ASSESSMENT OF SHEAR STRENGTH OF INTERIOR REINFORCED CONCRETE BEAM-COLUMN JOINT

Abrham Gbree [1,] Getu Segni[1] and Garomsa Fikadu [2]
[1]School of Civil and Environmental Engineering, Addis Ababa Institute of Technology
[2]Department of Civil Engineering, Mettu University
[2]Corresponding Author's E-mail: garomsafikadu.tefera@gmail.com

ABSTRACT

Even though beam-column joint is one of the most critical regions in reinforced concrete (RC) frames used to transfer loads from beam to column, a little attention is paid to its design in Ethiopian practice. In this paper, shear strength of an interior beam-column joint of a RC building frame designed to the old code (EBCS 2, 1995) has been investigated. The building is analyzed for seismic actions and the shear strength of the beam-column joint is estimated using both empirical expressions and analytically by using a finite element (FEM) modeling program. The interior joint of a RC frame is selected to be assessed under monotonic loading for a constant column axial load.

The study showed that there is a significant variation between the results from numerical analysis using VecTor2 and provisions in ESEN1998-1-2015. From the investigation, it is observed that the interior joint satisfies both ductility and shear strength requirements after the column has been strengthened by concrete jacketing. This study is not enough in exposing the problems regarding design and detailing of beam-column joints in Ethiopian code of practice. Laboratory investigation is highly recommended due to its accuracy compared to numerical simulations.

Keywords*:* *Beam-Column Joints, RC, Shear Strength, Interior Joints, FEM, Jacketing*

INTRODUCTION

Background

Beam-column joint should be designed and detailed properly as it is an important component of a reinforced concrete moment resisting frame especially when the frame is subjected to seismic forces. The failure of reinforced concrete frames during many earthquakes has demonstrated heavy distress due to shear in the joints that culminated in the collapse of the structure. In Ethiopia large building failures due to earthquake is not witnessed currently in big cities. But this shall not hold engineers back from designing beam-column joints for seismic forces as there have been some earth quake occurrences in some towns of the county.

Inadequate performance of some structures could be attributed to shear failure of beam-column joints. So, it becomes apparent to assess the shear resistance of beam-column joints in multistory reinforced concrete frames subjected to a certain amount of ground motion.To utilize the energy dissipating capacity of structural members, the joint connecting the beams and columns must function without brittle failure taking place and without excessive loss of stiffness [1].

The practice in Ethiopia towards design and construction of reinforced concrete beam-column joints may lead to weak beam-column joints. Ethiopian Building Code Sandard-8, 1995, "Design of Structures for

Earthquake"[2] gives detailing provisions within beam-column joints to enhance the strength of the system. Thus, assessment and strengthening of the shear strength of beam-column joints of frames designed to EBCS-8, 1995 is essential to ensure safety of existing reinforced concrete buildings.

The report by Joint ACI-ASCE Committee 352, i.e., Recommendations for design of beam-column connections in monolithic reinforced concrete structures, classifies beam-column joints into interior, exterior and corner joints based on their geometrical configuration and shown in Figure 1 [2].

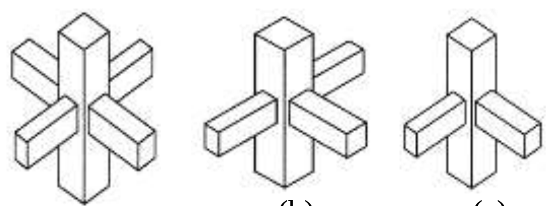


Figure 1: Classification of Joints [2]
(a) Interior (b) Exterior (c) Corner Joints

The response of beam-column joints is a significant factor that affects the overall behavior of RC framed structures subjected to lateral loads. This is affected by various parameters in the joint. Concrete strength, axial load in the column, reinforcement in the joint, geometric parameters, bond stress and plastic hinges in beams are some of the major parameters affecting joint response to lateral loading [2].

