Analysis of Joint Behaviour of Column Beams against Cyclic Load with Added Rebar in Joint Accordance to SK SNI T-15-1991-03

View the article online for updates and enhancements.

Analysis of Joint Behaviour of Column Beams against Cyclic Load with Added Rebar in Joint Accordance to SK SNI T-15-1991-03

Zardan Araby[1*], Abdullah[1] and Affifudin[1]

[1]Civil Engineering Faculty, Syiah Kuala University, Banda Aceh, Indonesia

*Corresponding author: zardan_araby@yahoo.com

Abstract. Joint beam-columns are the main structural components that function to support other structural loads. The beam-column relationship area is a critical area that needs to be designed to be truly accurate so that it can dissipate energy properly well in the event of an earthquake happen. As a structural component with the role and function, column joint beams occupy important positions in the building. The ability of column joint beams to deform cyclic loads in the inelastic region provides a good structure, so as to minimize damage caused by earthquake shaking. The failure of column joint beams directly affects other structural components associated with it. The purpose of this study was to study the ability of building structures on concrete beam-column joint elements to resist cyclic load with reinforcement in accordance with SK SNI T-15-1991. Test specimens amounted to 1 (one) with a concrete quality of 19.17 MPa. The beam measuring 120 x 30 x 40 cm, column measuring 30 x 30 x 200 cm using reinforcement 8, 13.4 mm with a melting voltage (fy) 310,03 MPa and stirrup reinforcement Ø9.8-100 mm with melting stress (fy) 374,59 MPa. The test was carried out by giving a cyclic load to the end of the beam with 0.75 mm, 1.5 mm, 3 mm, 6 mm, 12 mm, 24 mm and monotonic loading, until the specimen was destroyed. The results achieved in this study are the use of reinforcement reinforcement according to SK SNI T-15-1991-03 the capacity of the cyclic load produced is higher, namely 6,97 tf (press) and 5.09 tf (tensile).

Keywords: Beam-column joint, Cyclic Load, Joint SK SNI T-15-1991-03

1. Introduction

Beam-column joint is the main structural component that functions to bind other structural loads which are cyclic loads to the column joint. As a structural component with these roles and functions beam-column joints occupy important positions in the building. Failure in beam-column joints will have a direct effect on other structural components associated with it. The planning of beam-column joint structures must be carried out carefully in order to provide higher strength reserves for other structural components, so that if a building is damaged, it is expected that the column can still support other structural components. Schodek mentions that joint stiffness giving a lot of stability to lateral forces [1]. Loads that work laterally such as wind and earthquake forces can cause structures to collapse laterally if the connecting point is not rigid enough.

In general, the behavior of destruction of beam-column joints that occur due to cyclic loads at minimum to maximum load conditions begins with shear cracks in the joint area. If the cyclic load continues to increase in the beam-column joints and the main reinforcement is not enough to bind the

joint column beam and maintain it against local buckling, then immediate destruction occurs . To prevent this, it is necessary to plan a beam-column joint that is stronger in resisting cyclic loads by considering the effects of restraints. One way that can be done is to add Sengkang reinforcement to the joint in the hope that it can increase the effect of restraints on the beam-column joints so that the risk of destruction can be minimized [2].

Given the magnitude of the role of beam-column joints in preventing the total collapse of building structures, the purpose of this study is to study the ability of building structures on reinforced concrete column joint elements in resisting cyclic loads with reinforcement configuration in accordance with SK SNI T-15-1991 and in this study termed SNI91 [3]. The reason for using the old regulation is to get the results compared and applied according to the conditions in the field so that old buildings that use SK SNI T-15-1991 regulations that have suffered damage to the joints can be found the best solution to repair without having to destroy buildings.

The addition of stirrup reinforcement in the joint area and distribution of reinforcement to the column is an important variable in determining the level of capacitance of beam-column joints in reinforced concrete construction. The specimens used in this study were reinforced concrete column beams, beams measuring 30 x 40 x 120 cm3 columns measuring 30 x 30 x 200 cm3 using 8Ø14 mm reinforcement with yield stress (fy) 310.03 MPa and stirrup reinforcement Ø10-100 mm with melting stress (fy) 374.59 MPa [4]. The specimen is mounted on top of the frame with a horizontal column vertical beam configuration and the two ends of the column are tied using a steel elbow plate with a thickness of 15 mm.

