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Behaviour of Precast Interior Joint Using a Notch Connection under Cyclic Loading

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Abstract: The research has aimed behaviour of precast interior joint. The research consists of analyze crack patterns, hysteresis loop characteristics, ductility and strength of precast joint. The speciment consists of 2 precast interior joints using a notch models known as BTK-30 and 40 and 1 monolith interior joint known as BN. The beams were connected in area where plastic hinges. The dimension of speciments were 200×300×1.500 mm and column 300×300×1.500 mm. The length of notch were 150 mm which connected by welding system and grouting system. The load was a lateral loading as cyclic loading. The method of analysis using European Convention for Constructional Steelwork (ECCS) 1986 standard. The results are all cracks were flexural cracks where in the plastic hinge area. The hysteresis loop characteristics shows a curves identical to joint monolith. The comparison of two precast joint that BTK-40 is the best value on cracking, strength and ductility.

Key words: Joint, precast, notch connection, cyclic, ECCS, hinge area

INTRODUCTION

The precast concrete has more advantages than the convensional concrete. When the precast are connecting in the site project then the important thing to do is controlling, method of connection and connection models. If these did not do so the distribution of energy does not occur in connection area.

During earthquake, many buildings were damaged especially in the joints. The most seriously damaged areas is in joints. The joints are areas where connecting elements, dissipation of energy happen, shear forces are very large. The shear forces can cause damage in joint area because of the poor planning, the poor reinforcement ties or both. The first cracking is a sign and control that concrete has been damaged before being collapse.

Paulay and Priestley (1992) explains that join is a critical area that can respond to earthquake resistant in inelastic conditions. The shear forces working on joint as horizontal shear and vertical shear which has a value greater than the shear forces on the beams and columns (ECCS., 1986).

Some researches behavior of beam connections to joint due cyclic loading. Shriatmadar and Beydokhti (2013) had investigated of seismic response of precast concrete beam to colomn connections. The results were behavior of monolith was satisfactory in term of strength and ductility and panching occurred in speciment. Jamal *et al*. (2014 a, b) had researched behavior of join using various beam connection models under cyclic loading and result is that SBK 4 could use in earthquake area. Some researches were produced innovations, methods and models. Scott and Fenves (2006) researched effect of flexural crack on concrete beam failure mechanism design which compared with a numerical simulation. The new researches on joints behaviour of precast was done by Rante *et al*. (2017) and Djamaluddin *et al*. (2017).

Based on the researches ware used to study on joint interior precast which an otch connection model. This study aims to research on behavior of precast interior joint under cyclic loading and the results will be compare with monolith joint.

Precast: Based on the location of the point, the join can be divided into 2, i.e.,:

- Exterior joint is a pont view of column with beam which located on out side of the building as shown in Fig. 1 point c-g
- Interior joint is a pont view of column with beam which located on inside of the building as shown in Fig. 2 point a-d
- Corner joint interior joint is a pont view of column with beam which located on corner of the building as shown in Fig. 1 point a-b

Pauly and Priestly (1992) devided precast connections in two parts, i.e., strong connection, if the

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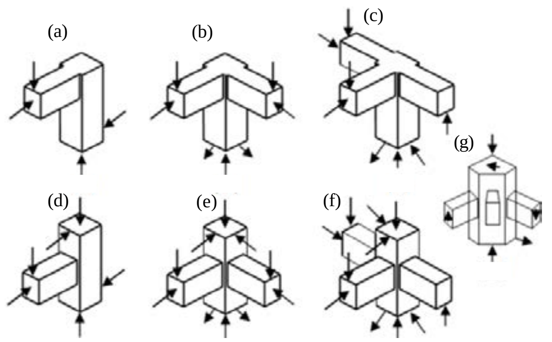

Fig. 1a-g): Exterior joints and corner joints

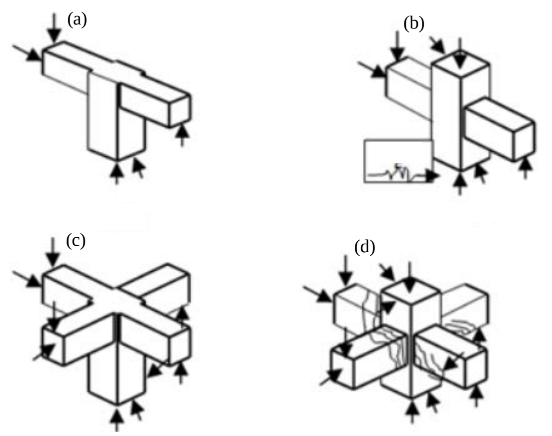

Fig. 2a-d): Interior joints

precast is in elastic condition then the structure can receive large earthquake load. The precast connection must be prove in theoretical and an experimental which must be the same as the conventional connection. Ductile connection is a connection that allow inelastic deformation. The connection system must also prove in theoretical and an experimental, so, it can be qualified earthquake resistant of structures.