Various joint problems occur in existing buildings designed by old codes. Scholars tried to estimate the shear strength of reinforced concrete beam-column joints of existing buildings both experimentally and analytically. The research is significant in revealing that joints are not properly designed and detailed although the old code (EBCS-8, 1995) gives detailing provisions within beam-column joints to enhance the strength of the system. The research is also significant in pointing out how joints of reinforced concrete buildings designed and detailed according to old codes behaves under a certain seismic loads. Moreover, the research initiates researchers to focus on assessment of the strengths of beam-column joints of frames designed to old codes to ensure safety of existing RC buildings.

Shear Strength Models in RC Beam-Column Joints

According to Paulay & Priestley, shear strength of beam-column joints in reinforced concrete frames is based on diagonal concrete strut and truss mechanisms [3] and the horizontal joint shear strength, V_{jh}, is usually proposed to be composed of two components: as shown in Eq. 1:

$$V_{jh} = V_{ch} + V_{sh} \tag{1}$$

where:

- V_{jh} is horizontal joint shear strength
- V_{ch} is contribution of strut mechanism on joint shear strength
- V_{sh} is contribution of truss mechanism on joint shear strength

In assessing the shear strength of RC beam-column joints, ACI 352R-02 [2] ignores the contribution of contribution of truss mechanism and the joint shear strength is expressed as a function of concrete compressive strength and the joint geometry. And accordingly, the horizontal shear strength of RC beam-column joint is given as [2]:

$$V_{jh} = 0.083\gamma\sqrt{f_{ck}}\, b_j h_c \qquad [2]$$

where:

b_j is the effective joint width.

h_c is depth of the column in the direction of joint shear being considered.

f_{ck} is cylinder compressive strength of concrete

Table 1: Values of γ for Beam-to-Column Connections [2]

Joint type	Interior	Exterior	Corner
Joints with a continuous column	20	15	12
Joints with a discontinuous column (Joints at roof level)	15	12	8

The joint shear strength of an interior beam-column joint is estimated using following expression according to EBCS -8, 1995 [1]:

$$V_{jh} = 5.0 f_{ctd} b_j h_c \qquad [3]$$

where:

V_{jh} is joint shear strength

f_{ctd} is design axial tensile strength of concrete

b_j is effective width of beam-column joint

h_c is width of column in the direction of a beam framing into the column

Effective width of beam-column joints can be calculated using eq. [1, 4]

$$b_j = \begin{cases} \min\{b_c \ and \ (b_w + 0.5h_c)\} & for \ \ b_c > b_w, \\ \min\{b_w \ and \ (b_c + 0.5h_c)\} & for \ \ b_c < b_w \end{cases} \qquad [4]$$

where ;

b_w is width of a web of a beam

b_c is width of a column parallel to the width of b_w a beam framing into the column

For estimation of joint shear strength in interior beam-column joints, ES EN1998-1-2015 gives the following expression [4].

$$V_{jh} = \eta \ f_{cd} \sqrt{1 - \frac{v_d}{\eta}}\, b_j h_c \qquad [5]$$

$$\eta = 0.6\left(1 - f_{ck}/250\right) \qquad [6]$$

where:

f_{cd} is design compressive strength of concrete

v_d is normalized axial force in the column above the joint

The joint shear strength, v_{jh} (MPa) is obtained as follows:

$$v_{jh} = \frac{V_{jh}}{b_j h_c} \qquad [7]$$

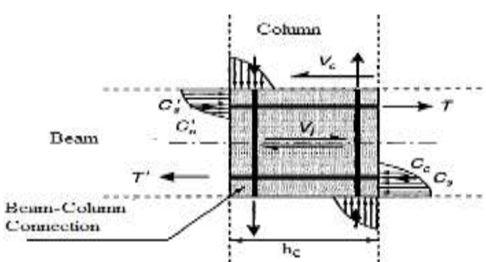
Finite Element Modeling is also an important tool in simulating shear strength of beam-column joints. Compared with experimental studies on reinforced concrete joints subjected to cyclic loading under progressive collapse, predictions using Finite Element Modeling are much more economic, convenient and efficient. Non-linear finite element analysis computer programs can efficiently predict the shear strengths of RC beam-column joints [7, 8].