When casting reinforced concrete column test specimens, cylindrical control specimens are made 15 cm in diameter and 30 cm in height as many as 3 (three) pieces as concrete quality controllers. Testing of reinforced concrete column beam objects is carried out after the concrete age reaches 28 days, the tested column balom test object is rigidly installed on the steel frame (frame) available at the Civil Engineering Department of Construction and Building Materials Laboratory. In reinforced concrete column test specimens, Linear Variable Displacement Tranduser (LVDT) is used to measure deflection of reinforced concrete column beam, Omega Tranduser measuring device which serves to measure the width of concrete cracks that occur in the beam-column joint area. All of these measuring devices are connected and monitored through the Portable Data Logger TDS 302.

Reinforced concrete column beam test is carried out by loading cyclic loads with varying pulling cycles, namely diplacement of 0.75, 1.5, 3, 6, 12, 24 mm and monotonic so that the column beam specimens are destroyed [4]. The cyclic load capacity obtained by beam-column joints referring to SK SNI T-15-1991 (SNI91) is 6.97 reject tons and 5.09 tons of tensile. The amount of displacement at maximum load is 12 mm. The ductility of the specimen is 4.22 and the largest displacement that occurs in the LVDT reading after monotonic loading is 50.98 mm with a load of only 5.63 tons.

The crack pattern that occurs in reinforced concrete column beam specimens predominantly forms a horizontal crack pattern in the beam support area and is followed by shear cracks and flexible cracks in the area joint. Larger cracks occur at the beam connection point with the column. This is due to the column beam and joint shear capacity being reinforced with stirrups so that the weak point is flexural capacity. The initial cracks of reinforced concrete column test specimens occurred when the compressive load was 2.80 tons and the tensile load was 1.70 tons [5].

2. Literature Review
2.1. A Column
Column is a vertical press rod from the frame structure that bears the burden of the beam. Column is a compressive structural element that plays an important role of a building, so that a collapse in a column is a critical location that can cause the collapse of the relevant floor and also total collapse of the entire structure [6]. SK SNI T-15-1991-03 defines columns as components of building structures whose main task is to support vertical press axial loads with high parts that are not supported at least three times the smallest lateral dimensions.

According to [7] in reinforced concrete structure books, there are three types of reinforced concrete columns, namely:

  i. The column uses a lateral stirring binder. This reinforcement serves to hold the main reinforcement to keep it firmly in place.

  ii. The column uses a spiral binder. The shape is the same as the first except that as a binder the longitudinal staple is a rounded spiral loop forming a continuous helix along the column.

  iii. Composite column structure is a compressed structural component that is reinforced in the longitudinal direction with a profile steel girder or pipe, with or without the main reinforcement bars

2.2. Beam

Beam is a structural part of a building that is rigid and is designed to bear and transfer loads to the supporting column elements. In addition, the beam ring also functions as a binder of the columns so that if there is a movement of the columns it remains united to maintain the original shape and position. Ring beams are made of the same material as the column so that the ring beam relationship with the column is rigid, not easily deformed. Non-uniform force patterns can result in curved or deflected beams which must be held by the internal strength of the material [8].

2.3. Concrete

Concrete is a composite building material made of aggregate and cement bonding. The most common form of concrete is portland cement concrete, which consists of mineral, cement and water aggregates. The small cement water factor will cause porosity in the concrete. The porosity of the concrete is affected by less than optimal compaction of concrete due to the low cement water factor value. The greater the FAS value (Cement Water Factor), the greater the porosity and vice versa. To get a strong concrete as planned, it must use the appropriate FAS value, while the use of a low FAS value will make it difficult to work on the concrete, so that the compaction in the concrete is not optimal and results in porous concrete which will reduce the compressive strength [9].

2.4. The compressive strength of concrete

The compressive strength of concrete is the quality produced from a specimen structure. The higher the level of strength of the desired structure, the higher the quality of the concrete produced. Factors that influence the compressive strength of concrete include the proportion of constituent materials, methods of implementation, maintenance, and circumstances at the time of casting [10]. Testing of concrete compressive strength was obtained through standard testing using a compressive testing machine by giving a multilevel load at a certain load increasing speed on the concrete cylinder test specimen to disintegration. The test procedure commonly used is the standard of the American Society for Testing.

