DUCTILITY OF THE PRECAST AND MONOLITH CONCRETE ON BEAM-COLUMN JOINTS UNDER CYCLIC LOADING

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ABSTRACT

The use of precast construction in recent years is increasing rapidly, and therefore has several advantages over conventional constructs which can provide high quality control, efficient in manufacturing of construction, can save time and costs and can reduce construction waste resulting from the use of formwork. One important part of the work is the work on the construction of precast beam-column connections, connection areas need to be designed such that it can meet the criteria of strength and ductility of the main building in case of earthquake loads. This study is an experimental study to investigate the ductility of precast concrete compared to monolith construction on the beam-column joints structure subjected to cyclic loading. Test specimen consists of 2 beam-column joints, 1 precast construction (PC) and 1 monolith construction (MC) is made with a full-scale 1: 1. Column dimensions are 300 x 300 x 2600 mm and beam 200 x 250 x 1500 mm. connecting the precast concrete is a straight model, spliced using cement grout. Testing was conducted using displacement control, with the gradual type. The study reveals that PC has higher ductility compared with MC. Ductility of PC, μ = 4,379, while the MC, μ = 2,333.

Keywords: precast concrete, beam-column joint, cyclic loading and ductility.

INTRODUCTION

Concrete as a structural material has been known for a long time and is widely used because it has many benefits / advantages compared to other building materials; hence the concrete is almost always used in civil projects mainly in the construction of buildings, bridges, roads and so on. Construction of concrete used to consider various aspects of good advantages such as flexibility, high compressive strength, enough to fire and weather resistant, easy to obtain constituent materials and so forth. In building construction, the panel meeting beams and columns are part prone to earthquake resistant structures for the specific nature of transmitting energy. When the structure was hit by an earthquake, there will be a very large shear force on the beam-column panel meeting, especially when the onset of the beam plastic hinge on the face of the column. This shear force can result in the collapse of the core of the joint panel shear capacity either because of its path or due to loss of attachment of the reinforcement or as a result of both [7].

Many researchers were interested to further investigate this issue, due to the beam-column connections are a vital component in a building structure. This part is very important because it has a major role in transferring the style of an element in a structure to other element. Sometimes the influence of lateral forces such as earthquakes, beam-column connections this experienced and horizontal shear force greater than the beam elements and the adjacent column. Flow through style beam-column connection can be interrupted if the connection is not able to provide adequate shear strength. When the shear capacity in the field of this meeting is not sufficient, cracks may occur and ultimately failure structure occurs [5].

Based on the author is also interested in studying the beam-column connection, by making it in a precast construction. Precast concrete is a structural element that is not printed in the place where the element is installed, but printed in other places where the casting is well done and appropriate treatment methods. The advantages of precast concrete compared to conventional concrete of which could accelerate the execution time of the project. The many advantages of making use of precast concrete increased in recent years.

Research on precast concrete has been done, including by Tjahyono et al. [9]. Ductility ratio obtained quite adequate, it produces ductility in the top 3.
Neither study conducted by Suherman [8], ductility values obtained from precast connection using the BSC model is 6.45. This has to be the full ductile value. Various other studies indicate that the ductility of precast concrete is still better than the concrete monolith.

So the object of this research is devoted to the precast beam-column joints, which are given cyclic loading. This research is an experimental study to determine differences in ductility of monolith and precast structures, where the connection of precast is in the area plastic hinge. Analysis of cracks on the beam to be reviewed primarily in the area connecting the plastic hinge. The results are compared with existing models of precast previously.

BASIC THEORY

Precast Concrete

Component of precast concrete is a structural element that is not in-cast / printed in the place where the element is installed, but printed / on-cast in other places where the casting is well done and appropriate treatment

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methods. After the elements so, then brought to the location to be arranged into a unified structure according to its function. Basically it is not made of precast concrete in the project exercising their place, but precast factory [1].