Based on the deformation area, the joint can be divided as follows: elastic joint is the joint where inelastic deformation does not occur on beams and columns and around of the joint because it have a strong reinforcement. Inelastic joint is the joint where the plastic hinge occurs on beam in front of column and after several cycles then the inelastic deformation occurs on joint.

According to Elliot that the terms of connection planning on precast are: the connection is capable of translating within certain limits at the point view which in area occurs deformation and cause cracks. The connection capable of resist the load according to design as an overall system as well as individual members. The connection have strength and rigidity to be able to behave in a stable resist the load.

The connection system and connection controled were very important to do because in this areas were designed to be distribute energy on it.

Ductility: The ductility of analysis was based European Convention for Constructional Stellwork 1968 (ECCS) which is dividing ductility in two forms. The formulas are the ductility partial and the full ductility. The partial ductility for positive areas and negative areas, i.e.:

$$\mu_{oi}^{+} = \frac{\mu_e^{+}}{\mu_y^{+}} \quad (1)$$

$$\mu_{oi}^{-} = \frac{\mu_e^{-}}{\mu_y^{-}} \quad (2)$$

Equation for full ductility conditions in positive area and negative area, i.e.:

$$\mu_i^{+} = \frac{\Delta\mu_e^{+}}{\mu_y^{+}} \quad (3)$$

$$\mu_i^{-} = \frac{\Delta\mu_e^{-}}{\mu_y^{-}} \quad (4)$$

Where:

μ_{oi}^{+} and μ_{oi} = A partial ductility
μ_e^{+} and μ_e = Deflection limits
μ_i^{+} and μ_i = Full ductility
$\Delta\mu_e^{+}$ and $\Delta\mu_e$ = The total deflection limit
μ_y^{+} and μ_y = Yield deflection

Resistance ratio: The strength of connection must be distribute of force without damage. The resistensi ratio is ratio of the maximum load to the yield load. The formulas are in positive areas and negative area, i.e.,:

$$P^{+} = \frac{P^{+}_{max}}{P_y^{+}} \quad (5)$$

$$P^{+} = \frac{P^{+}_{max}}{P_y^{+}} \quad (6)$$

where, P^+ and P^- are maximum load (P_{max}). With load of yield (P_y) ratio in positive and negative area. The strength of structure will be turn down after a sectional crack in a certain area which will reduce if value of strength more than moment of the area.

MATERIALS AND METHODS

The researches using an experimental method which in real condition implementation. The stages are:

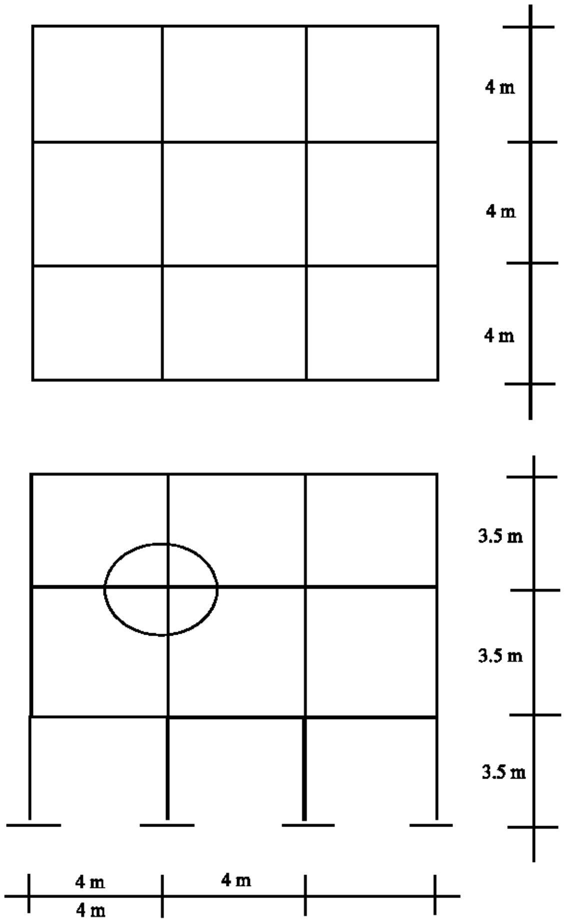

Fig. 3: Design of preliminary test

Preliminary tests: The preliminary tests includes: review of the literature and researches, prepare tools and materials and mix design. Research was conducted by Parung *et al*. (2016) using 6 notch connections with 2 variation of connection length of notch. The best of result experimental behavior of notch connections was length of notch 15 cm. The best model of connection will be used in cyclic testing. Before we doing cyclic testing, we planned a design used theoretical analysis based on SNI 1726 : 2012 will be compared with compared with experimental results. Design was a building as shown in Fig. 3.

