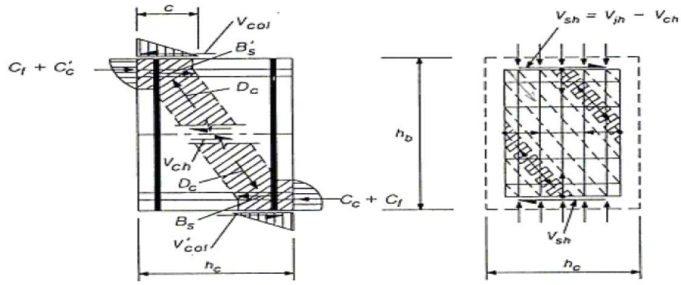


Figure 2. Balance on Joint shear
(Uma & Meher Prasad, 2006)



(a) Press Mechanism (b) The force on reinforcement only

Figure 3. Idealization of the behavior of Beam-Column Joint
(Uma & Meher Prasad, 2006)



(a) Strut Mechanism (b) Truss Mechanism

Figure 4. Slide resistance mechanisms
(Uma & Meher Prasad, 2006)

Of reference the results this research, the idea arose to investigate the shear capacity of the joint partially prestressed concrete beams with reinforced concrete columns, shear ductility in particular reliability, to avoid story frame structure of shear failure due to lateral seismic loads. This study is the continuity of the previous year studies that have examined about bending ductility of the structure model of the same order. State of the Art this research is to explore and find the idea of the results of previous studies that the researchers "Column-Behavior Relations Slide Concrete Beams on the Framework Strukutr Daktil as Environmental Building a Reliable and Safe Housing"

3. METHODOLOGY

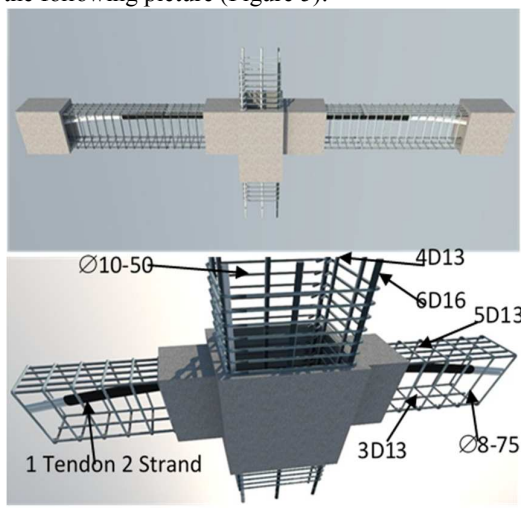
The manufacture Specimen

Concrete compressive strength f'c plan '≅ 40 Mpa, yield stress steel fy = 400 MPa, fy prestressing steel quality ≥ 1000 MPa. Preliminary test objects including concrete and tensile steel tendons, have been made in the implementation of research years ago. So in this study is planned immediately make Beam-Column Joint interior structure element model consisting of partially prestressed beam elements and reinforced concrete columns with shear reinforcement in accordance with the design results. Beam section dimensions of 250/400 mm, column section 400/400 mm. Specifications of the test objects are arranged in the following table 1.

Table 1. Specifications and criteria of the test specimen

Element Struktur	Element of Structure (cm)	Longitudinal Reinforcement	Stirrups	Tendons amount	Specimens amount
Interior Beam-Column Joint	Beam 25/40	Tensile Bar $5D_{13}$	∅8 - 75	1 (2Strand)	1
		Compressive Bar 3 D_{13}			
	Column 40/40	$6D_{16} + 4D_{13}$	∅10 -50	-	

The draft results of specimens shaped Beam-Column Joint interiors that are resistant to earthquake lateral shear forces such as sketch the following picture (Figure 5):



Figur 5. Design Interior Joint Spesimen

Design of limit Tendon area.

Design tendon area (cgs) is in the form of parabolic arch with curved peak there on axles the column, and is smooth on the ends of the beams are right in the center of gravity beam section (CGC). Parabolic Curve formula is: $y = (4f.x\ (L-x)) / L^2$, produce curve tendon as shown below (Figure 6):

