B. Sri Umniati, Sri Murni Dewi, Agoes Soehardjono MD / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 1, January -February 2013, pp.1704-1709

Joint Characteristics of Bamboo Reinforced Concrete Using Bamboo Mechanical Bamboo Anchors in Cyclic Loading

B. Sri Umniati*, Sri Murni Dewi, Agoes Soehardjono MD****
*Lecturer, Department of Civil Engineering, Malang State University, Indonesia
*Doctoral Candidate, Department of Civil Engineering, Brawijaya University, Malang, Indonesia
** Professor, Department of of Civil Engineering, Brawijaya University, Malang, Indonesia

ABSTRACT

A major cause of collapse in structures from earthquakes is the failure of beam column joints, thus the need for strengthening them. Therefore, the aim of this study was to investigate bamboo anchor (headed bar) characteristics when used in the beam column joints of bamboo reinforced concrete structures, and their mechanical anchors which consisted of two parts namely, the head and the leg. This study was conducted in the Civil Engineering Structural Laboratory of Brawijaya University. The materials employed were mechanical bamboo anchors heads made in three sizes from bamboo culms, B1, B2, and B3. Ratios of the head area to the bar area were 2.09, 2.88, and 2.78 for B1, B2, and B3 respectively. Method, these three specimens of the beam column joints were tested using cyclic loading. Deformations for each stage of the load were plotted, and the relationship between load and deformations (P-Δ and P-ε) were noted on graph paper in the form of loop hysteresis. The results indicated that the maximum shear force strain reached by the B1 and B3 specimen was 16.56 kN. Whereas, the B2 specimen reached 12.42 kN.

Keywords – **anchors, bamboo reinforced concrete, beam column joint, cyclic loading, headed bars**

I. INTRODUCTION

Bamboo is a building material that is not only renewable but also abundant in Indonesia and, of the 1,250 species in the world, 140 or 11% are found in Indonesia [1]. Bamboo can be used as a replacement for steel bars in concrete because it has a high tensile strength. In addition, it is abundant and far cheaper than steel. Also, it is easy to plant and grows quickly, can be harvested 3 years after planting and can be harvested again the following year.

Several species of bamboo have been used by the authors as bars in concrete, such as 'petung' (Dendrocalamus Asper), 'ori' (Bambusa Blumeana) and 'tali' (Gigantochloa Apus). These 3 types of bamboo have proved to be extremely suitable for replacing steel bars in concrete. For this study, the bamboo was prepared as follows: 1) the bamboo was cut and split into the sizes required and then dried for about 28 days ; 2) when dry, it was painted with 2 coats of paint used for wood as water proofing with an interval 24 hours between coats ; 3) immediately after the second coat, the freshly painted bamboo was buried in sand. Sand adheres to the bamboo and improves the binding of the concrete to the bamboo and, as soon as the paint is dry, the bamboo is ready for use as bars in concrete [2].

Earlier research by the authors [3,4] into the development of a confined design for quake proof frame structures made with bamboo bars, found that most structural damage was to the beam column joints, whereas, the beams themselves and columns were untouched except for a few hairline cracks in the parts nearest to the beam column joints indicating that they worked well. This was supported by previous studies in which a frame made with bamboo bars that had collapsed due to cyclic load; the column portion was taken and subjected to axial loading from a UTM machine. The results from this axial test found that the confined columns were able to withstand loads of between 120 kN and 175 kN. This was far exceeded column axial force capacity for unconfined concrete columns of 18 kN, which showed that the confined effect worked well and that the bamboo bars still firmly adhered to the concrete. It follows, therefore, that these areas of column joints (reinforced with bamboo bars) require to be strengthened in order to optimize the strength of the whole structure. Much research has already been done into the mechanics of steel bars amongst others [5,6,7,8], whereas little or none have been enacted into the application of bamboo bars in concrete structures.

The aim of this study was to investigate the characteristics of beam column joints in various uses with differing sized bamboo headed bars, tested experimentally in the laboratory by employing cyclic loads to play the part of the effects of earthquakes. The characteristics of the beam column joints investigated are depicted in graphs of the relationship of the joint shear force displacement (P-Δ) and graphs showing the relationship between shear force strain (P- ε) and the patterns of cracks in the specimens tested.

This study is the continuation of the previous one. The finding of this research can be used as a reference to assist in the construction of earthquake resistant buildings. In addition, it can also be helpful to governments in order that they can draw up the necessary building codes for bamboo reinforced concrete structures.