3. Method of Research

The materials used in this study were portland cement, water, reinforced iron, sand and split. The cement used is type I Portland Cement produced by PT. Semen Andalas Indonesia. The water used for concrete mixture and its treatment comes from clean water from the Regional Water Company (PDAM) Tirta Daroy Banda Aceh. The main reinforcement iron used is plain steel 8Ø14 mm, while for stirrup reinforcement plain steel Ø10-100 mm is used which is obtained from stores around Darussalam. The aggregates and sand used for concrete mixtures are the result of natural disintegration of the rocks, aggregates and sand obtained from the Krueng Aceh river.

3.1 Test of Cylinder Concrete Press Strength

Concrete cylinder compressive strength testing is done to determine the desired compressive strength of the concrete. Compressive strength testing was carried out when the specimen was 28 days old. Concrete cylinder compressive strength testing is used to represent the casting of the beam as a control specimen. Testing the compressive strength of cylindrical specimens can be seen in figure 1.
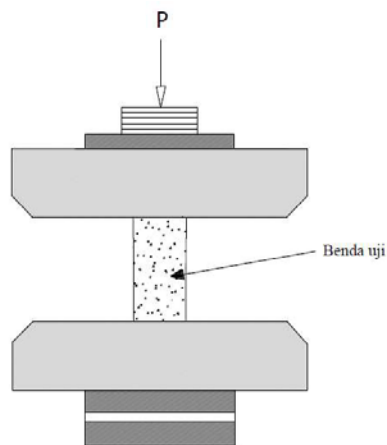
Figure 1 Cylindrical test object
strength testing.

3.2 Steel Tensile Testing
The reinforcing steel used for beam columns is plain reinforcement of 8 × 14 mm and plain steel Ø10-100 mm for dash. The quality of steel is determined by the steel tensile test according to ASTM E.8-81 procedure. At the pull of this steel, the load is provided continuously until the steel breaks. Stretching readings are performed every 100 kg load by transducer dial readings. The result of this test is illustrated in a steel strain tension relationship with strain so that it can be obtained by tensile strength of steel and stretch of lengge.

3.3 Mix Proportion Planning
The concrete mix design is planned based on the American Concrete Institute (ACI 211.1-91) method for normal concrete. Based on this method, the weight of each material used will be obtained, namely the amount of aggregate, cement, and water. The concrete used in this specimen is normal concrete with a maximum size of the aggregate diameter of 19.1 mm with the quality obtained at f'c = 19.17 MPa.

3.4 Details of Joint Beam Column Test Objects
The planned specimen is a reinforced concrete beam element with a cylinder compressive strength of 19.17 MPa with columns measuring 30 x 30 x 200 cm and 30 x 40 x 120 cm for beams. Test specimens were made based on research needs, namely test specimens for testing cyclic load capacity in reinforced concrete column joints. The planned specimen consists of normal reinforced concrete with fine aggregates, coarse aggregates, reinforcing iron and water. The main reinforcement used is 8Ø14 with a melting tensile strength (fy) of 310.03 MPa. Sengkang Reinforcement uses steel Ø10-100 mm with a strong melting pull (fy) of 374.59 MPa. Clearer the shape and details of column joint beam test objects can be seen in figure 2 below.
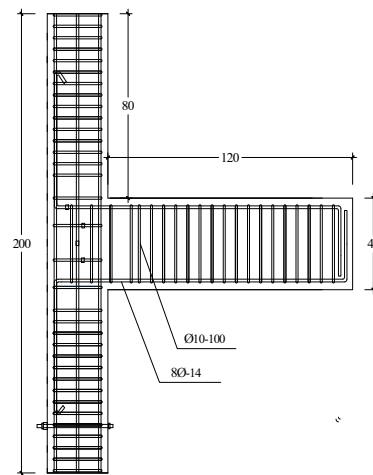
Figure 2. Form of cross-section testing.

