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Ductility of Precast Concrete Beam-Column Connection Using Dry Connection Method

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Abstract— *There is a major problem in the installation of precast concrete systems, such as the connection. Connections on precast systems must have strength that can withstand the loads that occur. One system used in precast concrete connections is by using the dry connection method. The test method is based on the Quasi Static Loading Test method on existing specimens with lateral loading based on the displacement control pattern as a simplified form of earthquake load. The specimens used were precast specimens using 2 anchors, and the specimen using 4 anchors. Ductility analysis uses 2 methods, such as tangential ductility, and secant ductility.*

Keywords— *Precast Concrete, Dry connection, Tangential Ductility, Secant Ductility.*

I. INTRODUCTION

In order to increase the community's need for the construction of various types of infrastructure, such as housing, hotels, offices, toll roads and others in all corners of Indonesia, a structural design that is economical, efficient, and quick to implement is needed. To support the development of this construction, precast concrete is increasingly taken into account as an alternative material used in the construction world. The use of precast concrete in building construction is relatively more efficient, compared to the use of monolithic concrete.

However, there is a major problem in the installation of precast concrete systems, such as the connection. Connections on precast systems must have strength that can withstand the loads that occur. Inaccuracies or deviations that are not in accordance with the planned tolerance dimensions can affect the stress distribution of the structure to be built. Therefore, the connection on the precast column must be designed so that it can withstand earthquake forces.

One system used in precast concrete connections is by using the dry connection method. Dry connection is a connection between precast concrete elements using an iron plate as a connector, which is then bolted or welded.

Judging from the connection problems in precast concrete, a study was conducted to observe the precast beam-column ductility behavior.

II. LITERATURE REVIEW

Ductility

Ductility is the ability of a structure to change shape to a certain degree (in static or dynamic loading), without being followed by the collapse of the structure. According to SNI 03-1726-2002, building ductility is expressed in ductility factor (μ). Ductility can be formulated as a comparison between displacement when the ultimate divided deformed when the first yield occur.

$$\mu = \frac{\Delta_u}{\Delta_y}$$

Several alternatives suggested to determining the yield point. One of that is from (Park R. & T. Paulay, 1988) given suggest to determine yield point.

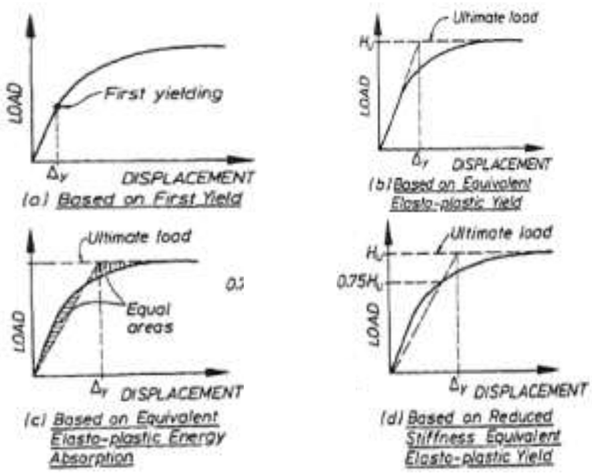

Fig. 1. Alternative for determining yield points (Park R. & T. Paulay, 1988)

In this study, the yielding point can be taken from 2 (two) methods, such as, the tangential method, and the secant method. The tangential method is used to approach the structure when the concrete is still good, or it is still in a condition not yet cracked. While the secant method is used to approach the actual yielding behavior during testing.

The melting point using the tangential method is taken based on equivalent elasto-plastic yield. While the yielding point using the secant method is taken based on reduced stiffness equivalent elasto-plastic yield.

The ultimate condition here, can be interpreted as 3 (three) conditions, such as the condition when the structure reaches the maximum load (peak), the condition when structure have decreased up to 5% of peak load, and structural conditions at the end of the test.