Precast concrete has many advantages compared to conventional concrete. Following advantages of precast concrete [1]:

1. Timing of the project could be faster. By using precast concrete, eg in the building project, at the time the work is still in the stage of foundation structures, where implementation could simultaneously with the production of precast concrete. The elements that will be installed in advance can be produced earlier, when the life of the concrete has been achieved and the work completed under the structure of these elements ready to be installed. With the work of the project so overlapping shorter
2. The use of less formwork.
3. Quality is assured, as is done with a good method and good care in precast concrete manufacturer.
4. Reducing the cost of construction, because the manufacturer of precast wage workers lowers wages than workers in the project.
5. Has no effect on the weather.
6. More environmentally friendly, because the project site is not a lot of dirt and concrete remnants formwork.

The principle of connection planning in precast elements can be classified in two categories [4], namely:

1. Strong Connection, when joints between precast elements still behave elastic during a strong earthquake, the connection system and proved to be theoretically and experimentally have the strength and hardness of the minimum equal to that of the structure of the connection equivalent concrete monolith.
2. Connection Ductile, when the connection inelastic deformation may occur, the system connection must be proven theoretically and experimental meet reliability requirements and stiffness of earthquake resistant structures.

Precast portal system developed in this study is planned to use a strong connection.

Ductility

Ductility is the ability of the structure or structural components to undergo inelastic deformation alternating repetitive after the first melting, while maintaining sufficient strength and rigidity to support the load, so that the structure remains standing despite being cracked / damaged and on the verge of collapse [2].

Building structure ductility factor μ is the ratio between the maximum deviation of the building structure due to the influence of the plan at the time of the earthquake reached the brink of collapse conditions and deviation δm building structure at the time of the first melting δy. At full elastic condition value μ = 1.0.

Ductility level structure is influenced by the pattern of cracks or plastic hinge, wherein the plastic joints must be arranged to form at the ends of the beams and columns and walls not on the bear. Mathematically ductility is as a comparison parameter displacement structure collapsed during the displacement at the outer tensile reinforcement when experiencing fatigue [2, 3].

According to Paulay and Priestley [6] ductility divided into:

1. Ductility strain is the ratio of maximum strain to strain on the beam melting experiencing tensile axial load or press;

$$\mu_\varepsilon = \frac{\varepsilon_u}{\varepsilon_y}$$

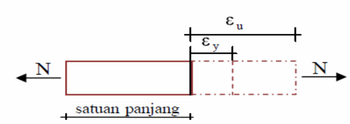

Figure-1. Ductility strain.

2. Ductility curvature (curvature ductility), is the ratio between the curvature angle (rotation angle per unit length) with a maximum angle of curvature of the melting of a structural element due to bending force;

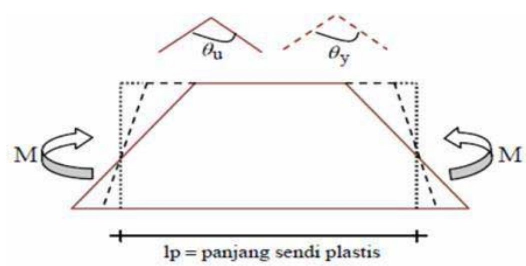

Figure-2. Ductility curvature.

3. Rotational ductility is the ratio between the maximum rotation angle of the rotation angle of melting

$$\mu\theta = \frac{\theta u}{\theta y}$$

$$\mu_\varphi = \frac{\varphi_u}{\varphi_y}$$

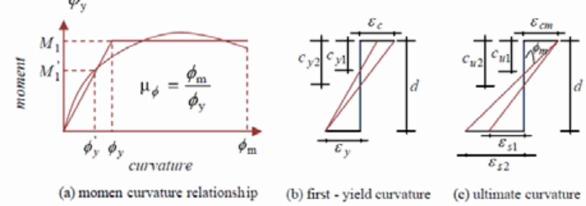

Figure-3. Ductility rotation.

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4. Displacement ductility is the ratio between the maximum structural displacements in the lateral direction of the movement of the structure while melting.

$$\mu_\Delta = \frac{\Delta_u}{\Delta_y}$$

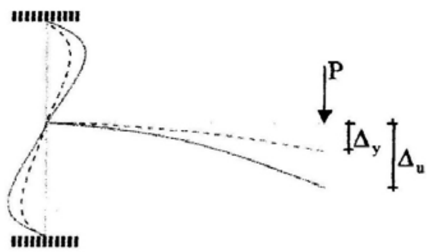

Figure-4. Ductility displacement.