3.5 Procedure for Testing Joint Column Test Objects

Tests are carried out when the test object is 28 days old. Testing of column beam test objects is carried out together with cylindrical specimens. The cyclic load capacity that will be taken into account is the load compressive strength resulting from the testing of the compressive strength of the cylindrical specimen. Before testing, the surface of the test object is painted in white and the grid is drawn first, to make it easier to draw the resulting crack pattern. The series of test kits and the installation of specimens in steel frames (frames) in detail are presented in the following figure 3. The test object is rigidly mounted on the frame beam. At the end surface of the beam field a two-way steel plate is attached, which is connected with a bolt, the plate is tied to the load cell to be given the desired cyclic load. Load is given horizontally against the end of the beam. Horizontal load is given by the hydraulic jack connected to the load cell and forwarded to the column beam test object. The given load is controlled by reading the dial in the data logger. Loading is carried out in a cycle and each cycle is read load and illustrated the crack pattern that arises. Load is given until the test object is destroyed. On the side of the beam a transducer is installed to read the deflection in the lateral direction.
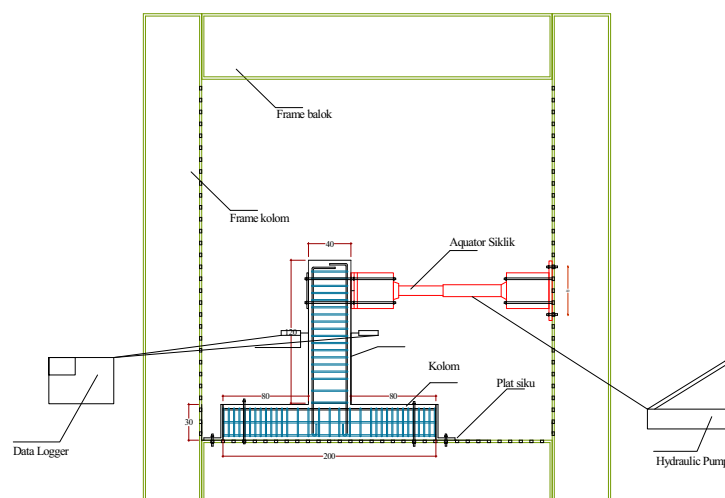

Figure 3. Beam-column joint speciment test set up.

Strains that occur in beam-column joints are read by a Portable Data Logger that has been connected to a strain gauge. Loads is stopped when the load no longer increases due to the test object being unable to accept the load so that the specimen is cracked and destroyed. The pattern of crack development is monitored at all times by making a crack image that occurs in the column according to the amount of load given.

4. Results and Discussion

The discussion carried out based on the results of testing the cyclic load capacity of the joint reinforced concrete column beam includes the cracking pattern, ductility, stiffness and energy dissipation that occurs in the joint.

4.1 Joint Beam Column Crack Pattern

Testing of beam-column joint test objects shows a crack pattern that is relatively horizontal in shape on the pedestal, as shown in figure 4.
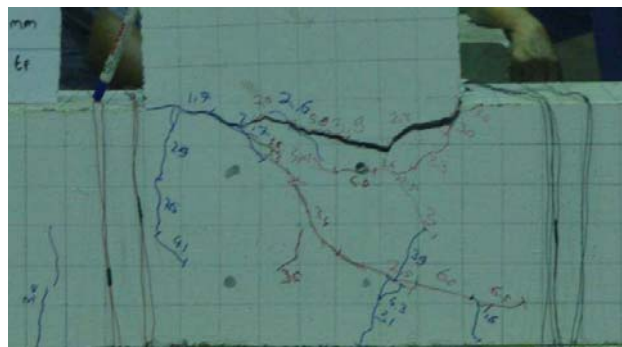

Figure 4. Crack load pattern (-), 24 mm.