Design of speciment: The joint interior monolith and joint interior precast were used notch connection models as shown in Fig. 4 and 5 and code of the speciment shown in Table 1.

Dimensions as follows: Beam was 200×300×1.500 mm, column was 300×300×1.500 mm. The beam was connected by grouting which quality of 40 MPa, fc' 25 MPa, stirrups were D8, main reinforcement were D13.The length of connections were 300 and 400 mm. The length of notch was 15 cm. The cyclic load testing method shown in Fig. 3.

The testing speciment consists of: the concrete material tests among others: the compressive strength test, the tensile strength test, the elastic modulus test and the tensile strength reinforcement test. The connection models: the precast which beam connection using notch models. The test was used displacement control. The specimens gave lateral load as a cyclic load as shown in Fig. 6 and 7.

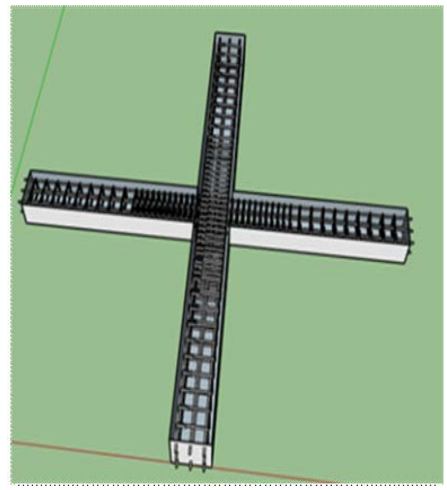

Fig. 4: Monolith joint (BN)

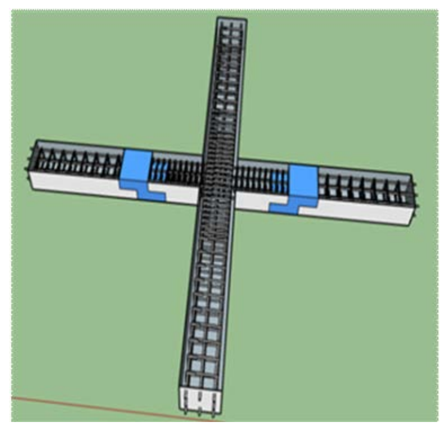

Fig. 5: Precast (BTK)

Table 1: Code of speciment

Specimens	Code
Monilith	BN
Precast which length of connection 30 (cm)	BTK 30
Precast which length of connection 40 (cm)	BTK 40