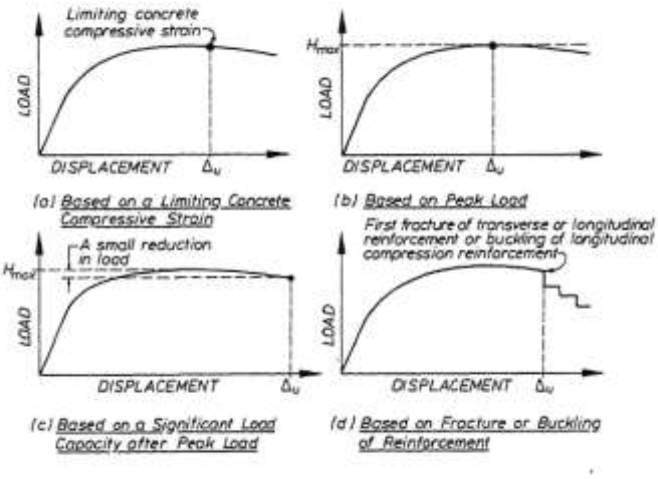

Fig. 2. Alternative for determining ultimate points (Park R. & T. Paulay, 1988)

Ductility analysis with the tangential method is used to approach the structure when the concrete is still good, or still in a condition not yet cracked. While the secant method is used to approach the actual melting behavior during testing.

III. Research Concept Framework

A. *Research Conceptual Frame work*

Based on the problems, so an algorithm was made to facilitate problem solving. The following is an overview of the conceptual framework in this research:

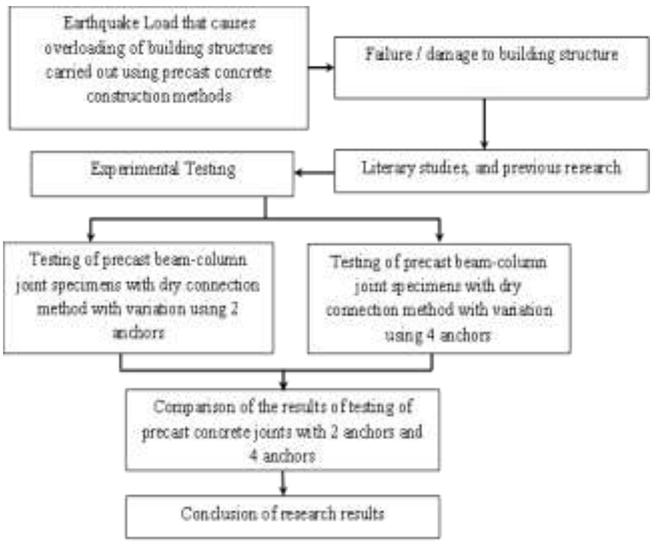

Fig. 3. Algorithm conceptual framework of research

B. *Research Hypothesis*

- Tangential ductility values in precast concrete both using 4 anchors and specimens using 2 anchors will be higher when compared with the ductility value of the secant that occurs in the four test specimens.
- The results of calculation of ductility on 4 anchor specimens using the tangential method, and the secant method has a higher value when compared with the specimen using 2 anchors.

IV. Research Method

A. *Detail of Specimens*

The table of detail specimens used in this study are as follows:

TABLE I. Detail of Specimens

	2 Anchors	4 Anchors
Dimension	150 mm x 200 mm	150 mm x 200 mm
Detail		
Amount of Specimen	2	2
Label of Specimen	• A2-1 • A2-2	• A4-1 • A4-2
Anchor	• M 19 (D 16)	• M 16 (D 14)

B. *Material Testing*

- f'c = 25 MPa
- fy, steel reinforcement = 367 MPa
- fy, anchor M 19 = 532 MPa
- fy, anchor M 16 = 464 MPa

V. Results and Discussion

The ductility value is obtained from the results of the study found in the load-deflection comparison chart (P-Δ). where the value of ductility is based on the ratio between the maximum deviation with the first melting deviation. Below is a graph of the results of testing:

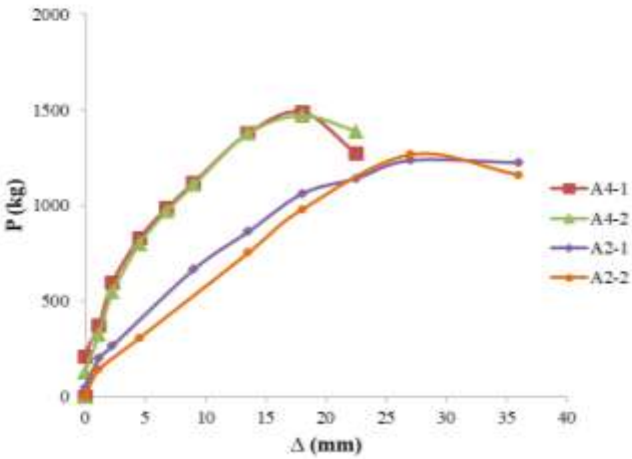

Fig. 4. Backbone curve on testing 4 test objects between loads-deflection

From the backbone curve above, it can be determined the ultimate point and the first yield point to be used in the ductility analysis.