The initial crack occurs in the beam-column joint test object is in the cycle (1) 3 mm tensile load where the load that occurs is equal to 2.80 tf, while the crack that occurs lies in the shear angle. Furthermore, in the same cycle of cycle (1) 3 mm, which is tensile load, cracks also occur again at 1.70 tf load, with the shape and location of cracks in the upper left corner of the joint area stretching down the column for about 16 cm and after being given flexion full ie 3 mm (+) produces a load of 3.60 tons. The results are shown in figure 5 and 6 below.
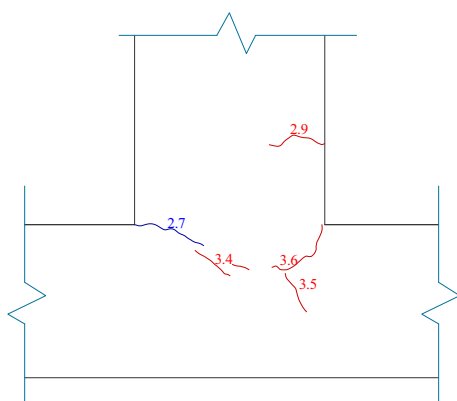

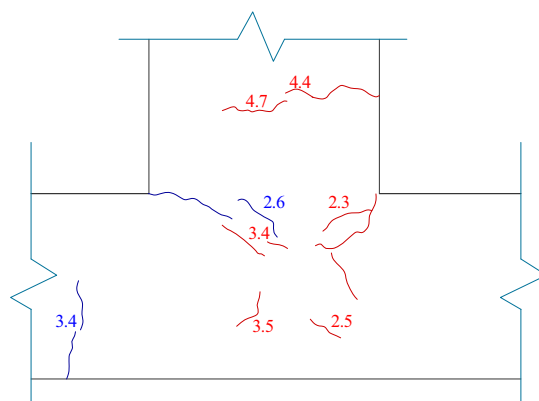**Figure 5.** Loads Cracked Pattern 3 mm.

Figure 6. Loads Cracked Pattern 6 mm.

In monotonic loading, cracks occur in the area around the beam-column joint, which occurs continuously widening. The biggest cracks occur in the beam support area that has fused and continues to expand as it does loading. For a clearer variety of crack patterns that occur in monotonic loading is in figure 7. below.
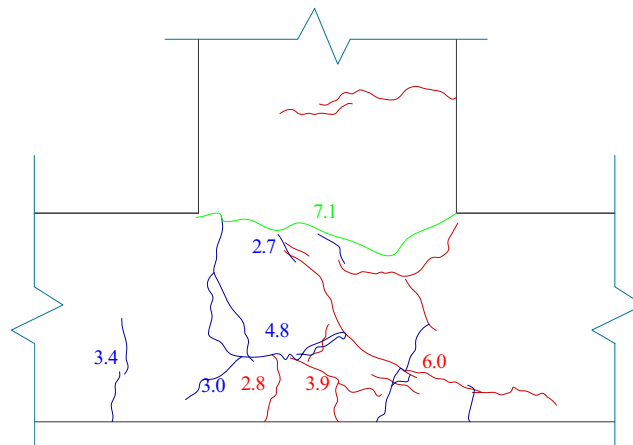

Figure 7. Monotonic loads cracked pattern.

4.2 Column Beam Secants Stiffness
The decrease in secant stiffness in column beam specimens is calculated based on section 2.9.1. The graph of the relationship of decreasing stiffness with lateral displacement can be seen in figure 8.
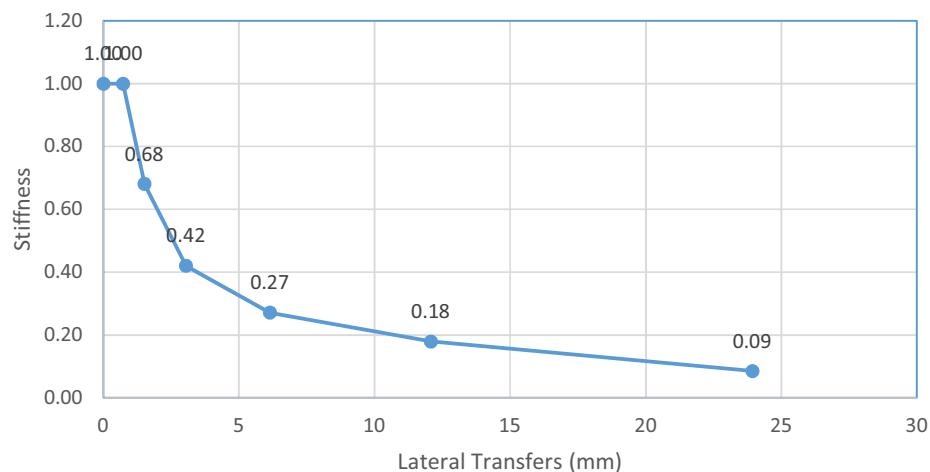

Figure 8. Graph of relative decreases relative securities stiffness.