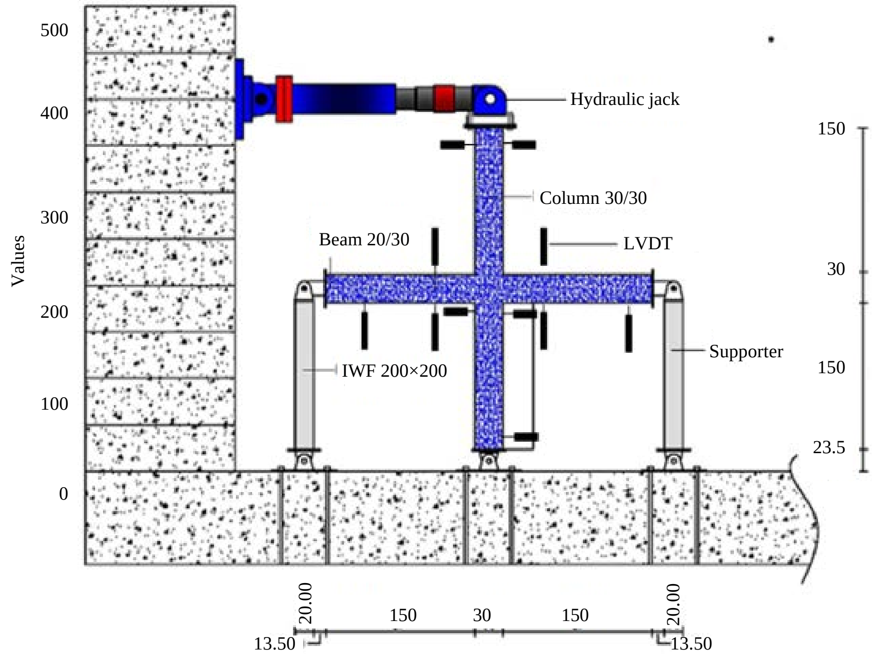

Fig. 6: Cyclic load testing method

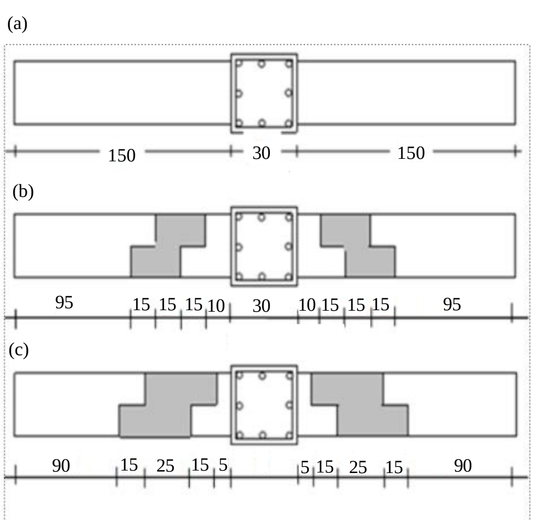

Fig. 7: Top view of the specimen: a) BN; b) BTK 30 and c) BTK 40

RESULTS AND DISCUSSION

The hysteresis loop is a curve which positive direction (push load) and negative direction (pull load) which is relationship of load between deflection. The loading method was used displacement control which starting from the smallest to the largest loading. The loading was a lateral loading assumed as cyclic loading.

The cyclic test with increase of displacement based on ECCS 1968. The cyclic tests were carried out only in 7 stage (each stage consisted of 3 cycles). All speciments were in elastic condition until the third stage. Based on the results obtained hysteresis loops as shown in Fig. 8-10.

Figure 8 shown elastic condition (BN) reached in push load (P_y^+) was 12.44 kN and deflection of beam (Δ_y^+) was 2.38 mm and pull load (P_y^-) was 12.95 kN and deflection (Δ_y^-) was 1.92 mm. The maximum of push load (P_u^+) was 18.53 kN and deflection was (Δ_u^+) was 8.86 mm. The maximum of pull load (P_u^-) was 18.64 kN and deflection (Δ_y^-) was 9.33 mm (Shariatmadar and Baydokhty, 2013; Prasad and Pavithara, 2016; Caronge and Triwiyono, 2011; Pimanmas and Supaviriyakit, 2008; Scott and Fenves, 2006; LaFave and Kim, 2011; Hooda *et al.*, 2013; Vaghani *et al.*, 2015; Zheng *et al.*, 2018; Ketiyot and Hansapinyo, 2018; Krishna and Mathew, 2017).

Figure 9 shown elastic condition (BTK 30) reached in P_y^+ was 12.46 kN and Δ_y^+ was 2.38 mm and P_y^- was 12.60 kN and Δ_y^- was 2.42 mm. The maximum of push load (P_u^+) was 19.17 kN and Δ_u^+ was 10.87 mm. The maximum of pull load (P_u^-) was 20.04 kN and Δ_y^- was 10.89 mm.

Figure 10 shown elastic condition (BTK 40) reached in P_y^+ was 12.50 kN and Δ_y^+ was 2.71 mm and P_y^- was 12.63 kN and Δ_y^- was 2.63 mm. The maximum of push load (P_u^+) was 19.93 kN and Δ_u^+ was 11.17 mm. The maximum of pull load (P_u^-) was 20.07 kN and Δ_y^- was 11.13 mm.

