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The Load-Carrying Capacity of Reinforced Concrete Beam to Beam Connection: An Experimental Program

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Abstract. Demand of precast concrete in the building construction is increasing because the precast concrete is faster in construction and higher quality control compared to the site-cast concrete. The weight of precast concrete sometimes must be under consideration due to the reasoning of the erection precast concrete element into the building construction. If the span of reinforced concrete beam is quite long, therefore the beam needs to be divided into two or more segments so that the segment can be easily carried and put in the building construction. This experimental program to study about the capacity of reinforced concrete beam to beam connection. Three beams were cast and tested under monotonic loading. The first beam was the beam without any connection as a reference beam. The second beam had a connection in the middle span using steel plate in top and bottom of beam. While the third beam had a connection in middle span with a connection was using the steel plate which was fully covering the connection. All the beams' dimensions were (150 mm × 250 mm) and span of the beam is 3000 mm. Four longitudinal bars 10 mm in diameter were used to be tension reinforcements and two longitudinal bars having 10 mm of diameter to be compression reinforcements. Reinforcements with diameter of 8 mm were used as stirrups. The results of the study show that the capacity of load-carrying of the beam with the connection of the steel plate in top and bottom connection (BC-1 beam) was lower compared to the reference beam (BN beam) and BC-2 beam. While the beam with the connection fully covering with the steel plates (BC-2 beam) showed had higher load-carrying capacity and more ductile than the reference beam (BN beam) and BC-1 beam.

Keywords: Precast reinforced concrete; beam to beam connection; load-carrying capacity; experimental program

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INTRODUCTION

A building construction needs time and high-quality control to make a good building. Usually site-cast concrete needs time for arrangement of the reinforcement and the formwork in preparing the element of structure before pouring the concrete. Not only preparing of reinforcement and formwork, but also sometimes needs several days to reach the full strength of the concrete. Precast concrete is one of the alternative methods to solve the above problem. Now, the demand of precast concrete in building construction becomes increasing because precast concrete provides faster construction and high-quality control compared to the site-cast concrete.

Study of precast beam connection and precast concrete frame had been developed several years ago [1, 2, 3, 4]. Precast concrete has advantages such as faster construction and high-quality control. However, this method also has disadvantages. The disadvantage is if the dimension and the weight of the element structure is larger and heavier, than it makes difficult to carry in the project site. The solution to solve this problem is to make the element of structure become several segments, so that the weight of the element becomes lighter.

Munaf et al. [5] investigated the precast beam-to-beam connection where the connection was in the middle span of beam. The section of beam was I section and the connection was in the middle span of the beam (see Figure 1). The result was quite satisfied, however the connection had disadvantages such as the dimension at the connection was bigger than the section of the beam and heavy reinforcement at the connection. Hence, the concept of connection was not simple and not easily implemented in the real construction.

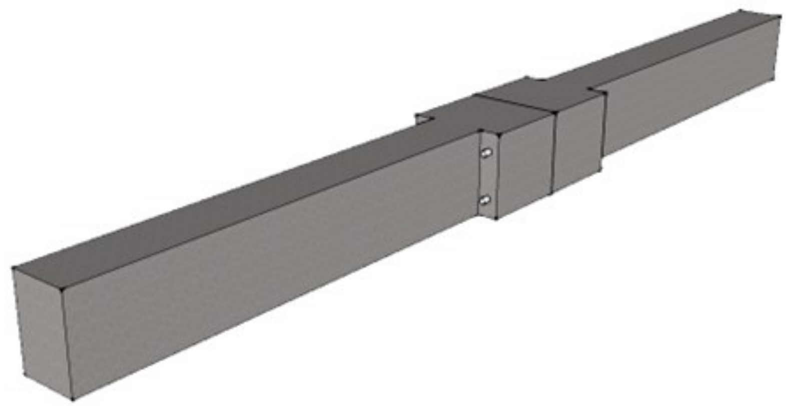


FIGURE 1. The precast beam to beam connevction proposed by Munaf et al. [5]

Chatarina [6] also investigated about a precast beam connection with the connection also in the middle span of the beam with the detail of connection can be seen in Figure 2. The load in this research was static and quasi static loading. The results show that using static loading the maximum load was 62% compared to the calculation using section analysis, while the quasi-static loading gave the loading decreased for around 40-55% compared to the static loading.