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The following table is the result of an analysis of the calculation of tangential ductility of 4 specimens in peak P conditions.

TABLE II. The results of tangential ductility in peak conditions on 4 specimens

ID	Pu (kg)	Δu (mm)	Δy (mm)	Ductility (μ)	Average
A4-1	1488	18.00	4.90	3.67	3.57
A4-2	1470	18.00	5.20	3.46	
A2-1	1236	27.00	6.20	4.35	3.68
A2-2	1266	27.00	9.00	3.00	

From TABLE II above, it can be seen that the tangential ductility that occurs in specimens with 4 anchors has a lower ductility value compared to anchor 2 specimens.

The following table is the result of an analysis of the calculation of secant ductility of 4 specimens in peak P conditions.

TABLE IIII. The results of secant ductility in peak conditions on 4 specimens

ID	Pu (kg)	Δu (mm)	Δy (mm)	Ductility (μ)	Average
A4-1	1488	18.00	11.96	1.51	1.51
A4-2	1470	18.00	11.94	1.51	
A2-1	1236	27.00	20.95	1.29	1.22
A2-2	1266	27.00	23.25	1.16	

From TABLE III above, it can be seen that the ductility of the secant that occurs in specimens with 4 anchors has a higher ductility value compared to anchor 2 specimens. This is clearly different when compared to the analysis of tangential ductility that has been calculated previously.

For more details, it can be seen in Fig. 5, such as the comparison of the results of tangential ductility, and secant ductility at P peak in 4 specimens.

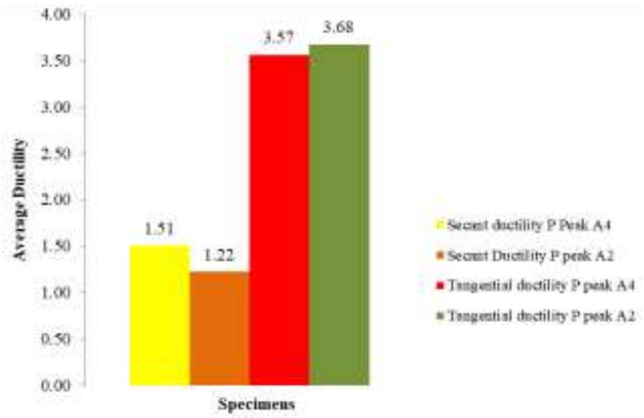

Fig. 5. The results of the comparison of tangential ductility and secant ductility in P peak on 4 specimens

The following table is the result of an analysis of the calculation of tangential ductility of 4 specimens in structural conditions have decreased P loads up to 5% of the maximum load.

TABLE IV. The results of tangential ductility in structural conditions have decreased P loads up to 5% of the maximum load on 4 specimens

ID	Pu (kg)	Δu (mm)	Δy (mm)	Ductility (μ)	Average
A4-1	1413.6	13.85	4.90	2.83	2.73
A4-2	1396.5	13.70	5.20	2.63	
A2-1	1174.2	24.35	6.20	3.93	3.39
A2-2	1202.7	25.65	9.00	2.85	

As same as TABLE II, from Table IV above, it can be seen that the tangential ductility that occurs in specimens with 4 anchors has a lower ductility value compared to anchor 2 specimens.

TABLE V. The results of secant ductility in structural conditions have decreased P loads up to 5% of the maximum load on 4 specimens

ID	Pu (kg)	Δu (mm)	Δy (mm)	Ductility (μ)	Average
A4-1	1413.6	13.85	11.96	1.16	1.15
A4-2	1396.5	13.70	11.94	1.15	
A2-1	1174.2	24.35	20.95	1.16	1.13
A2-2	1202.7	25.65	23.25	1.10	

From TABLE V above, it can be seen that the ductility of the secant that occurs in specimens with 4 anchors has a higher ductility value compared to anchor 2 specimens. This is clearly different when compared to the analysis of tangential ductility that has been calculated previously.

For more details, it can be seen in Fig. 6, such as the comparison of the results of tangential ductility, and secant ductility in structural conditions have decreased P loads up to 5% of the maximum load.