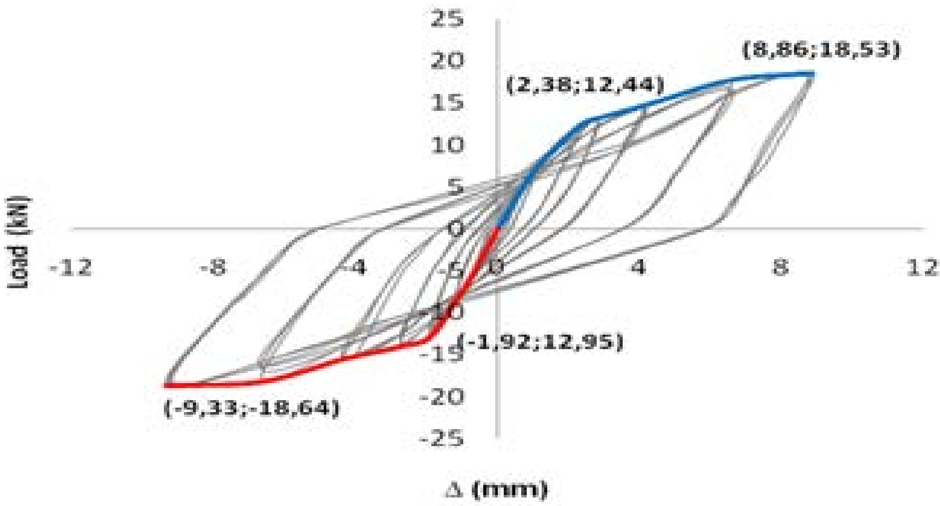

Fig. 8: Hysteresis loop of BN

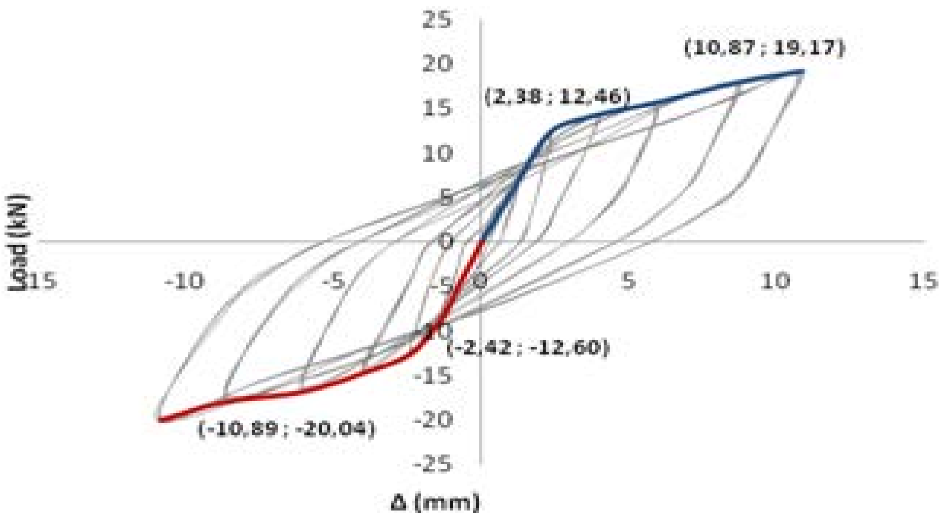

Fig. 9: Hysteresis loop (BTK 30)

The red curve was relationship maximum load to maximum deflection on beam in positive direction (push load) while the blue curve in negative direction (pull load). The third curve shown in Fig. 11.

From curves of precast shows that was identical to monolith joint (BN) can be conclude that the dissipation of energy distributed well on beam, so, the precast strength was almost the same as the monolith

Resistensi ratio: Resistensi ratio is the ratio of ultimate strength (Pu) to yield strength (Py) as shown in Table 2. The load applied was a lateral force which assumed cyclic loading. The fastest reaching yield condition was the monolith when the loading of cyclic loading was 10.95 kN. In Table 3 can be seen that the strength of precast almost same as monolith. The connection using welding and grouting was able to distribute the force. The cyclic test was used a hidroulic jack, supporters and LVDT as shown in Fig. 12.

Ductility: The analysis data of ductility can be seen in Tabel 3. The ductility of precast joint were partial ductility. The collapse of speciments were preventable if failure of ductile rather than brittle-ductility with large energy dissipation capacity. The elements of structure should be that can be withstand of seismic or earthquake force and according standart ie strong colomn-weak beam. The reitrofing on beam area contributes for energy dissipation, so that, the forces between elements can be well distributed. Conclusion that the speciments were in ductile condition.