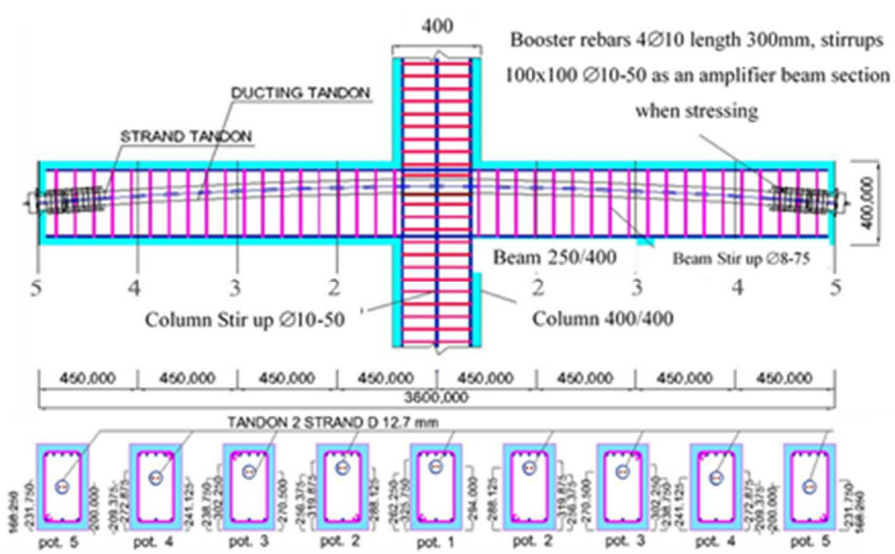


Figure 6. Curve limit Tendon area

Shear reinforcement Design in the joint

Actuator = 1000 kN capacity, effective 80% = 0.8(1000)=800kN.

For the design load capacity of the structure, all the specimens were taken into account in the structural condition of the elastic condition, so the structure has not been cracked. For Beam-Column Joint specimens Interior:

The actuator moment due to lateral force P:
800 kN.(1,00 m) = 800 KNM, a primary moment. Members stiffness (Figure 7):

$$k_{1,3} = \frac{3\,EI_1}{L_1} = \frac{3.\frac{1}{12}.25.40^3}{160} = 4{,}0;\ \ k_{2,4} = \frac{3.EI_2}{L_2} = \frac{3.\frac{1}{12}40.40^3}{130} = 6{,}4;$$

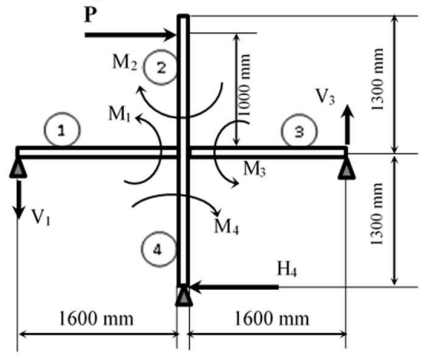


Figure 7. Moment distribution in the specimen

Moment distribution factors:

$$fd_1 = fd_3 = \frac{k_1}{k_1+k_2+k_3+k_4} = \frac{4}{4+6{,}4+4+6{,}4} = 0{,}19;\ fd_2 = fd_4 = \frac{k_2}{\sum k} = \frac{6{,}4}{4+6{,}4+4+6{,}4} = 0{,}31$$

$M_1 = M_3 = 0{,}19\ (800) = 152$ kNm ; M2 = M4 = 0,31 (800) = 248 kNm
Mn1 reinforced bar = 102,54 kNm
Mn of strand tendon :
$X = a/\beta_1 = 82{,}4/0{,}77 = 107$ mm ; e = 282-107 = 175 mm ; Mn2 = F (e) = 379 (175).10^{-3} = 66,33 kNm
Mn=Mn1+25%(Mn2)=85,96+0,25(66,33) =102,54 kNm < 152 kNm (OK).
Calculate the Strong Column-weak beam requirement : Me = 248 kNm ; Mg = 102,54 kNm
Requirements of SNI 03-2847-2002 part 23.4.2 (2) :
Me≥6/5Mg, accordingly $248 \geq {}^{6}/_{5}\ (102{,}54) \rightarrow 248\ \text{kNm} > 123{,}05\text{kNm}$ ... (OK)

Shear Stirrups Design in the Joint
According to the provisions of SNI 03-2847-2002 part 23.4.4) :

$$A_{sh} = 0{,}3\left(\frac{s.h_c.f'_c}{f_{yh}}\right)\left[\left(\frac{A_g}{A_{ch}}\right) - 1\right] \qquad \ldots\ldots\ldots (3.1)$$

$$\text{Or } A_{sh} = 0{,}09\left(\frac{s.h_c.f'_c}{f_{yh}}\right) \qquad \ldots\ldots\ldots (3.2)$$

stirrups ∅10, 40 mm concrete cover
Ach = (320) (320) = 102400 mm^2, h_c = 320 – 2(0,5. 10) = 310 mm.
Stirrup spacing S is taken 50 mm.

$$A_{sh} = 0{,}3\left(\frac{50.310.40}{400}\right)\left(\frac{160000}{102400} - 1\right) = 261{,}56\ \text{mm}^2$$

or $A_{sh} = 0{,}9\left(\frac{50.310.40}{400}\right) = 139\ \text{mm}^2$, used a great value,
1 bar area1∅10, $As = 78{,}5\ \text{mm}^2$,
the amount of stirrups =261.56/78.5=3.33 it takes 4 stirrups,
but because S = 50 mm, and height of the beam space
= 400-2(35)-2(8)-2(13) = 288 mm,
we used amount of stirrups = 288/50 = 5,76 ;
Aplaided 6 pieces rounded stirrups with A_{sh} = 471 mm^2