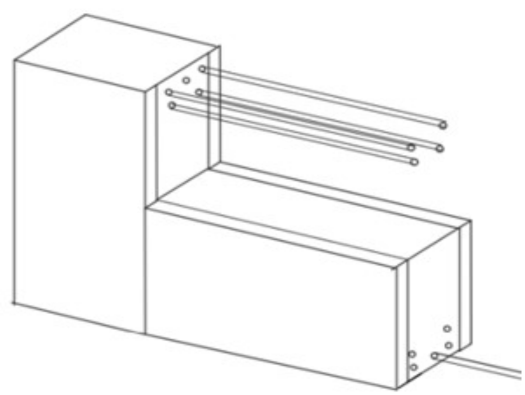


FIGURE 2. The precast beam to beam connection proposed by Chatarina et al. [6]

Nurjaman [7] stated that the location and the model of the precast connection must be design carefully so that the precast connection does not make the premature failure on the element of structure. It means that the research on the precast beam to beam connection must be developed with another idea and concept so that the element of structure will give the best performance and avoid the premature failure. Therefore, it is still needed to carry out and investigate the simple connection of precast beam to beam connection.

RESEARCH SIGNIFICANT

This research describes the experimental program of precast beam to beam connection. Through the experimental program, it can be seen the real load-carrying capacities of the precast beam connection. There are two types of the precast beam connection were investigated in this research. Both of precast beam connection will be compared to the beam without connection as reference beam. Through these comparisons, it will be known whether the precast beam to beam connection have the lower or higher load-carrying capacities than the beam without connection.

EXPERIMENTAL PROGRAM

Materials

Materials of concrete were taken from local materials. The coarse aggregates were collected from Clereng, Kulon Progo County the West part of the Yogyakarta Province. The size of coarse aggregates was equal or less than 20 mm. And, the fine aggregates were collected from the Progo River which is located in the North part of Yogyakarta Province. The size of fine aggregates was 0.125-0.5 mm. Pozzolan Portland Cement type was used in concrete. The reinforcement with diameter 10 mm and 8 mm with yield stress = 270 MPa were used for longitudinal and stirrup, respectively. While steel plate with thickness = 6 mm had yield stress = 240 MPa were used for cover plate in the precast beam to beam connection.

Specimens

Cylinder specimens having a size of 150 mm × 300 mm were prepared to obtain the compressive strength, the elasticity and rupture of concrete in 28 days. Three beam specimens were made to get the behaviour of precast beam to beam connection. First beam specimen was made without connection, namely BN as reference beam (see Figure 3). Second beam was made with the steel plate in top and bottom of the beam in connection, namely BC-1 (see Figure 4). Third beam was made with fully covering by the steel plate at the connection, namely BC-2 (see Figure 5). The dimensions of all beams were (150 mm × 250 mm) and the span of the beam is 3000 mm. Four longitudinal bars having 10 mm in diameter were used as tension reinforcements and two longitudinal bars having 10 mm in diameter as compression reinforcements. Reinforcements which have a diameter of 8 mm were used as stirrups.

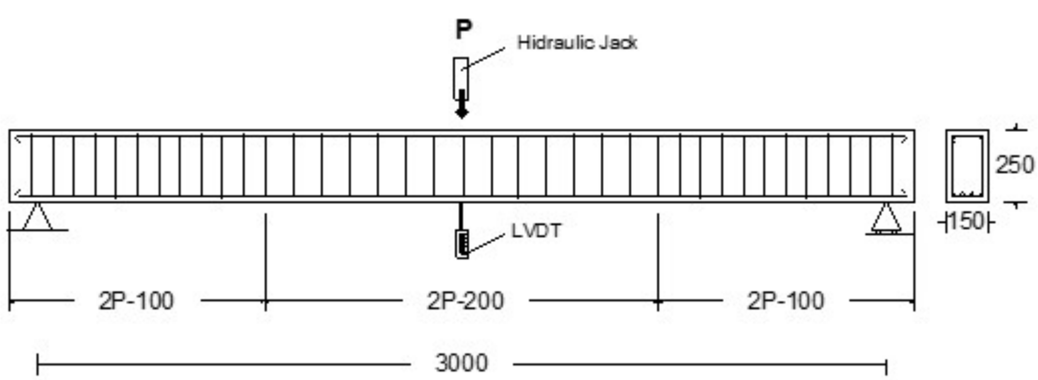


FIGURE 3. The first beam without connection or BN (unit in mm)