ACI 352R-02 requires four major design parameters, as follows [9]:

1. The ratio of flexural strength of the columns (M_{nc}) to flexural strength of the beams (M_{nb}) that frame into a joint, M_r, should satisfy

$$M_r = \frac{\sum M_{nc}}{\sum M_{nb}} \geq 1.2 \quad \text{……………..(1)}$$

where ΣMnb and ΣMnc are the sum of nominal flexural strengths of beams and columns, respectively, evaluated at the face of the joint. This recommendation is intended to produce flexural hinging in the beams.

2. To prevent joint shear failure before beam hinging, the shear strength Vn computed on a horizontal plane within the joint shall satisfy

$$\phi V_n \geq V_u \quad \text{………….(2)}$$

$$V_n = 0.083\gamma\sqrt{fc'}\,b_j h_c \;\; x10^{-3} \quad (kN) \quad \text{...........(3)}$$

where ϕ is the strength reduction factor of 0.85, b_j is the effective joint width, h_c is the depth of the column in the direction of joint shear being considered, and γ is the shear force factor in accordance with the confinement on the joints by lateral structural elements, compatible with table 1 ACI 352R-02. For a joint without slabs, the design shear force can be estimated by Vu = 1.25fyAs – Vcol, for Type 2 connections using ASTM A706 or equivalent reinforcement.

3.The total cross-sectional area of stirrups (rectangular hoops and crossties) within the joint A_{sh} should be at least equal to that specified in equations 4 as follows:

$$A_{sh} = 0.3s.b_c''.\frac{f_c'}{f_{yt}}\left(\frac{A_g}{A_{ch}} - 1\right) \text{………..(4)}$$

and not be less than 0.09s.bc″ fc′/fyt ……..(5)

where s is the spacing of hoops (center to center), b_c'' is the core dimension of tied column, outside to outside edge of transverse reinforcement bars, fc' is specified compressive strength of concrete, Ag is the gross area of column section, f_{yt} is the specified yield stress of transverse reinforcement, A_{ch} is the area of column core measured from outside edge to outside edge of either spiral or hoop reinforcement.

4. The minimum development length of longitudinal beam bars with standard hooks anchored in the joint is determined by

$$l_{dh,352} = \frac{f_y d_b}{5\sqrt{f_c'}} \quad (mm) \quad \text{……….(6)}$$

while the minimum development length of headed bars is $0.75 l_{dh,352}$ where fy is the yield strength of longitudinal reinforcement, and d_b is the nominal diameter of bar.

II. Material and Methods

2.1. Test Specimens

The specimens tested were three concrete beam column joints reinforced with bamboo bars. Their specifications and cross section dimensions are shown in the figures below. Column dimensions were 150mm x 200mm, beam dimensions 150mm x 200mm. Concrete compression strength was 29.969 MPa. The bamboo bars were made from Ori bamboo and employed as longitudinal bars measuring 30mm x 10mm. The yield strength of the bamboo bars was 98.527 MPa. Whereas, for the transversal bars made from steel of 6mm diameter, the yield strength was 718.88 MPa. In order to anchor the area of the column joints, 3 kinds of mechanical bamboo anchors were used. Ratios of the head area to the bar area of mechanical bamboo anchors were 2.09, 2.88, and 2.78 for B1, B2, and B3 respectively. The three specimens meet the requirements of ACI 352R-02 as written in equation 1 to equation 6.

Specifications of the specimens tested:

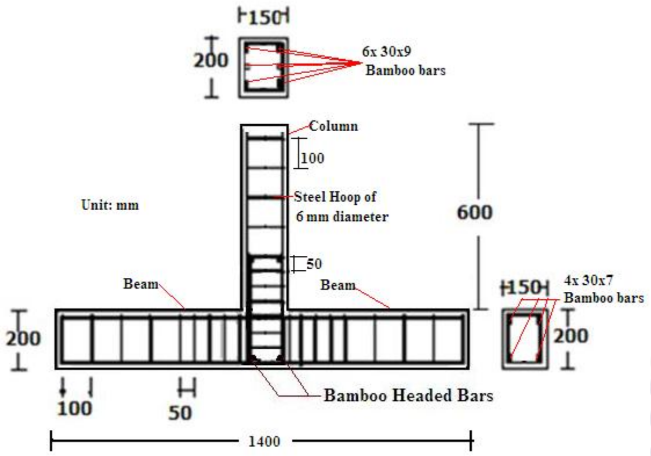
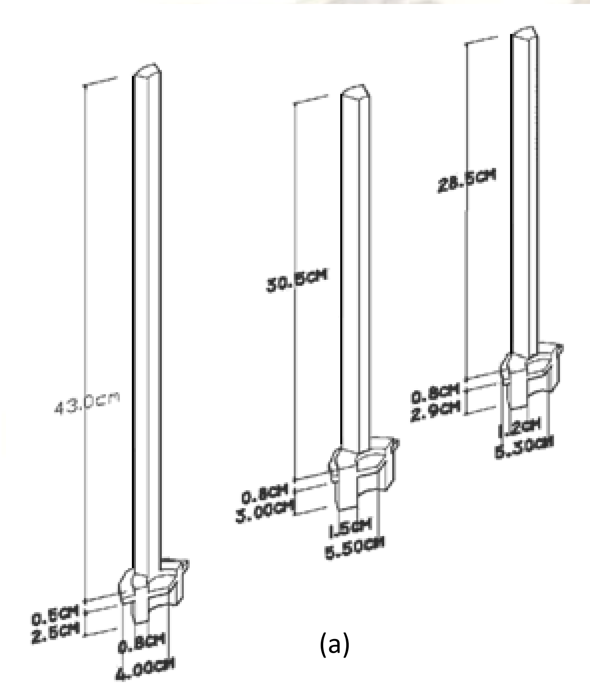


Figure 1. Dimensions of cross section areas.

Bamboo Mechanical Anchors:



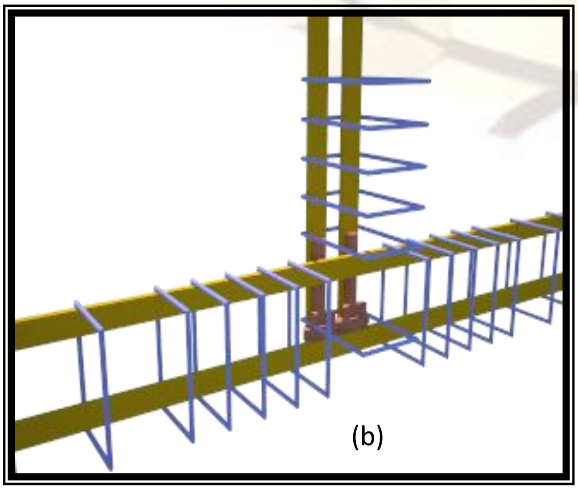
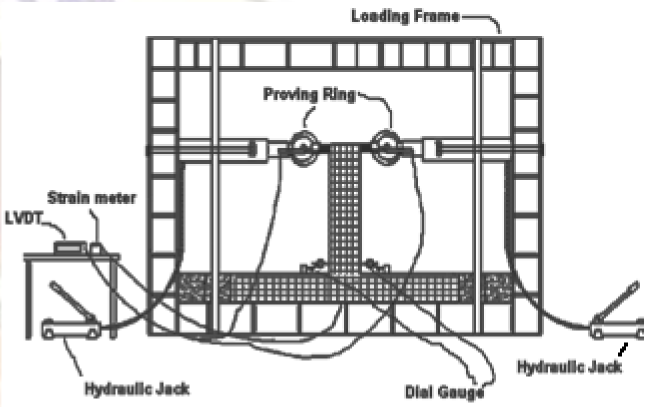


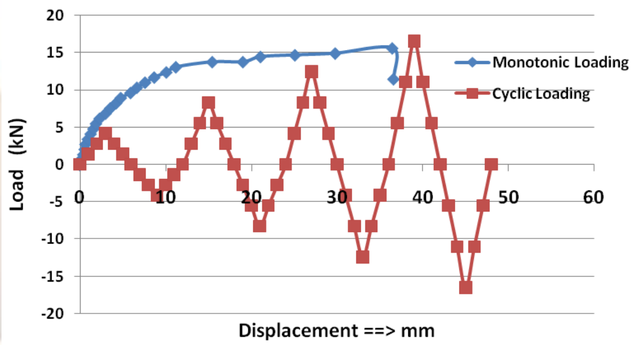
Figure 2. (a) Mechanical bamboo anchor B1, B2 and B3; (b) the position of the anchor.

2.2. Test Setup and Loading Sequence

The general arrangement of the experimental setup is shown in Fig. 3(a). All specimens were subjected to 4 cycles applied by slowly displacing the column's free end according to the load history shown in Fig. 3(b) below. The amplitudes of the peaks in the loading history were 4.14 kN, 8.28 kN, 12.42 kN and 16.56 kN. One displacement cycle was performed at each loading amplitude. No axial load was applied to the columns of the specimens.