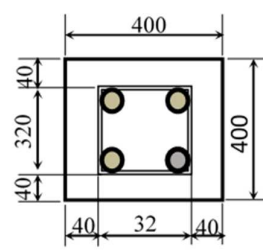


Figure 8. Stirrups position

Calculating the shear strength of joint.
Above beam reinforcement is 5D13 with As = 663.7 mm^2. 3D13 reinforcement in bottom beam with As = 398.2mm2
Effectively the high block requirements for concrete compressive stress is partially prestressed concrete $a = 0{,}235d \leq 0{,}2h\ s/d\ 0{,}25\,h$, then taken : $a = 0{,}235\ (350{,}5) = 82{,}4\ \text{mm} \leq 0{,}25.400 \rightarrow 82{,}4\text{mm} < 100\ \text{mm}$ ... (OK)
As-as Column high = 3,0 m

$$V_{col} = \frac{2T_b.Z_b + V_b.h_c}{l_c} \quad \text{from the equation} \qquad \ldots\ldots\ldots (2.7)$$

$V_{jh} = V_{col}\left(\frac{l_c}{Z_b} - 1\right) - V_b\left(\frac{h_c}{Z_b}\right)$ from the equation ……. (2.8)

V_b = 0,4. 0,25. 24(1,6) + 192/1,6 = 123,84 kN

$$V_{col} = \frac{102{,}54 + (398{,}2.400)\left(365 - {}^{82{,}4}/_{2}\right)10^{-6} + 123{,}84(0{,}4)}{3{,}0} = 68 \text{ kN}$$

$$V_{jh} = 68\left(\frac{3{,}0}{0{,}3238} - 1\right) - 123{,}84\left(\frac{0{,}4}{0{,}3238}\right) = 409 \text{ kN}$$

Shear strength at the joint.

Are Calculated of the nominal strong concrete and reinforcement in the joint stirrups

$V_{jh} = V_{ch} + V_{sh}$ from the equation ……. (2.9)

$V_n \leq 12\sqrt{f'_c}.A_j$ from the equation ……. (2.3)

The equation 2.4 is applicable for Beam-Column Joint frame field.

High joint taken = Column high = 400 mm, the effective width taken of the smallest value: beam width (b), or b + 2X; X = difference thick outer edge of the beam to the column. b+h = 250 + 400 = 650 mm; b+2X = 250 +2(75) = 400 mm, taken effective width = 325 mm. then Aj = 400(325) = 130000 mm^2.

$V_n \leq 12\sqrt{40}.130000.10^{-3} = 9866{,}3$ kN

Reduction factor of 0.55 according to SNI 2847:2013 section 11.3 (3) (a) for the structure to withstand earthquake forces.Vch=ϕ.Vn=0,55(9866,3)=5426,5 kN

Vsh = ϕ.Ash. f_{yh} = 0,55(471)400.10^{-3} = 103,62 kN

$V_{jh} = V_{ch} + V_{sh}$ = 5426,5 + 103,62 = 5530,12 kN ... (OK)

But the decisive factor is the smallest vjh = 409 kN.

Test specimens in laboratory.

Test specimens was performed by laboratory testing machine, where the specimens were installed tool: Linear Variable Displacement Transducer (LVDT) on the vertical and horizontal displacement to measure deformation (displacement) that occurred. To detect strains occurs in both the beam or the column, then at certain points-installed strain gauge (SG). Loading pattern is Cyclic loading pattern (pseudo dynamic) that resembles a real earthquake lateral loads, driven actuator with a capacity of 2000 kN. For the vertical load on the column is static loading capacity of 1000 kN.

Structures ductility.

Calculated from yield condition due to cyclic loading on the lateral drift ratio of 3.50% and 4.50%. When the value of the yield conditions = δy and the stable condition = δi, accordingly ductility level μ= δy/δi ≥ 4.0

4. RESULTS AND DISCUSSION

To get accurate data from Beam-Column Joint research is then mounted several sensors at the points that are important to the tool, including the form; LVDT, (SG). Each outcome data at every point in the form of graphs will be presented sequentially. Results analysis Test Specimens at peak Interior Column. For the beam-column joint specimens Interior, the Static Axial load on a given column by vertical actuator load capacity by10 % Column = 10% (400x400) 40 X 10^{-3}= 640kN. Set-up Specimen and testing process is shown in the following figure

Figure 9. Set-up Specimen and testing process

1. Load Structure resist capability at Joint Shears.

From reading the data starin-gauge (SG) in a row: SG-13 (reinforcement columns) + SG-16 (Transversal Scroll) + SG-25 (Strand Tendons) + SG-40 (Concrete Column). Lateral Compression Forces = 142.3 kN +142.3kN+44.3kN+142kN=470.9kN.