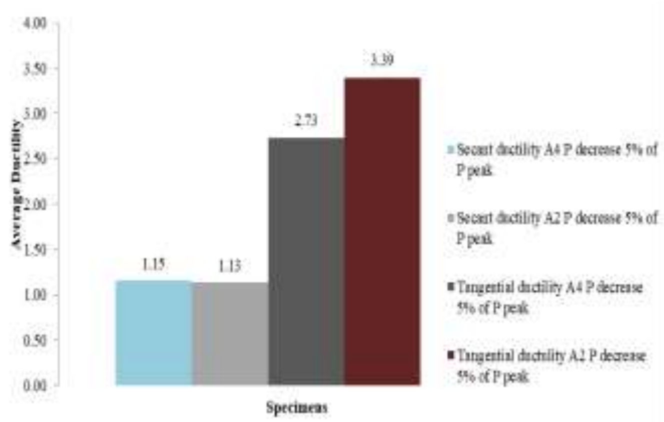

Fig. 6. The results of the comparison of tangential ductility and secant ductility in P decrease 5% of P peak on 4 specimens

The following table is the result of an analysis of the calculation of tangential ductility of 4 specimens in structural conditions at the end of the test.

TABLE VI. The results of secant ductility in structural conditions at the end of the test on 4 specimens

ID	Pu (kg)	Δu (mm)	Δy (mm)	Ductility (μ)	Average
A4-1	1270	22.50	4.90	4.59	4.46
A4-2	1388	22.50	5.20	4.33	
A2-1	1224	36.00	6.20	5.81	4.90
A2-2	1160	36.00	9.00	4.00	

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As same as Table II, and Table IV before, Table VI above, showed that the tangential ductility that occurs in specimens with 4 anchors has a lower ductility value compared to anchor 2 specimens.

TABLE VII. The results of tangential ductility in structural conditions at the end of the test on 4 specimens

ID	Pu (kg)	Δu (mm)	Δy (mm)	Ductility (μ)	Average
A4-1	1270	22.50	11.96	1.88	1.88
A4-2	1388	22.50	11.94	1.88	
A2-1	1224	36.00	20.95	1.72	1.63
A2-2	1160	36.00	23.25	1.55	

From TABLE VII above, it can be seen that the ductility of the secant that occurs in specimens with 4 anchors has a higher ductility value compared to anchor 2 specimens. This is different when compared to the analysis of tangential ductility that has been calculated previously.

For more details, it can be seen in Fig. 7, such as the comparison of the results of tangential ductility, and secant ductility in structural conditions have decreased P loads up to 5% of the maximum load.

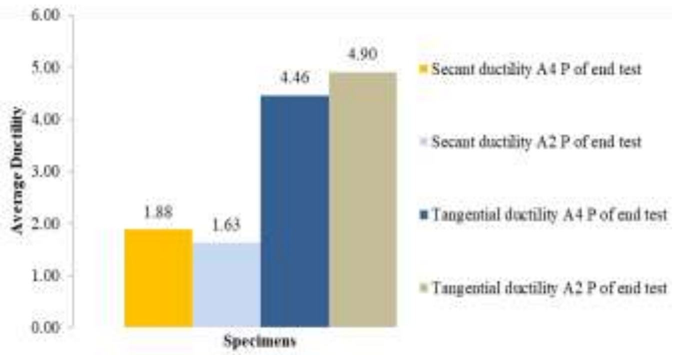

Fig. 7. The results of the comparison of tangential ductility and secant ductility in structural conditions at the end of the test on 4 specimens

From the data in Figures 5, 6 and 7, it can be concluded that the secant ductility occur is smaller when compared to tangential ductility. If seen from the results of the ductility analysis secant, the ductility value of the secant that occur in precast concrete specimens with 4 anchors tends to be greater when compared with the specimen using 2 anchors. It showed that, the hypothesis taken previously regarding Tangential ductility values in precast concrete both using 4 anchors and specimens using 2 anchors will be higher when compared with the ductility of the value that occurs in the four test specimens, according to the results of the analysis research conducted.

Unlike the case in the previous hypothesis, the results of the calculation of ductility on 4 anchor specimens using the tangential method, and the secant method have a higher value compared with the specimen using 2 anchors. The results of the research analysis show that the tangential ductility values in the 2 anchors were higher when compared to the precast test using 4 anchors in ultimate condition of structural peak, and structural end of the test. This is inversely proportional on structural in P decreases 5% of P peak. The tangential ductility of specimen using 4 anchors is higher than specimens using 2 anchors.