(a)



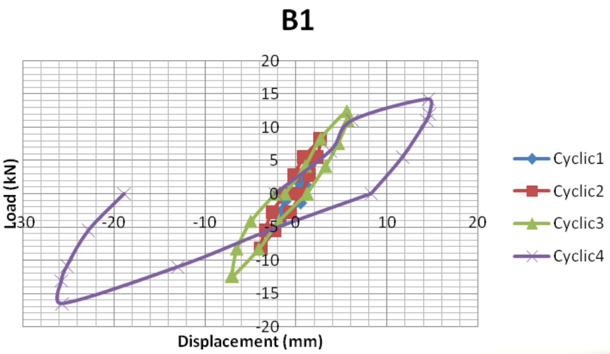
(b)

Figure 3. Test set-up (a); Loading sequence (b)

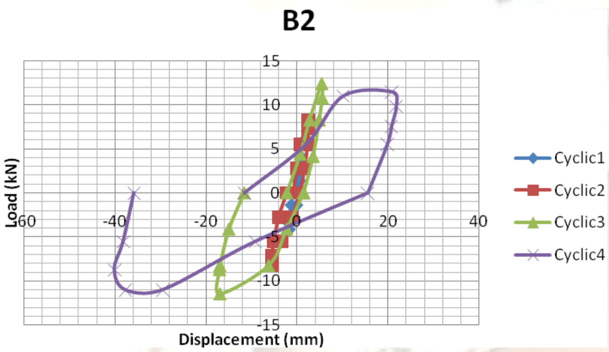
III. RESULTS AND DISCUSSION

3.1. Force Displacement Relationship

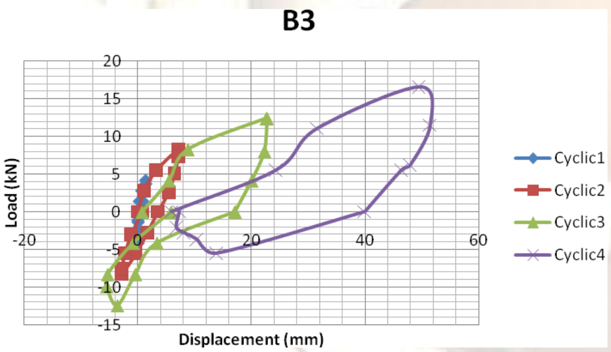
The relationship between load and lateral column displacement at a height of 55 cm above the beam is shown in Figure 4 below.



(a)



(b)



(c)

Figure 4. The relationship of test specimen load-displacement : (a) B1; (b) B2; (c) B3

The loops hysteretic of the specimens tested give the figures for maximum lateral load and maximum lateral displacement, see Table 1 below:

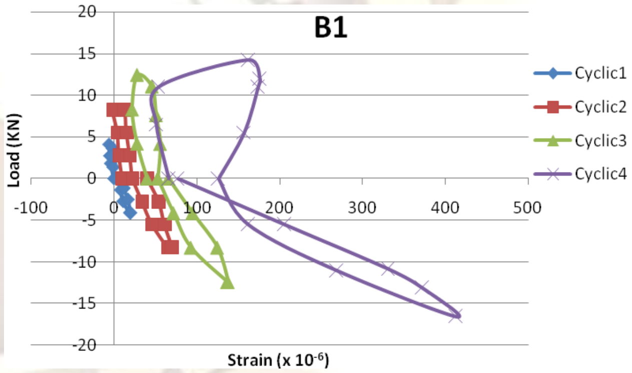
Table 1. Maximum lateral load capacity and maximum lateral displacement

Specimens	Maximum Lateral Load	Maximum Lateral Displacement	Total Energy Dissipation
	(kN)	(mm)	(kNmm)
B1	16.56	42.363	468.649
B2	12.42	40.188	797.829
B3	16.56	50.444	647.667