Joint Shear Demand

Beam bending moments due to seismic loading have opposite sign at opposite faces of the joint. These joints in a laterally loaded frame require diagonal tensile and compressive forces within the joint. Cracks develop perpendicular to the tension diagonal in the joint and at the faces of the joint where the beams frame into the joint [9].

From the joint mechanism, shear forces in the joint are induced from over strengths of adjacent members. The method of estimation of joint shear demand adopted in this paper is the method used by many researchers and incorporated in building codes. When estimating shear demands at joints it is always recommended to calculate moment resistance of beams and columns. For the estimation of horizontal joint shear demand and column shear force, Equations (8) and (9), respectively can be used [3].

A free body diagram for Horizontal Joint Shear in Interior RC Beam-Column Joints in shown in Figure. 2. In the figure: V_j is joint shear force, $C_c{}'$ is the compressive force in the concrete, $C_s{}'$ and C_s are the compressive force in top and bottom longitudinal reinforcing bars in beam respectively. C_c is the compressive force in the concrete in bottom fiber, T and T' are the tensile forces in the top and bottom reinforcing bars in beam passing through the connection respectively. Moreover, h_c is width of column in the direction of a beam framing into the column and V_c is the column shear force obtained from beam flexural strength



at column faces [9].

Figure 2: Horizontal Joint Shear in Interior RC Beam-Column Joints [9]

$$V_j = T + T' - V_c \qquad [8]$$

where:

- V_j is joint shear force
- T is tensile forces in top reinforcing bars in beam passing through the connection;
- T' is tensile forces in bottom reinforcing bars in beam passing through the connection;
- V_c is column shear force obtained from beam flexural strength at column faces.

$$V_c \cong \frac{2*\left(\frac{l_1}{l_{1n}} M_{Rb1} + \frac{l_2}{l_{2n}} M_{Rb2}\right)}{(l_c + l_c')} \qquad [9]$$

where:

- M_{Rb1} and M_{Rb2} are moment resistances of left and right beams of the joint
- l_1 and l_2 are lengths of left and right beams of the joint
- l_{1n} and l_{2n} are clear lengths of left and right beams of the joint
- l_c and l'_c are lengths of upper and lower column of the joint

Moreover; EBCS 8, 1995 [1] and ES EN1998-1-2015 [4] give the following expression for estimation of horizontal joint shear demand of an interior joint.

$$V_j = \gamma_{Rd} \beta \left(A_{s1} + A_{s2}\right) f_{yd} - V_c \qquad [10]$$

where:

- A_{S1} is area of the beam tensile reinforcement
- A_{S2} is area of the beam compressive reinforcement
- V_c is column shear obtained from the structural analysis for the combination considered
- γ_{Rd} is 1.25 for joints of DC"H" and 1.15 for joints of DC"M" [1]

γ_{Rd} is factor to account for over-strength and should not be taken less than 1.2 [4]

β=2/3 (EBCS 8, 1995), and β=1 (ES EN 1998-1-2015)

Both Equations (8) and (10) are derived based on equilibrium forces around the joint region. In Equation (8), the column shear, V_c is obtained from Equation (9) whereas V_c in Equation (10) is to be determined from the structural analysis for the combination considered.

The joint shear demand, v_j (MPa) is given as [3]:

$$v_j = \frac{V_j}{b_j h_c} \qquad [11]$$

NUMERICAL MODELING AND VALIDATION

In this paper, for the estimation of shear strength of interior joint, FEM based simulation software (VecTor2) was used. VecTor2is a finite element computer program for nonlinear analysis of two-dimensional reinforced concrete structures. Formworks-Plus is a universal pre-processor for the entire VecTor2 software [10].