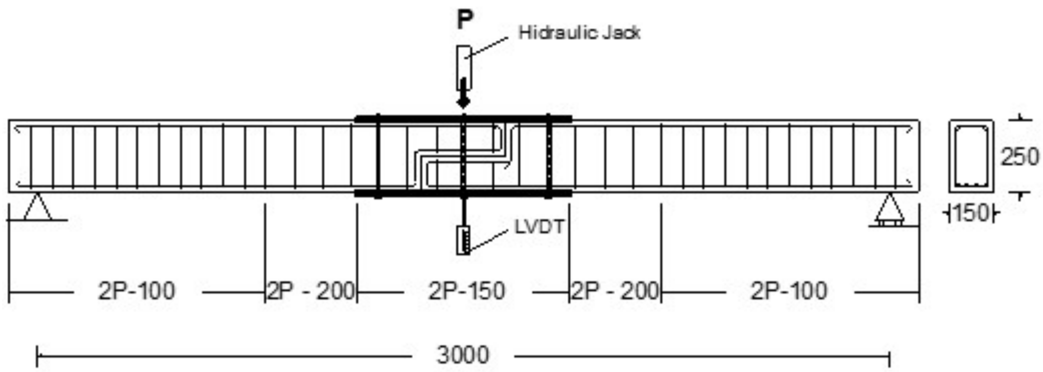


FIGURE 4. The second beam with steel plate in top and bottom in connection or BC-1 (unit in mm)

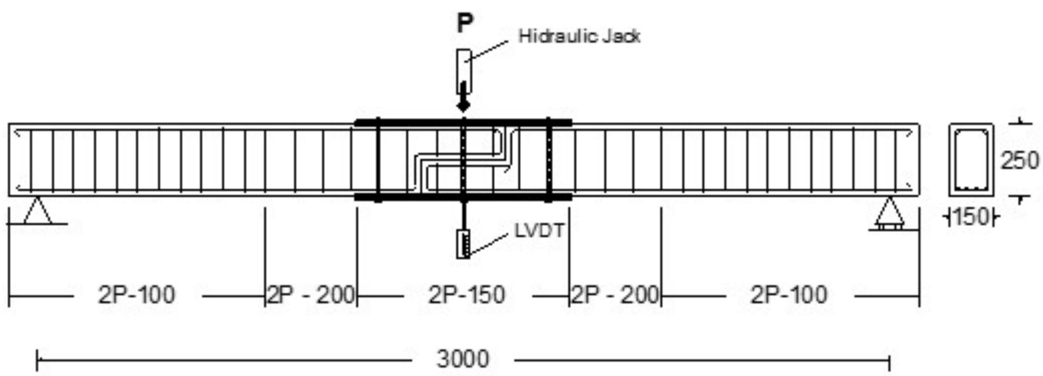
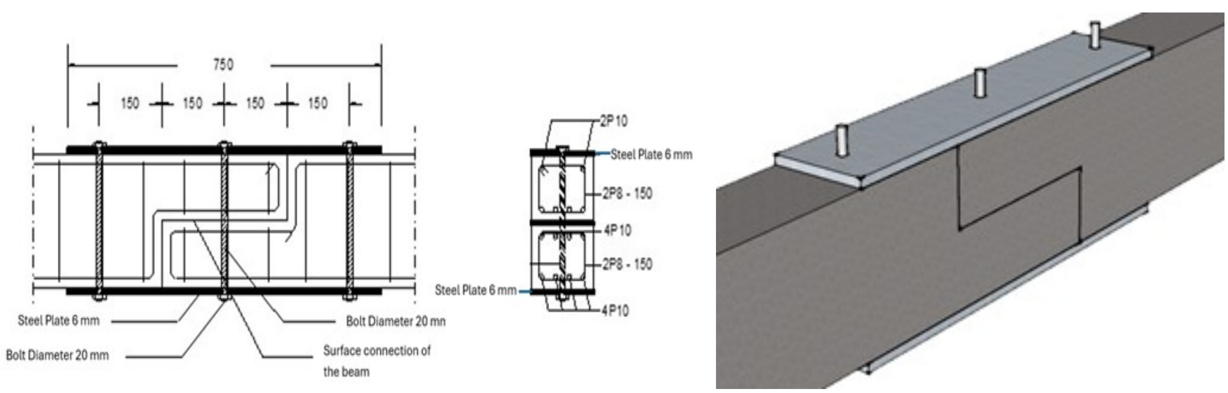