Table 2: Resistance ratio

	Load (P) kN								
	P_{cr}		P_y		P_{ult}		$P = P_{ult}/P_y$		
Speciment	+	-	+	-	+	-	+	-	Average
BN	6.76	7.61	10.43	10.95	18.53	18.79	1.78	1.72	1.75
BTK 30	6.90	6.90	12.16	12.12	19.93	20.07	1.64	1.66	1.65
BTK 40	9.36	7.53	11.84	12.37	19.17	20.04	1.62	1.62	1.62

Table 3: Ductility

	μ_o				μ_i			
Speciments	+	-	Average	Ratio (%)	+	-	Average	Ratio (%)
BN	3.43	4.26	-	-	5.22	6.26	5.74	-
BTK 30	4.04	4.04	5.07	5.07	5.72	5.88	5.80	1.05
BTK 40	4.02	4.44	10.01	10.01	6.55	6.48	6.52	13.50

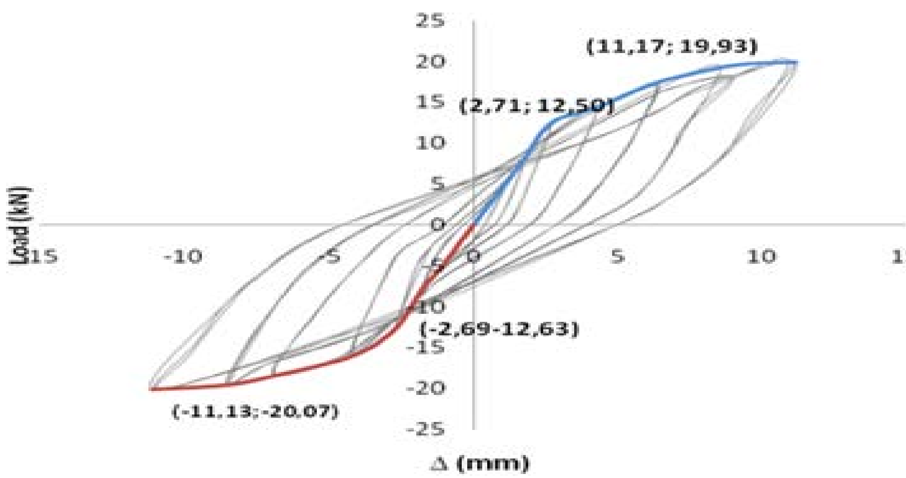

Fig. 10: Hysteresis loop (BTK 40)

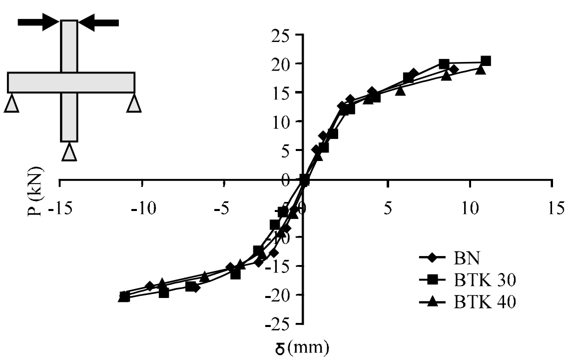

Fig. 11: Load deflection on beam

Fig. 12: The cyclic test was used a hidroulic jack, supporters and LVDT

Cracks pattern: The structure provides with strength, rigidy and deformation. However, result in concrete structures lacking the flexibility to move in response, environmental or volume changes. Cracking is usually the first sign of damage. When the involved tensile stresses being loaded onto the concrete and the loads exceeds maximum tensile strength then the cracks are occurring. The cracks occurs from the plastic hinge area and creep to joint area. If the displacement were increases, the length

Table 4: Comparison of speciment

Speciments	Parameter: Load max (1) +	-	Average	δ max (2) +	-	Average	Ductility (3) Partial	Full
BN	18.64	18.79	18.17	8.170	8.190	8.180	3.84	5.74
BTK 30	19.93	20.07	20.00	11.17	11.13	11.15	4.04	5.80
BTK 40	19.17	20.04	19.61	10.87	10.89	10.88	4.23	6.51

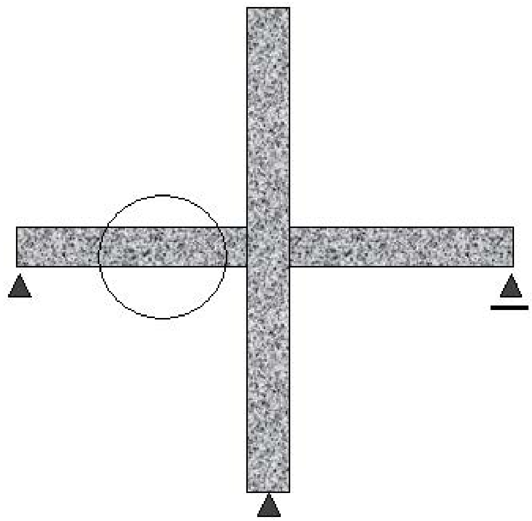

Fig. 13: Detail of cracks area

(a) (b)