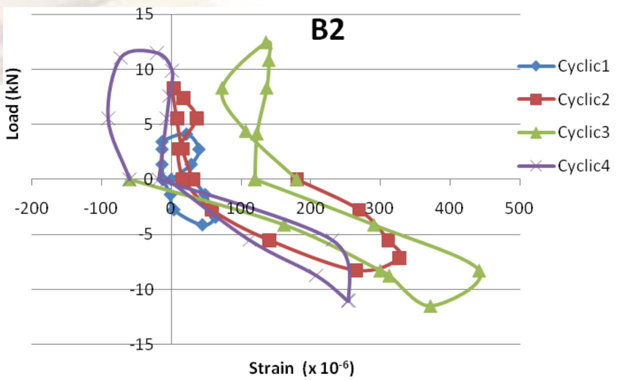
Based on the maximum lateral loads in Table 1, two specimens had the highest shear force, namely, 16.56 kN in B1 and B3. By computing the total area of curve of relationship load-displacement for each specimen, the total amount of energy dissipated (E) by the beam column joints can be obtained, namely, 468.649 kNmm, 797.829 kNmm, and 647.667 kNmm, for B1, B2, and B3, respectively, see Table 1. Then the magnitude of earthquake, for deep or intermediate events, m_B (long period body wave magnitude) can be obtained using equation Log E = 5.8 + 2.4 m_B (Gutenberg and Richter, 1956), where E denotes energy in ergs (note: 1 Erg = 1.0168 x 10-7 kNmm) or using equation Log E = 11.8 + 1.5 M_s for shallow event of earthquake, where M_s denotes surface wave magnitude.

3.2 Load Strain Relationships

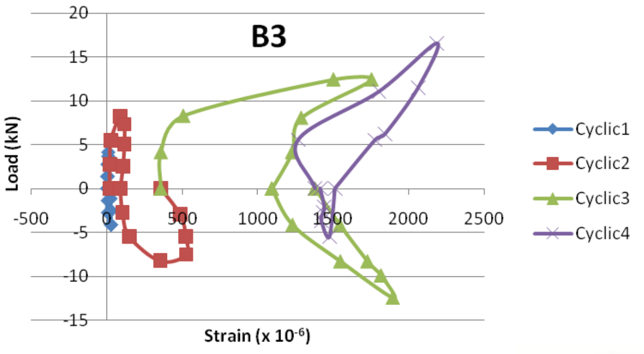
In order to measure strain on the headed bars, a strain gauge was placed on their feet. The amount of strain at each load stage was plotted on the load strain relationship graphs below.



(a)



(b)



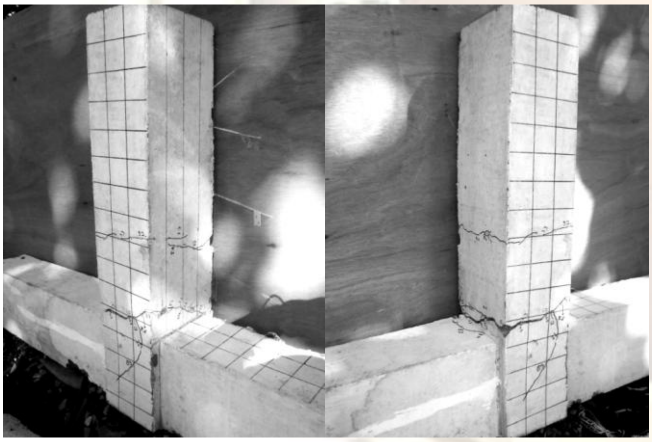
(c)

Figure 5. Load – HB strain relationship for each specimen : (a) B1; (b) B2; and (c) B3

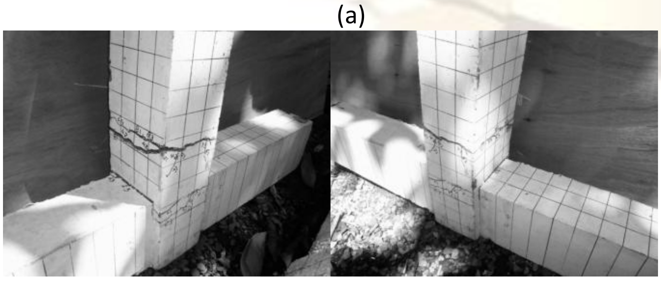
Figure 5 indicates that the greatest strain exerted on the specimens was that for B3, namely, 2184 x 10^6 . This was a little less than that for the bamboo bar yield strength and demonstrates that the bamboo head bars in the beam columns had nearly yielded. This was due to the high shear force reached by the B3. For the other two specimens, the shear force strength was much lower showing that all specimens were still elastic.