If Ve is the maximum load due to the influence of the earthquake a plan that can be absorbed by the structure of the building in a state of full elastic on the verge of collapse and Vy loading that causes melting of the first in the structure of the building.

The maximum deviation of ∂ m in the same conditions on the verge of collapse, then apply the following relationship:

$$Vy = \frac{Ve}{\mu} \tag{1}$$

If Vn is the nominal earthquake loading due to the influence of the earthquake that plans should be reviewed in the structural design of the building, then apply the following relationship:

$$Vn = \frac{Vy}{F1} = \frac{Ve}{R} \tag{2}$$

where f1 is a more powerful factor loads and material contained in the structure of the building and its value is set at:

$$f_1 = 1.6 \tag{3}$$

and R is called reduction factor according to the equation:

$$1.6 \leq R = \mu f_1 \leq R_m \tag{4}$$

R = 1.6 is the reduction factor for building structures that behave fully elastic, while the reduction factor Rm is the maximum that can be deployed by the structure of the system in question in accordance with Article 4.3.4.SNI-1726-2002 [3].

Table-1. Parameters ductility building structure [3].

Performance level of Building Structures	μ	R
Full elastic	1 1.5 2 2.5	1.6 2.4 3.2 4.0
Partial ductile	3 3.5 4 4.5 5	4.8 5.6 6.4 7.2 8.0
Full ductile	5.3	8.5

EXPERIMENTAL PROGRAM

Framework

In addition to literature review, the research will be carried out on an experimental test which is an implementation of the actual conditions in the field. Experimental studies will be carried out in accordance with the following stages of this research.

The size of the tested beams and columns are shown in the following Table:

Table-2. Dimensional beams and columns.

Description	Beam	Column
Width (B)	200 mm	300 mm
Height (H)	250 mm	300 mm
Concrete cover (d)	40 mm	40 mm
(f'c)	25 MPa	25 MPa
The length (L)	1500 mm	2600 mm

Details of beam-column connection models (SBK) can be seen in the following table:

Table-3. Specimen number of beam-column joints.

No	Shape	Testing Code
1	Monolith Construction	MC
2	Precast Construction	PC

The reinforcement detail can be seen in the following Figure:

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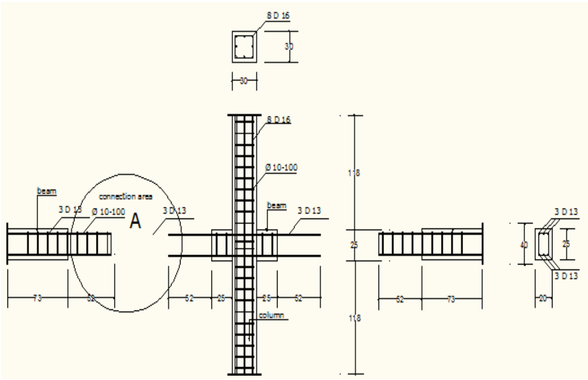

Figure-5. Reinforcement details (PC).

The connection is in the area plastic hinge of the face of the column, A detail is the connecting area. Connection models are shown in A detail can be clearly seen in the following figure.

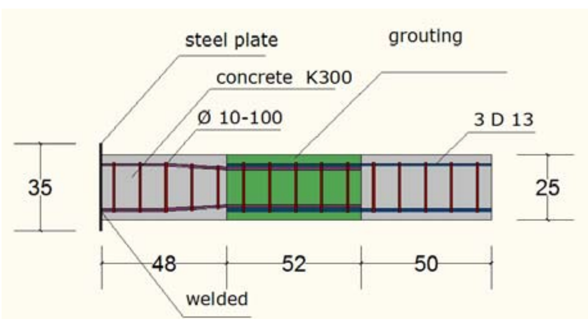

Figure-6. A detail (PC).