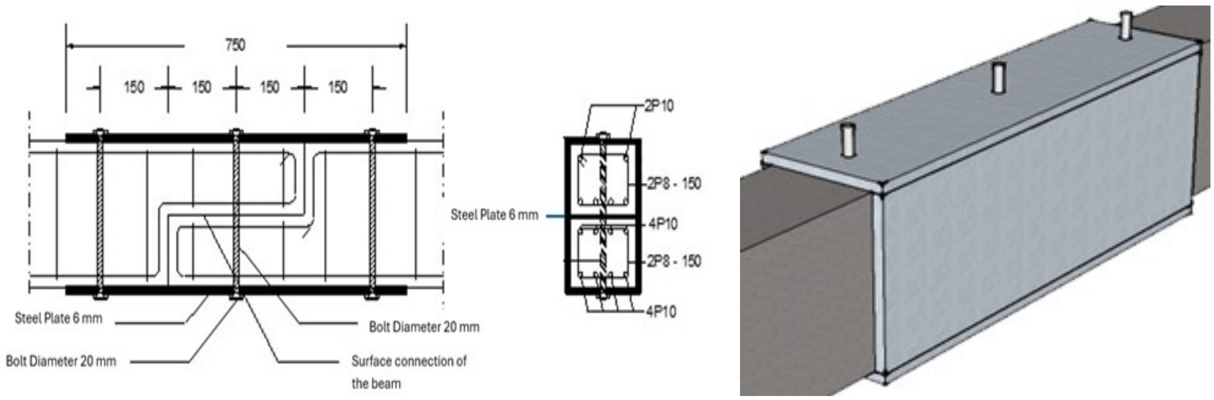
FIGURE 5. The third beam with fully covering steel plate at the connection or BC-2 (unit in mm)

The detailing of steel plate covering at the connection of the second and the third beams are respectively shown in Figure 6 and Figure 7.



(a) (b)

FIGURE 6. The detailing of steel plate covering at the connection of the BC-1 (unit in mm)



(a) (b)

FIGURE 7. The detailing of fully steel plate covering at the connection of the BC-2 (unit in mm)

Set-up beam specimen

The beam specimen was set-up on Loading Frame and tested using monotonic loading. The actuator or hydraulic jack had the capacity of 250 kN and the position of the actuator was placed in the middle span of the beam. A Linear Variable Differential Transformers (LVDT) was located at the middle span of the beam to measured deflection of the beam. The surface of the beam was painted by white colour first and then square grids of 50 mm were drawn to facilitate the observation of crack propagation on the surface of the beam. All data were recorded from a computer driven data acquisition system by using data logger. The set-up of the tested beam can be seen in Figure 8.

FIGURE 8. The set-up test of the beam

RESULT AND DISCUSSION

Concrete and Steel Materials

The obtained average compressive strength belong to the concrete in 28 days tested from three cylinders specimens was 34.8 MPa. And, the average value of the yield stress of reinforcement bar with diameter 10 mm and diameter 8 mm were 488.4 MPa and 402.3 MPa, respectively. While the yield stress of the steel plate was 349.6 MPa.

Load Capacity and Deflection of the Beam

Comparison of the beams' loading capacity can be seen in Figure 9. The reference beam (BN beam) showed a little bit stiffer than BC-1 beam and BC-2 beam. It can be seen from Figure 7 that BN beam at the small deflection up to for around 8 mm had higher load capacity compared to BC-1 beam and BC-2 beam. The load carrying capacity increased and reached up to 3000 kg, then the load decreased. After decreasing the load increased again up to 3154.53 kg and then the beam was failure. The BC-1 beam had the lower stiffness compared to the BN and BC-2 beam. It can be seen that the curve of load-deflection relationship. After the first crack the slope of the curve was below the BN and BC-2 beam. After reaching the maximum load, the curve was going horizontally up to failure.

The BC-2 beam had better behavior than the BN beam and BC-1 beam. It can be seen from the load-deflection relationship curve. Although the stiffness of the beam was lower than the BN beam, the load carrying capacity of the beam was higher than the BN beam and the curve more ductile than the BN beam. It can be seen from the curve that the BC-2 beam after reaching the maximum load, the deformation of the beam was better than the BN beam (reference beam).