If viewed from previous experiments, which have been carried out by Tjahjono (2004) on 4 specimens, using precast concrete with L elbow joints then welded results in ductility of 4.61, 4.32, 3.17, and 3.43. Furthermore, experiments conducted by Wibowo et. al. (2011), namely testing of beam-column joints using anchor joints welded with steel plates, resulting in 4.75, and 5.18. From the two previous experiments, then compared with the results of the analysis of tangential ductility, and secant ductility that has been done.

For more details, it can be seen in Fig. 8, and Fig. 9, such as the comparison of the results from previous experiments by Tjahjono (2004), and Wibowo et. al. (2011), with the results of the analysis of tangential ductility, and secant ductility that has been done.

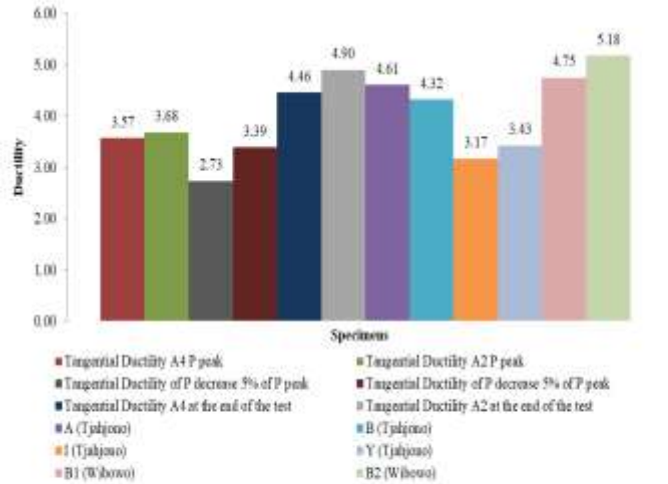

Fig. 8. Comparison chart of tangential ductility, with 2 different studies

From Figure 8, it is concluded that, the test object with the dry connection method with the type of connection using anchor bolts, and using welded steel, has varying ductility values as well.

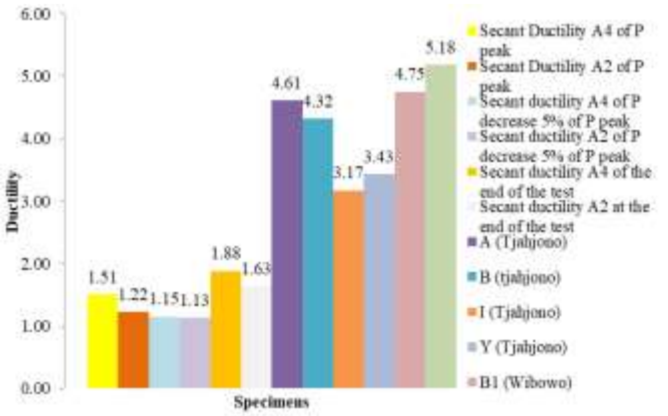

Fig. 9. Comparison chart of secant ductility, with 2 different studies

From Figure 9, it was concluded that the secant ductility of the anchor 4 and 2 anchor test specimens was smaller than the

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2 previous studies. The secant ductility value on the test object with 2 anchors has the lowest value.

VI. CONCLUSION

From the research result and analysis that has been done, the conclusion are as follows:

1. The result of ductility analysis showed that secant ductility is smaller than tangential ductility on 4 specimens.
2. The secant ductility of precast concrete specimens using 4 anchor tends to be greater when compared with the specimen using 2 anchors.
3. The result of tangential ductility showed different result than before. The tangential ductility values in the specimens with 2 anchors were higher when compared to the precast test using 4 anchors in ultimate condition of structural on P peak, and structural at the end of the test. This is inversely proportional on structural in P decrease 5% of P peak. The tangential ductility of specimen using 4 anchors is higher than specimens using 2 anchors.

VII. SUGGESTION

From the research result and analysis that has been done, the conclusion are as follows:

1. Further research need to be done using full scale, so that actual results are obtained in accordance with the actual implementation.
2. Research need to be done with several variations of beam-column connection locations using other methods, so that the information can be obtained about the effect of location and connection variations on behavior of the precast beam-column connection.

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