Experimental setup and Instrumentation

The test setup is shown in Figure 7. The test specimen using actuator with a load of hydraulic jack / horizontal jack is connected to the cable received by the transducer and cable strain gage.

Strain gage to obtain the data strain. Strain gage installation is done on the reinforcing steel and the surface of concrete. And transducer to determine the deflection or displacement of the specimen. Load is given at the upper of the column and moved in a horizontal direction.

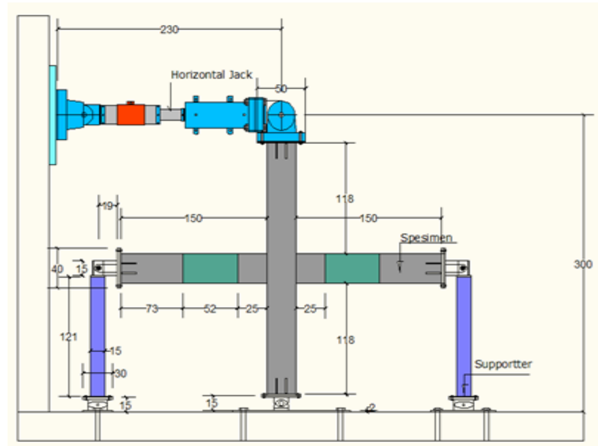

Figure-7. Test set-up

Test Procedure

Testing is done by giving cyclic lateral loads representing seismic loads.

Testing was conducted using displacement control, with the gradual type of loading starts from the smallest displacement gradually up to the largest displacement that can be achieved with the following conditions:

- one cycle in the $e_y^+/4$, $e_y^-/4$ interval ;
- one cycle in the $2e_y^+/4$, $2e_y^-/4$ interval ;
- one cycle in the $3e_y^+/4$, $3e_y^-/4$ interval ;
- one cycle in the e_y^+, e_y^- interval ;
- three cycle in the $2e_y^+$, $2e_y^-$ interval ;
- three cycle in the (2+2n) e_y^+, (2+2n) e_y^- interval (n = 1, 2,…) more cycles or more intervals may be used if necessary. e_y^+ is the displacement corresponding to the intersection.

RESULTS

After testing changes deflection of the test specimen of monolith construction (MC) at as figure below:

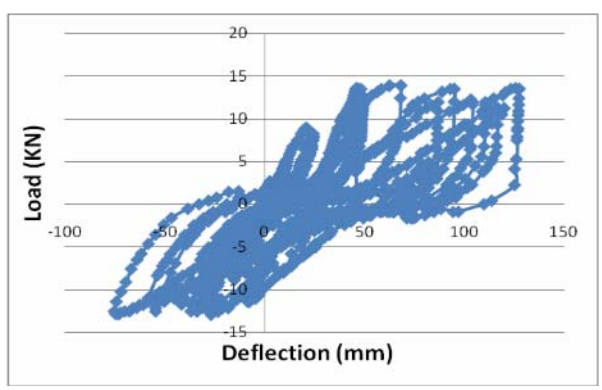

Figure-8. Hysteresis curve load vs deflection of MC specimen at the top of the column.

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In the figure shows that the maximum deflection in the positive direction is 134.59 mm and ductility of MC specimen μ = 2.333.

Deflection of the test specimen of precast construction (PC) as figure below:

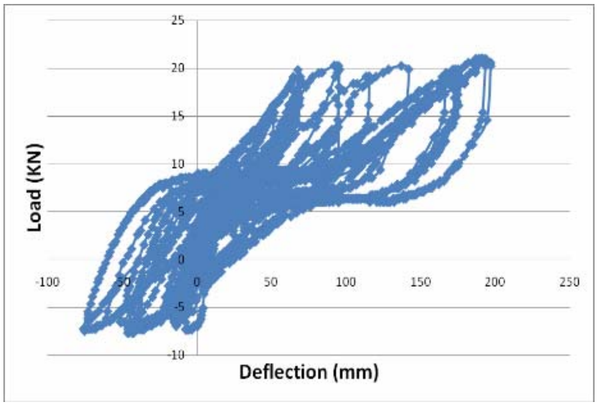

Figure-10. Hysteresis curve load vs deflection of PC specimen at the top of the column.