Material Modeling

In modeling beam-column joints, material parameters and mesh data concerning FEM modeling are as required by VecTor2 code. Material behavior models for concrete and reinforcement bars are shown in Tables 2 and 3, respectively. The concrete portion was modeled by using a four-nod rectangular element and the reinforcement was modeled by using a truss element [10]. For a bond between concrete and reinforcement Eligehausen model which is the default model in VecTor2 is used.

Table 2: Material Behavior Models for Concrete

Material Property	**Model**
Concrete Compression Pre-Peak Response	Hognestad Parabola
Concrete Compression Post-Peak Response	Modified Park-Kent
Concrete Compression Softening	Vecchio 1992-A (e1/e2-Form)
Concrete Tension Stiffening	Modified Bentz 2003
Concrete Tension Softening	Linear
Concrete Confined Strength	Kupfer/Richard Model
Concrete Dilation	Variable Kupfer
Concrete Cracking Criterion	Mohr-Coulomb (Stress)
Concrete Crack Slip Check	Vecchio-Collins 1986
Concrete Crack Width Check	Agg/2.5 Max Crack Width

Table 3: Material Behavior Models for Reinforcement

Material Property	**Model**
Reinforcement Dowel Action	Tassios Model (Crack Slip)
Reinforcement Buckling	Akkaya 2012 (Modified Dhakal-Maeka)

For a bond between concrete and reinforcement Eligehausen model which is the default model in VecTor2 is used [3]

Loading and Boundary Conditions

In the assessment of shear strength of beam-column joints using FEM model, the load can be applied at top of the column or at the tip end of a beam [11].

Validation of Numerical Modeling

For validation of the numerical model, an interior beam-column joint of an RC specimen tested by Noguchi and Kashiwazaki [12] was used. The cross-sectional dimension of the beams is 200x300mm. Seven bottom and nine top reinforcing bars of diameter 13mm were provided. For the stirrups, diameter 6mm bars spaced at 50mm was used. The dimension of the column is 300x300mm, twenty diameter 13mm bars and transversal reinforcements of diameter 8mm spaced at 40mm were provided.

Concrete with 28-day compressive strength, f'_c, of 70MPa and steel bar with yield strength of 1140MPa for the stirrups and 767MPa for the main reinforcements were used. The beam-column joint was modeled in VecTor2 and a monotonic load is applied at the ends of two beams with constant axial load of 756kN. Figures 3 and 4 show the experimentally tested beam and its model in VecTor2, respectively and validation of the numerical model was confirmed as shown in Figure 5.

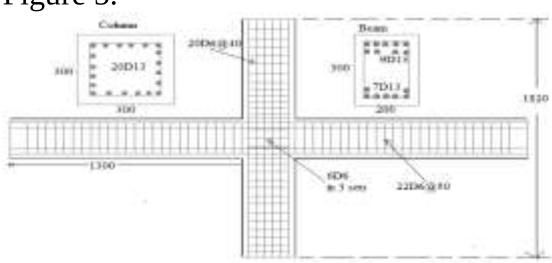


Figure 3: Beam-Column Joint [12]

In case of loading and boundary condition scenario when the beam ends is subjected to a lateral load, story drift angle is estimated as $2\Delta/L$, where Δ is the vertical deflection of beams and L is the sum of lengths of right and left beams. The story drift is then obtained by multiplying the story drift angle by the sum of column height above and below the joint.

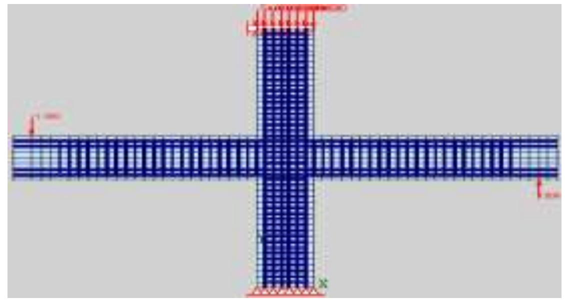


Figure 4: Model used for validation of the Beam-Column Joint

In case of loading and boundary condition scenario when the beam ends is subjected to a lateral load, story drift angle is estimated as $2\Delta/L$, where Δ is the vertical deflection of beams and L is the sum of lengths of right and left beams. The story drift is then obtained by multiplying the story drift angle by the sum of column height above and below the joint.