3.3 Crack Patterns

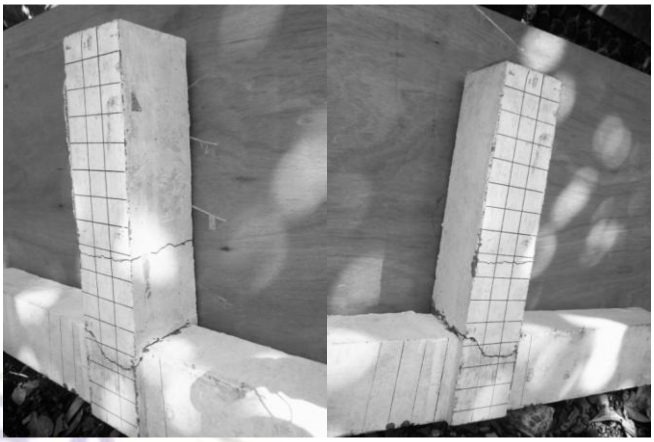
Crack patterns in the three specimens tested are shown in the Figure 6 photographs below.



(a)



(b)



(c)

Figure 6. Crack patterns in the specimens tested: (a) B1; (b) B2; and (c) B3

The photographs in Figure 6 show that flexure cracks occurred in all three specimens in the column regions. This indicates that flexure failure happened before shear failure in the joint areas. This means that all specimens performed well under seismic stress. The biggest cracks in each specimen were found in the critical sections of the beam column joints, i.e., the sections where the columns connect with the beams.

IV. CONCLUSION

From the above findings, it can be concluded that the mechanical bamboo anchors withstood the cyclic loads very well and are thus eminently suitable for use in mechanical anchors, their strength being equal to or greater than that of the steel ones (in the other part of mechanical anchor study conducted by the authors) and can, therefore, stand up to seismic shocks better. This was proved by the fact that flexure failure occurred before shear joint failure in all three specimens. In the mechanical bamboo anchors, the greatest shear force was reached by the smaller thickness anchors, B1 and B3 (of 8mm and 12mm thickness respectively).

For energy dissipation of the joint, from the ratio of the head area to the bar area of the bamboo anchors, can be made tentative conclusion: the greater the ratio of the head area to the bar area, the greater the amount of energy absorbed by the beam column joints.

ACKNOWLEDGEMENTS

This research can be established with a grant of PHB DP2M Indonesian Directorate General of Higher Education, and Brawijaya University, Malang Indonesia.

REFERENCES

[1] Sahabat Bambu, *Bamboo Preservation* (IndoGlobalWeb.com, 2008).

[2] Kankam, J. A.,George, M. Ben, and Perry, S. H., Bamboo Reinforced Concrete Beams Subjected to Third-Point Loading, *ACI Structural Journal, January-February*, 1988, 61-67.

[3] Umniati, B.S. & Karyadi, Pengembangan Model Struktur Beton Bertulangan Bambu Tahan Gempa Sistim Ganda Untuk Pembangunan Rumah Sederhana Tahan Gempa pada Wilayah Gempa Tertinggi (Zona 6) di Indonesia, *Laporan Penelitian Hibah Strategis Nasional. Dana DP2M*, 2009. (In Indonesian).

[4] Nindyawati & Umniati, B.S., Portal Beton Bertulangan Bambu Yang Dikekang Di Jalur Gaya Tekannya, Sebuah Solusi Pembangunan Rumah Sederhana Tahan Gempa, *Laporan Penelitian Hibah Bersaing. Dana DP2M*, 2009. (In Indonesian).

[5] Chun, S.,C., Bohwan,O., Lee, S.,H., Kang, T.,H.,K., and Wallace, J., W., Mechanical Anchorage In Eksterior Beam Column Joints Subjected to Cyclic Loading, *ACI Structural Journal. January-February*, 2007, 102-111.

[6] Chun, S.,C., Bohwan,O., Ho Lee, S., and Naito, J., C., Anchorage Strength and Behavior of Headed Bars In Eksterior Beam Column Joints, *ACI Structural Journal, September-Oktober*, 2009, 579-590.

[7] Lee, H.,J., and Yu, S.,Y., Cyclic Response of Eksterior Beam Column Joints With Different Angchorage Methods, *ACI Structural Journal, September-Oktober, May-June,* 2009, 329-339.

[8] Lee, N.H., Park, K.R., and Suh, Y.P., Shear Behavior of Headed Anchors with Large Diameters and Deep Embedments, *ACI Structural Journal. March-April,'* 2010, 146-156.

[9] Lee, H.,J., dan Yu, S.,Y., Cyclic Response of Eksterior Beam Column Joints With Different Angchorage Methods, ACI *Structural Journal. May-June*. 2009, 329-339.