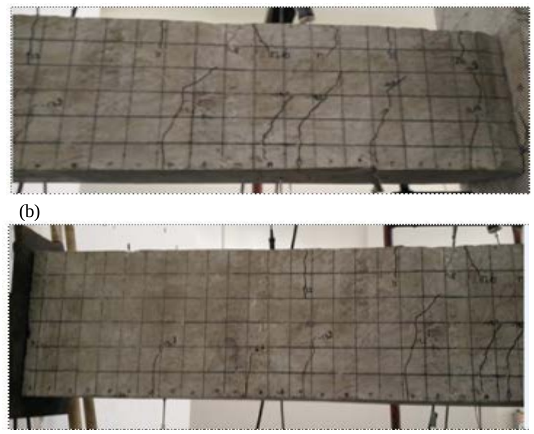

Fig. 14a, b): The cracks on plastic hinge area (BN)

(a) (b)

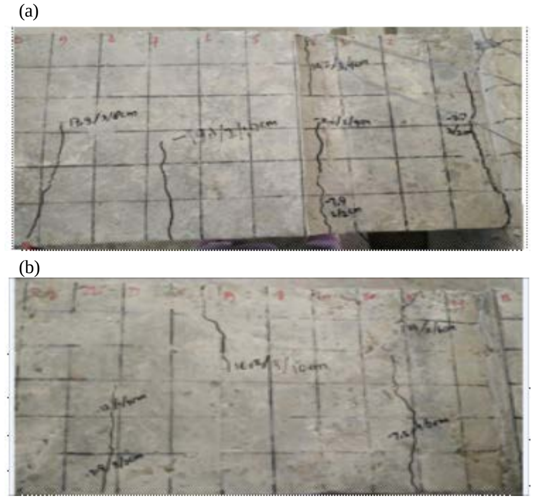

Fig. 15a, b): The cracks on plastic hinge area (BTK 30)

and the number of cracks also increases which happened after the beam in yield condition. The cracks pattern took in plastic hinge area of the beam and can be seen in Fig. 10.

When maximum displacement or cyclic loading was gived, the cracks on BN shows a sign that the structure will collapse. At first the pattern of cracks that occurs were flexural cracks when displacement increase then the cracks becames shear cracks.

In Fig. 13 and 14 can be see that the cracks occurred were in tensile reinforcements area. The cracks pattern on BTK 30 and BTK 40 were flexural cracks until displacement maximum.

Comparison of speciments: The comparation joint precast to joint monolith has doneafter analyzing the data from the test results. The comparison consts of ductility, strength and pattern of cracks can see in Table 4.

Table 4 shown that BTK 30 has the largest strength of 20.07 kN on push direction and the largest deflection of 11.15 mm on direction pull. The strength of BTK 30 more 6.89% than BN and BTK 40 more 4.81% than BN. The deflection of BTK 30 more 36.31% than BN and BTK 40 more 33% than BN.

BTK 40 has the greatest ductility value including partial ductility of 4.23 and full ductility o f 6.51. Based on (Anonymous, 2012) that the join precast exceeds the capacity of design and can be implemented in the earthquake area.

The cracks occurs in the plastic hinge area and then creep to joint area. If the displacement were increases then the length and the number of cracks also increases which happen after yield condition. The crack patterns that occur on specimens are flexural cracking. So, it can be concluded that the specimen is in flexural failure. The cracks can see in Fig 12-16.

(a) (b)

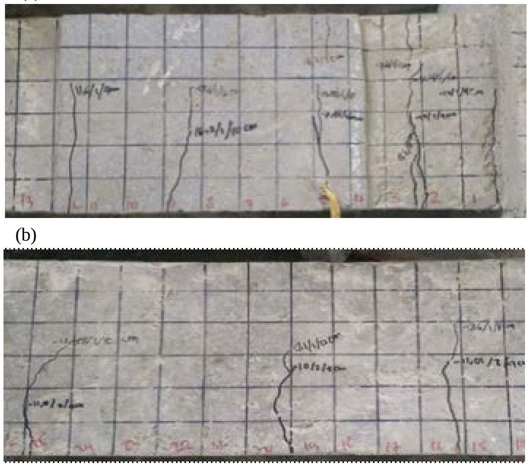

Fig. 16a, b): The cracks on plastic hinge area (BTK 30)

The composition of specimen from the best behavior as follows BTK-40, 30 and BN. The comparison of the analysis behaviour results can be conculed that the best precast was BTK 40.