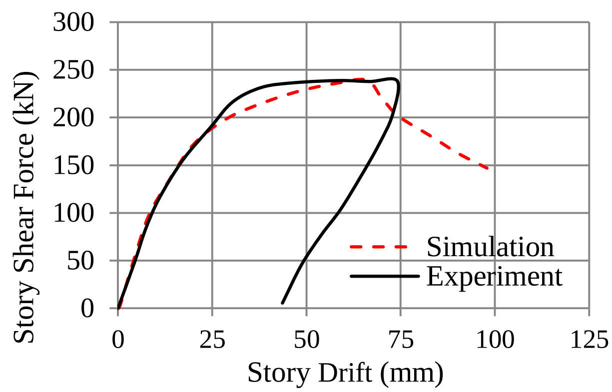


Figure 5: Load-Displacement Response of a Beam-Column Joint

ASSESSMENT OF SHEAR STRENGTH OF RC BEAM-COLUMN JOINTS

Analysis of members

An existing G+5 reinforced concrete building frame structure from which the interior joints are selected for the assessment of shear strength of beam- column joints is used. The building was designed according to the provisions of the old code, EBCS-8, 1995. The building is analyzed for seismic actions using an Extended Three dimensional Analysis of Building Systems (ETABS) to obtain responses around the joints. The cross-sectional dimension of the beams and columns of the joint are shown in Figure 6.

Modeling

After the analysis in ETABS has been completed and responses around the joints obtained, the joint is modeled in VecTor2 and the shear demand of beam-column joints is estimated based on the provision of the code and FEM based numerical simulation.

For the interior joint under investigation, the cross-sectional dimension of the beams is 200x450mm. Three bottom reinforcing bars of diameter 16mm and two top reinforcing bars of diameter 20mm were provided. For the stirrups, diameter 8mm spaced at 180mm was used. The dimension of the column is 300x300mm, eight diameter 14mm longitudinal bars and transversal reinforcements of diameter 8mm spaced at 160mm were provided. The materials used for the construction of the joint are specified as: Concrete C25 is used for all structural elements. Steel S400 is used for reinforcing bars.

The generally accepted modeling and boundary condition of beam-column joints are based on the assumption that the points of inflection of the prototype building subjected to lateral forces are at mid-span and mid-story height. It is from this assumption that loading conditions and boundary conditions are selected in the model. When building subjected to lateral forces, moments are assumed to be zero around mid-span and mid-story height in modeling beam-column joints. The model for interior Beam-Column joint is shown in Figure 7.