In the figure shows that the maximum deflection in the positive direction is 193.59 mm and ductility of PC specimen μ = 4.379.

Based on the value of ductility, MC is a full-elastic, and PC is partial ductile. This also proves that this experiment ductility of precast construction is greater than the monolith construction.

Crack Pattern

Pattern of cracks that occur in the monolith construction can be seen in the picture below, cracks that occur in monolithic construction is on the front of the column spread to the middle span beams in the vertical direction or also called flexural cracks.

Figure-11. Crack pattern of MC specimen.

The pattern of cracks that occur in precast construction can be seen in the picture below:

Figure-12. Crack pattern of PC specimen.

Based on this figure it can be seen that the pattern of cracks initial occurs is flexural crack and distribution breakdown fairly evenly along the beam. It can be concluded that the connection type can distribute the force well.

Characteristic pattern of cracks between the monolith construction and precast construction almost the same on the front of the first column have cracks, the difference lies in the connection area precast or on plastic hinge region, where the construction precast cracks that occur in the area grouting almost no cracks. This proves that the connection is made, no damage as expected.

The following is a picture of the largest deviation in the monolith construction.

Figure-13. The largest deviation at MC

The maximum deviation in the area of 13.605 KN tensile load.

And the following is a picture of the largest deviation in the precast construction.

Figure-14. The largest deviation at PC.

The maximum deviation in the area of 20.595 KN tensile load.

CONCLUSIONS

Precast concrete has many advantages over monolithic concrete which can shorten the time of execution of building work, but more accuracy is needed when making the connection between precast components. The method used can influence the results to be obtained or targeted job execution time.

Connection of precast concrete in this study was conducted using the method of grouting use cement grout, by tacking on plastic joint area. The strength of the grouting area larger than precast components is visible from no significant cracks in the grouting area.

Moreover the advantages of precast construction than monolith construction when viewed from the ductility properties are Precast Construction (PC) has a greater ductility of Monolith Construction (MC). Ductility of PC, $\mu = 4.379$, while the MC, $\mu = 2.333$. PC is partial ductile, whereas the MC is full elastic.

Crack pattern of PC and MC almost the same on the front of the first column, the difference lies in the connection area precast or on plastic hinge region, where the construction precast cracks that occur in the area grouting almost no cracks.

Based on the conclusion, the connection method in this study can be used in precast concrete connection.

REFERENCES

[1] Ariyanto Agus. 24 November 2011. (Precast Concrete), (online), (http://aghostariyanto.wordpress.com/2011/11/24/beton-pracetak-precast-concrete/, 24 June 2013).

[2] Department of Public Works, SNI 03-2847-2002. Calculation Procedure for Concrete Structure Building (Beta Version). Bandung.

[3] Department of Public Works, ISO-1726-2002. Planning Standards for Earthquake Resistance of Building Structures.

[4] N. Priestley. 1996. Structural Engineering International 1.

[5] Parung H., Irmawaty R., Ricko Mappanyukki A and Sudirman. 2010. Proceedings of the First Makassar International Conference on Civil Engineering (MICCE 2010). Study On The Behaviour of Precast Beam Column Joint Using Steel Plate Connection (JPSP).

[6] Paulay T., Priestley M.J.N. 1992. Seismic Design of Reinforced Concrete and Masonry Building. John Wiley and Sons.

[7] Purnomo Rachmat, Prof. Ir, MSc. 2005. Planning for Earthquake Resistant Reinforced Concrete Structures. Fourth Edition. Surabaya: Itspress.

[8] Suherman Jojon. 2011. Use of Block Sets Connection (BSC) in connection Precast Concrete Elements. Technology and Vocational. 34(2).

[9] Tjahyono Elly and Purnomo, Heru. 2004. Effect of Grafting Placement on Beam-Column Behavior circuit Precast Concrete Exterior Parts Side. Makara, Technology. 8(3).