Based on figure 8, the test specimen experienced a decrease in stiffness starting from the lateral displacement of 0.73 mm to the displacement of 1.515 mm at 0.68 mm. In the next stiffness the specimen continued to decrease stiffness in the lateral displacement of 6.14 mm by 0.27 to the final stiffness at the displacement of 23.93 mm at 0.09. The conclusion obtained from the graph above is that the SNI91 test object continues to decrease stiffness before the last loading cycle is carried out.

4.3 Relationship Load - Strain Reinforcement

Measurements of the main reinforcement steel and stirrup reinforcement on column specimens were carried out on 2 (two) reinforcing steel, columns and beams. Testing of beam-column joint test items with the SK SNI T-15-1991-03 regulation, greater reinforcement strain occurs than regulations that still use PBI, due to the addition of stirrup reinforcement in the column joint joint area, so that the reinforcement is more restrained resulting in a greater load.

5. Conclusion

Based on the results of research, data processing and discussion that has been done, a number of conclusions can be taken and suggestions include:

i. The addition of stirrup reinforcement in the beam-column joint area can increase the value of cyclic load capacity.

ii. Cyclic load capacity obtained when the maximum load is 6.97 tf (reject), 5.09 tf (pull).

iii. Displacement obtained when the maximum load is 50.98 mm.

iv. Decreased stiffness of column beam secant is 0.09 with displacement of 23.93 mm.

v. The biggest energy dissipation cycle occurs at a load of 24 mm. The biggest energy dissipation value is 13.25. The presence of stirrups on the joint can increase energy dissipation in the joint by giving stiffness to the joint.

References

[1]　Schodek, D.L (1998) *Struktur*, Terjemahan Bambang Suryoatmono, Refika Aditama, Bandung.

[2]　Dahl. K.K.B. (1992) : Uniaxial Stress Strain Curves for Normal and High-Strength Concrete, Departmenet of Structural Engineering, Lyngby, Technical University of Denmark.

[3]　Bae, S., dan Bayrak, O., (2003) : Early Cover Spalling in High Strength Concrete Columns, *Journal of Structural Engineering*, V.129, No.3, March, pp.314-323.

[4]　Ansari,F., dan Li, Q. (1998): High Strength Concrete Subjected to Triaxial Comression, *ACI Materials Journal* V.95, No. 6, November-December, pp747-755.

[5]　Richard, P. & Cheyrezy, M. (1994) RPC with High Ductility and 200-800 MPa Compression Strength, *Proceeding of V. Mohan Malhotra Symposium*, pp. 507-518, Farmington Hills.

[6]　R.Sudarmoko (1996), Diagram Perancangan Kolom Beton Bertulang, Jurusan teknik Sipil, fakultas Teknik, UGM, Yogyakarta.

[7]　Chapalkar, Subhash, Khetre, Meshran (2015), Modal Analysis of Cantilever Beam Structure Using Finite Element Analysis & Experimental Analysis, in *American Journal of Engineering Research*).

[8]　Sheikh, S.A., dan Khoury, S.S. (1993) : Confined Concrete Columns with Stubs, *ACI Structural Journal*, V.90, No.4, July-August 1993, pp.414-431.

[9]　Imran, I., Moestopo, M., dan Suharwanto (1999) : Strength and Deformation of Confined High Strength Concrete, *First International Conference on Advance in Structural Concrete Engineering and Mechanics*, Seoul, August 1999, pp.373-378.

[10]　Paultre, P., Légeron, F., (2008),"Confinement Reinforcement Design for Reinforced Concrete Columns", ASCE, *Journal of Structural Engineering*, Vol. 134, No. 5, May 1, pp. 738-749.

[11]　Dipohusodo (1999), *Struktur Beton Bertulang*, PT. Gramedia Pustaka Utama, Jakarta.