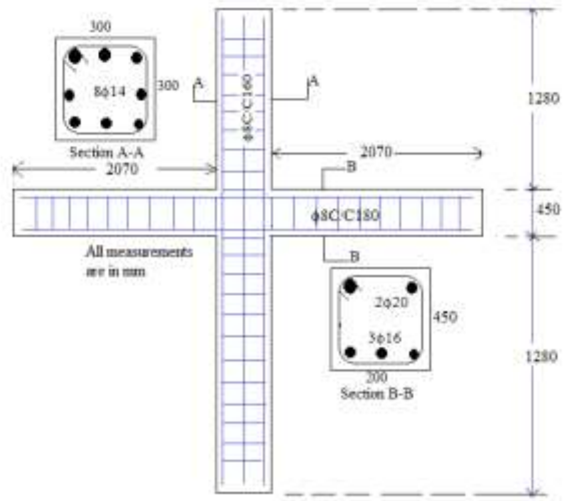


Figure 6: Interior Joint under Investigation

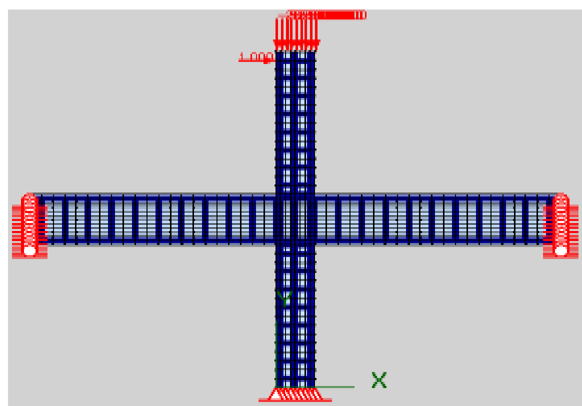


Figure 7: Model for interior Beam-Column joint (VecTor2)

Joint horizontal shear demand and shear strength

To identify the member that governs the shear input to the joint core, the joint horizontal shear demand and strength is estimated after the investigation for the strong column – weak beam requirement. The strong column – weak beam requirement is given in Equation (12).

$$\sum M_{Rc} / \sum M_{Rb} \geq 1.3 \qquad [12]$$

where:

M_{Rc} is Moment capacity of column

M_{Rb} is Moment capacity of beam

Moment and shear capacities of reinforced concrete sections are computed as per ES-EN 1992-1-1-2015[13]. The sagging and hogging moment capacities of the beams are: M_{Rb1}=105.8kNm, M_{Rb2}=106.7kNm and the moment capacity of columns are found to be M_{Rc1}=M_{Rc2}=52.044kN-m. The moment resistances of column above and below the joint is the same since the size and reinforcement in the column above and below the joint are the same and a single column axial load is taken to be applied to the joint. For the joint modeled the requirement of strong column – weak beam was checked using Equation (12) and a ratio of 0.245 was obtained. This value is less than 1.3 which is the minimum requirement.

So, the interior joint designed and detailed as per the provision of EBCS-8, 1995 is not adequate to satisfy the requirement of strong column-weak beam per the revised code (ES EN1998-1-2015). The column is weaker than the joining beams. This makes plastic hinges form in columns and column failure occurs before beam failure under the action of lateral loads, especially under seismic loads. This situation leads to global failure of the structure sooner as failure of column is more critical than failure of beams.

Horizontal joint shear demand and strengths calculated according to different code provisions of EBCS-8, 1995 and ES EN1998-1-2015are presented in the Table 4 and Table 5, respectively.

Table 4: Horizontal Joint Shear Demand

Models	Horizontal Joint Shear Demand (Interior Joint)	
	V_j(kN), Equation (10)	v_j(MPa) , Equation (11)
EBCS-8, 1995	318.68	3.54
ES EN1998-1-2015	490.02	5.44

Table 5: Horizontal Joint Shear Strength

Models	Horizontal Joint Shear Strength (Interior Joint)	
	V_{jh}(kN)	v_{jh}(MPa)
EBCS-8, 1995	450.00, Equation (3)	5.00, Equation (7)
ES EN1998-1-2015	284.74, Equation (5)	3.16, Equation (7)

As shown in Table 4, the seismic demand of the structure following the revision of the code has been increased; the horizontal shear demand of the joint has increased.

Estimation of Shear Strength of Joints using Numerical Simulation

To investigate the shear strength of the joint, an interior joint shown in Figure 6 is modeled in VecTor2. Columns in the joint are identified to be weaker than beams i.e, column governs the shear input into the joint core [4]. Hence, monotonic lateral load is applied in the form of displacements at upper column end.

A constant axial load of 416.09kN obtained from seismic analysis is also applied upper column end. The lower column end is provided with hinged boundary conditions and both the beam ends were provided with roller boundary conditions.