Table 1 shows that the BC-1 beam has lower load carrying capacity than the reference beam (BN). The decreasing load carrying capacity of the BC-1 beam was 74.05 % compared to the reference beam (BN). While the BC-2 beam has higher load carrying capacity compared the reference beam (BN). The increasing load carrying capacity of the BC-2 beam was 112.57% compared to the reference beam (BN).

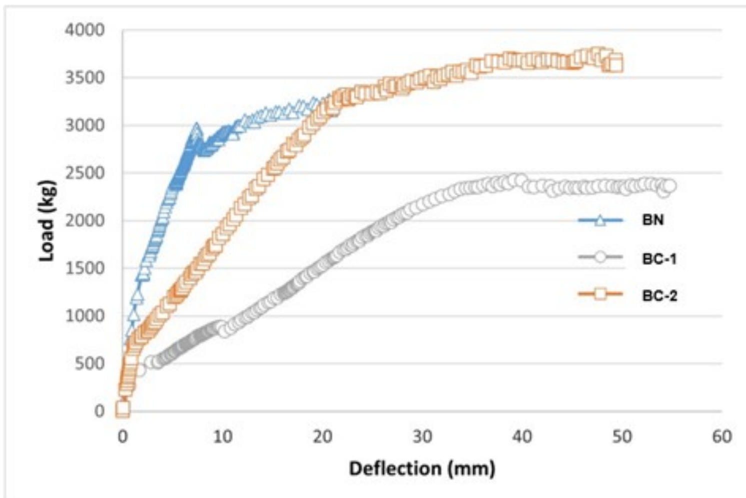


FIGURE 9. Comparison of the load vs deflection of the beams

While the comparison of the load capacity of beam BN, BC-1, and BC-2 can be seen in Table 1.

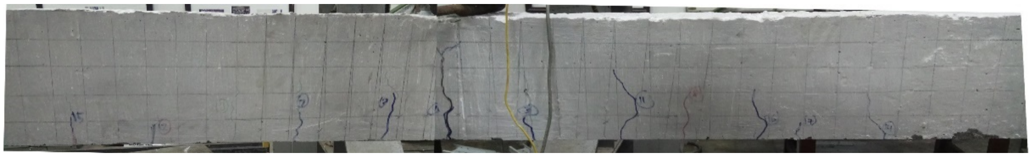
TABLE 1. The comparison of the load capacity of BN, BC-1, and BC-2.

Beam	Load Capacity (kg)
BN	3154.53
BC-1	2335.84
BC-2	3551.12

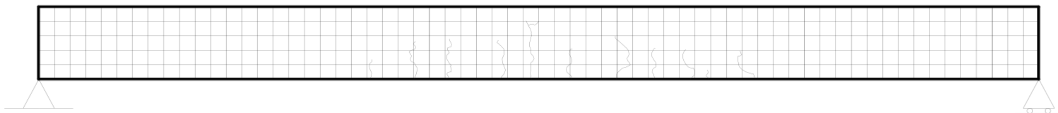
Deflection at maximum load capacity of the reference beam (BN) before failure was 20.67 mm, while the deflection of the BC-1 beam and the BC-2 Beam were 38.26 mm and 49.39 mm, respectively. It was shown that the beams with the connection in the middle covering with steel plate at the top and the bottom of the beam or covering with full steel plate had higher deflection compared to the reference beam.

Crack Pattern

The crack pattern of the reference BN beam was depicted in Figure 10. It can be seen from Figure 8 that the crack pattern of the reference beam (BN beam) as flexural crack. The first crack occurred at the bottom of the beam in the middle span of the beam. The others crack occurred together with increasing the load up to the failure.



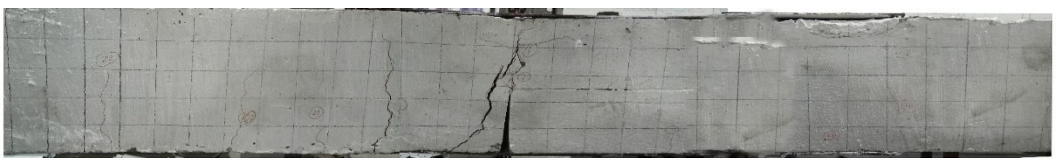
(a)



(b)

FIGURE 10. Crack pattern of BN beam

While crack pattern of the BC-1 beam and the BC-2 beam can be seen in Figure 11 and Figure 12, respectively. The first crack of the BC-1 beam occurred in the bottom of the beam but not in the middle span of the beam. The first crack occurred near to the surface connection for around 100 mm from the surface connection. This phenomenon was due to the steel plate at the top and the bottom of the connection that was tightened with bolt diameter 20 mm. The others crack occurred in the middle area together wit increasing of the load up to failure.