Lateral Pull Forces = 135 kN kN +138kN +58.5kN +134.3kNkN=465.8kN.

Vjh plan = 409kN, the ability resist lateral test force results of Specimen :

Press = 470.9 kN and Pull = 465.8 kN. All of them > 409 kN ... (OK)

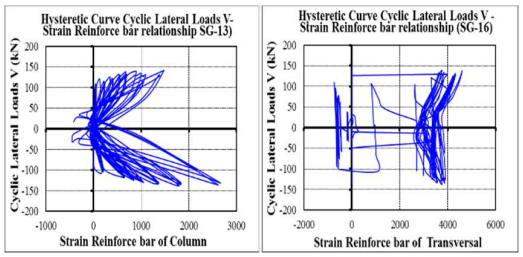


Figure 10. Relationships curve Cyclic Lateral V-Strain Reinforce (SG-13 and SG-16)

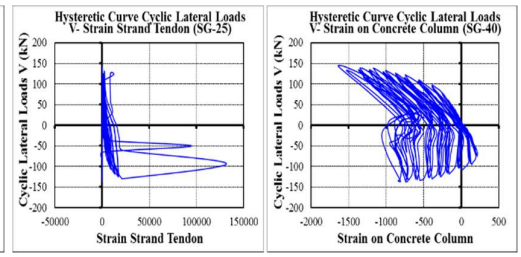


Figure 11. Relationships curve Cyclic Lateral V-Strain Strand and on Concrete Column (SG-13 and SG-16)

2. Ductility of Structure.

At Drift Ratio 3.50% 3rd Cycle - yield boundary conditions.
While working force of the cyclic press: $\delta y = 3.56$ mm
Stable condition at Drift ratio of 1.0% the first cycle, $\delta i = 0.62$ mm.
The level of ductility $\mu = \delta y / \delta i \geq 4.0$; $\mu = 3.56 / 0.62 = 5.74 > 4.0$ ... (OK)
While working cyclic tensile force: $\delta y = 2{,}64$ mm
Stable condition at Drift ratio of 1.0%, $\delta i = 0.53$ mm.
The level of ductility $\mu = \delta y / \delta i \geq 4.0$; $\mu = 2.64 / 0.53 = 4.98 > 4.0$ ... (OK)

5. CONCLUSIONS

The results of Analyze beam-column joint of Specimen interior were as follows:

1. Strong Joint Shear.
   Results: Strong Shear Joint Press = 470.9 kN; Strong Shear Pull = 465.8kN
   Planning Result = 409kN
   Experimental Results > Results of Planning. Structure are qualified
2. Ductility:
   The requirements ductility on drift ratio of 3.5% of all $\mu > 4.0$, so the ductility of structure meet is qualified.

Remarks

In general, the model structure is eligible at 3.50% Story Drift has qualified. So this research, strong Joint Shear and ductility qualified and acceptable.

Acknowledgement

Our gratitude to LPPM-ITS for assistance fund through Outstanding ITS Research, Research DITLITABMAS Decentralization Program, National Development University "Veteran" East Java which has given me the opportunity to study in the S3 ITS.

REFERENCES

1. SNI 03-1726-2002, “Earthquake Resistant Building Structures ", the National Standardization Agency in Indonesia, Jakarta.
2. SNI 03-2847-2002, “Procedure for Calculation of Concrete Structures for Buildings”, Concrete Laboratory ITS Surabaya.
3. B. Roger W. G, Park Robert, September 1971 ”Seismic Resistance of Prestressed Concrete Beam-Column Assemblies”, ACI Journal.
4. Magdy T. et al (1999), Seismic Behavior and Design of Unbonded Post-Tensioned Precast Concrete Frames.
5. Kashiwazaki T & Noguchi H (2000), Structural Performances of Prestressed Concrete Interior Beam-Column Joints.
6. Murahidy A. G, et al, 2004 “Design Construction and Dynamic Testing of a Post-tensioned Precast Reinforced Concrete Frame Building with Rocking Beam-Column Connections and Adas Element”, NZSEE Conference.
7. American Concrete Institute (ACI 318M-08) , 2008 ”Building Code Requirements for Structural Concrete and Commentary” First Printing June 2008.
8. Fanella David A, Munshi Javeed. A, 1998 “Design of Concrete Buildings for Earthquake and Wind Forces”, Portland Cement Association.
9. Uma S. R, Meher Prasad. A, “Seismic Behavior of Beam Column Joints in Reinforced Concrete Moment Resisting Frames”, Department of Civil Engineering Indian Institute of technology Madras Chennai.