The upper column end is allowed to move horizontally. As shown in Table 5, shear strength obtained according to ES EN1998-1 (2015) is 3.16MPa. However, the shear demand is 5.44MPa. This shows that the shear strength requirement is not satisfied as per ES EN1998-1 (2015). From numerical modeling in VecTor2, the joint shear strength is found to be 5.47MPa.

The joint shear stress versus column's horizontal displacement is shown in Figure 8. The result from numerical modeling (5.47MPa) is slightly greater than the shear demand (5.44MPa) estimated as per ES EN1998-1 (2015). This result may show that the shear demand can be resisted.

However, the result from numerical modeling does not mean the joint satisfies both strong column – weak beam and shear strength requirements as per ES EN1998-1 (2015) since the joint shear strength according to ES EN1998-1 (2015) is 3.16MPa.

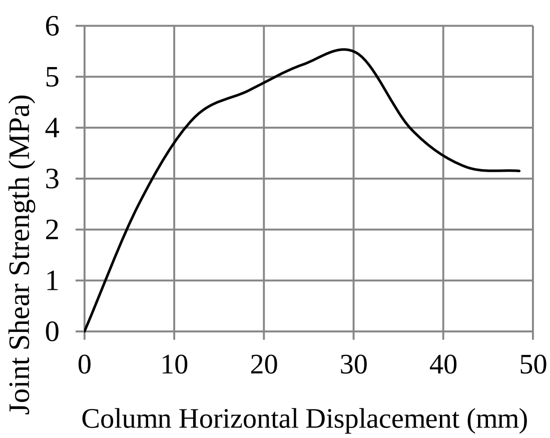


Figure 8: Shear Strength of Joint Core for the Interior Joint

Enhancement of the Shear Strength of an Interior Joint

As illustrated earlier, the interior joint investigated does not satisfy both capacity design rule and shear strength requirement of beam-column joints provided in ES EN1998-1 (2015). Thus, in this section, an interior column is strengthened by concrete jacketing and the behavior of the joint regarding both ductility and shear strength was investigated.

Strengthening of an Interior Column

The existing interior column investigated in this study is enough in resisting all axial, shear and moment responses from the seismic analysis. However it doesn't meet the capacity design rule specified in ES EN1998-1-2015. Both the shear and flexural capacities of the column (79kN, 52.04kN-m) are less than the shear and flexural capacities of the joining beams (97.5kN, 112.6kN-m). The moment capacity of the column shall be increased to enhance the strength, stiffness, ductility, stability, and integrity of the building. To handle this case, strengthening of the column in the interior joint becomes important.

Design of Column Jacketing

The seismic demand of the column was increased to 428kN and 143.78kNm.Even if different methods of column strengthening exist, in this study, strengthening of RC column by concrete jacketing was used. Design of column jacketing is carried out for the design actions specified and the column is redesigned accordingly [13]. The size of the column becomes a square section of size 450mm provided with additional 4 diameter 14mm longitudinal reinforcing bars and minimum transverse reinforcement of diameter 8 mm with a spacing of 160mm is provided.

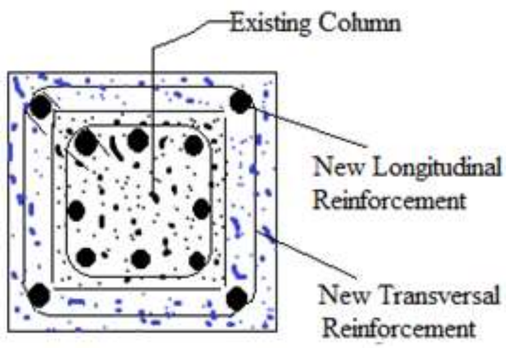


Figure 10: Detail of Column Jacketing [14]

Horizontal Shear Strength of the Interior Joint after Column Jacketing

After the column has been jacketed, a shear capacity of 140.35kN, axial load carrying capacity of 430kN and flexural capacity of 145.34kNm were achieved. Based on the analysis result, the strengthened column has been modeled and its capacity was assessed. The result shows that the requirement of strong column-weak beam was found to be satisfied.