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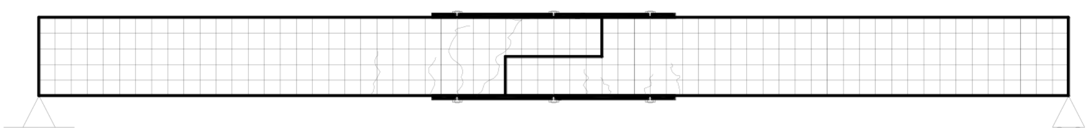

(b)

FIGURE 11. Crack pattern of BC-1 beam

The first crack of the BC-2 beam occurred in the bottom of the beam but not in the middle span of the beam. The first crack occurred near the surface connection for around 50 mm from the surface connection. Below the horizontal surface connection there was no crack occurring in this area. This phenomenon was due to the full covering of steel plate in the connection and this covering steel plate was tightened with bolt diameter 20 mm. The others crack occurred together with increasing the load up to failure.

(a)

(b)

FIGURE 12. Crack pattern of BC-2 beam

CONCLUSION

According to the evaluations given above, the following conclusions were drawn:

1. The load capacity of the reference beam (BN beam) was 3272.47 kg, while the capacity of the BC-1 beam and the BC-2 beam were 2423.166 kg and 3683.87 kg, respectively. This result showed that the BC-1 beam had lower load capacity compared to the reference beam (BN beam) or the decreasing capacity load of the BC-1 beam was 25.95% compared to the reference beam (BN beam). While the capacity load of the BC-2 beam was higher than the reference beam (BN beam) or the increasing capacity load of the BC-2 beam was 12.57% compared to the reference beam (BN beam)
2. Deflection at maximum load capacity of the reference beam (BN) before failure was 20.67 mm, while the deflection of the BC-1 beam and the BC-2 Beam were 38.26 mm and 49.39 mm, respectively. It was shown that the beams with the connection in the middle covering with steel plate at the top and the bottom of the beam or covering with full steel plate had higher deflection compared to the reference beam.
3. The BC-2 beam or the beam with connection full covering of steel plate can be recommended as precast connection of the beam in the middle span, because the BC-2 beam had higher load capacity and was more ductile compared to the reference beam (BN beam) and BC-1 beam.

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REFERENCES

1. J.J., Castro, H. Imai, and T. Yamaguchi, "Seismic Performance of Precast Concrete Beam-Column Joint", 10th World Conference of Earthquake Engineering, Balkema, Rotterdam, 3131-3137 (1992).
2. S.D., Nakaki, J.F., Stanton, and S. Sritharan, "An Overview of the PRESS Five Story Precast Test Building", PCI Journal, Maret-April, 26-39 (1999).
3. P. Nigel, "Seismic Design Philosophy for Precast Concrete Frame", University of California, San Diego, 1996.
4. H. Sucuoglu, "Inelastic Seismic Response of Precast Concrete Frame with Constructed Plastic Hinges", Computer and Structural, Vol. 56, No.1, 121-131 (1995).
5. D. R. Munaf, D. Suraatmadja, and N. Suhana, "The Investigation of Beam to Beam Connection of Precast Concrete Element Under Monotonic and Cyclic Loading", Proceeding Conference of 27th Our World in Concrete & Structures, Singapore, 373-380 (2002).
6. N. Chatarina, "Perilaku Lentur Sambungan Model Takik pada Balok Aplikasi untuk Beton Pracetak" (in Indonesian Language), Dinamika Teknik Sipil, Vol. **8**, No. **2**, 149-161 (2008).
7. H.N. Nurjaman, "Penentuan Model dan Parameter Titik Kumpul untuk Analisis Struktur Rangka Beton denagn Sistem Pracetak dan Sistem Hibrid Berdasarkan Uji Laboratorium" (in Indonesian Language), Ph.D thesis, Institut Teknologi Bandung, 2000.