The horizontal shear demand (V_j) and the horizontal joint shear strength (V_{jh}) were calculated as 614.20kN and 973.96kN, respectively. Moreover, the joint shear strength based on ES EN1998-1-2015 has improved from 3.16MPa to 5.093MPa.

CONCLUSIONS

This study has attempted to assess the shear strength of reinforced concrete beam-column joints. Based on the study, the interior to joint designed and detailed according to the old code (EBCS 8, 1995), the requirement for strong column-weak beam is not satisfied and the joint fails to satisfy the shear strength requirement of ES EN1998-1-2015.

The study also shows that there is a significant improvement in the capacity of the column after the section has been strengthened. RC test specimens tested by Noguchi and Kashiwazaki were used to verify the output of the model and it has been validated. Since the failure of joints is catastrophic, proper design and detailing of RC beam column joints is essential.

REFERENCES

[1] Paulay, T. and Priestley, M.J.N, *"Seismic Design of Reinforced Concrete and Masonry Buildings"*, John Wiley and Sons,Inc., 1992.

[2] EBCS-8, 1995, "*Design of Structures for Earthquake Resistance"* Ministry of Works and Urban Development, Addis Ababa, 1995.

[3] ACI352R-02, "*Recommendations for Design of Beam-Column Connections in Monolithic Reinforced Concrete Structures",* American Concrete Institution, 2002.

[4] Paulay, T. and Priestley, M.J.N, *"Seismic Design of Reinforced Concrete and Masonry Buildings"*, John Wiley and Sons,Inc., 1992.

[5] ES-EN 1998-1-1-2015, "Design of structures for earthquake resistance – Part 1", Ministry of Urban Development & Construction, Addis Ababa, 2015.

[6] Englekirk,E. Robert, "*Seismic Design of Reinforced and Precast Concrete Buildings"*, John Wiley & Sons,Inc., 2003.

[7] Altoontash, Laura N. Lowes and Arash,"*Modeling Reinforced-Concrete Beam-Column Joints Subjected to Cyclic Loading"*, Journal of Structural Engineering, ASCE, 2003.

[8] Del Vecchio, C. M. Di Ludovico, A. Prota and G. Manfredi. Greece *"Advanced Numerical Modeling for Damage Analysis of RC Structures: A Case Study on Beam-Column Joints"*, Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, 5th ECCOMAS, 2015.

[9] Zhangcheng Pan, Serhan Guner and Frank J. Vecchio, *"Modeling of interior beam-column joints for nonlinear analysis of reinforced concrete frames",* Journal of Engineering Structures, Elsevier Ltd., April 2017.

[10] Fardis, Michael N, *"Seismic Design, Assessment and Retrofitting of Concrete Buildings: Based on EN-Eurocode 8",* Greece, 2009.

[11] Wong,P. S. Vecchio F.J. and Trommels, H. "*Vector2 & Formworks User's Manual*", August 2002

[12] Dinh, Cong Thuat Dang and Ngoc Hieu, *"Experimental Study on the Structural Performance of Beam-Column Joints in Old Buildings without Designed Shear Reinforcement under Earthquake"*,Trans Tech Publications, 2017.

[13] Kashiwazaki, H. Noguchi and T. Rotterdam, *"Experimental Studies on Shear Performances of RC Interior Column-Beam Joints with High Strength Materials",*Tenth World Conference, Earthquake Engineering,pp. 3163-3167, 1992.

[14] ESEN1992-1-1:2013, "*Design of Concrete Structures*" , Ethiopian Building Code Sandard, Addis Ababa, 2013.

[15] Nikita Gupta et al. *"Design and Detailing of RC Jacketing for Concrete Columns"*, Journal of Mechanical and Civil Engineering, National Conference on Advances in Engineering, Technology & Management, PP 54-58, 2014.