CONCLUTION

The best precast behavior in terms of data analysis such as strength, stiffness and crack pattern was BTK 40. The precast joints which in partial ductility, ductile condition and the cracks were categorized as flexural failure. The composition of the best behavior as follows BTK-40, 30 and BN. The hysteresis loop characteristic of precast joints shows a curve identical to that of monolith joint. The strength and deflection of beams when push load are almost same as pull load, so, it can be concluded that the beam was in ductile conditions.
The comparison of the analysis behaviour results can be conculed that the best precast was BTK 40. Behavior of precast interior joints using a notch connection better than monolith joint.

REFERENCES

Anonymous, 2012. [Procedure for planning earthquake resistance for structures of buildings and non-buildings]. Badan Standardisasi Nasional, Indonesia. (In Indonesian) http://sni.litbang.pu.go.id/image/sni/isi/sni-17262012.pdf

Caronge, M.A. and I.I.A. Triwiyono, 2011. [Outer beam precast beam connection behavior with experimental method and push load analysis]. Ph.D Thesis, Gadjah Mada University, Yogyakarta, Indonesia. (In Indonesian)

Djamaluddin, R., H. Rante and R. Irmawaty, 2017. Flexural capacity of the precast RC beam-column connection using CFRP sheet. Civil Eng. Conf. Asian Region, 1: 1-10.

ECCS., 1986. Recommended Testing Procedure for Assessing the Behaviour of Structural Steel Elements Under Cyclic Loads. 1st Edn., European Convention for Constructional Steelwork, Brussels, Belgium,.

Hooda, N., J. Narwal, B. Sigh, V. Vivek and S. Parveen, 2013. An experimental investigation on structural behavior of beam column joint. Intl. J. Innovation Technol. Exploring Eng., 3: 84-88.

Jamal, M., H. Parung, M.W. Tjarongedan and V. Sampebulu, 2014b. Ductility of the precast and monolith concrete on beam column joints under cyclic loading. ARPN. J. Eng. Appl. Sci., 9: 1805-1810.

Jamal, M., H. Parung, W. Tjaronge and V. Sampebulu, 2014a. Ductility of precast concrete on interior beam-colomn join under cyclic loading. Proceedings of the 2nd International Seminar on Infrasructure Development, June 3, 2014, Hasanuddin University, Makassar, Indonesia, pp: 149-156.

Ketiyot, R. and C. Hansapinyo, 2018. Seismic performance of interior precast concrete beam-column connections with T-section steel inserts under cyclic loading. Earthquake Eng. Vibr., 17: 355-369.

Krishna, M.R. and A. Mathew, 2017. Effect of CFRP wrapping in ductile behaviour of RCC beam column joint under cyclic loading. Intl. Res. J. Eng. Tecnol., 4: 1360-1363.

LaFave, J.M. and J.M. Kim, 2011. Joint shear behavior prediction for RC beam-column connections. Intl. J. Concr. Struct. Mater., 5: 57-64.

Parung, M.H., W. Tjaronge and R. Djamaluddin, 2016. Experimental study on crack in beams connection with notches models. Proceedings of the 2016 International Seminar on Infrastructure Development (ISID 2016), September 22, 2016, Hasanuddin University, Makassar, Indonesia, ISBN:978-602-72676-7-1, pp: 379-383.

Paulay, T. and M.J.N. Priestley, 1992. Seismic Design of Reinforced Concrete and Masonry Buildings. Wiley Publishing Company, Hoboken, New Jersey, USA., ISBN:9780471549154, Pages: 768.

Pimanmas, A. and T. Supaviriyakit, 2008. Cyclic behavior of non-seismically designed interior reinforced concrete beam-column connections. Songklanakarin J. Sci. Technol., 30: 323-332.

Prasad, G.S. and C. Pavithra, 2016. Comparison between analytical and experimental behavior of interior RC beam column joint using steel fibers under cyclic loading. Intl. J. Sci. Eng. Technol. Res., 5: 1239-1244.

Rante, H., H. Parung, V. Sampebulu and R. Djamaluddin, 2017. Experimental study on precast beam-column joint method using Fiber Reinforced Plastic Sheet (CFRPS). Intl. J. Appl. Eng. Res., 12: 769-772.

Scott, M.H. and G.L. Fenves, 2006. Plastic hinge integration methods for force-based beam-column elements. J. Struct. Eng., 132: 244-252.

Shariatmadar, H. and E.Z. Beydokhti, 2013. An investigation of seismic response of precast concrete beam to coloumn connections: Experimental study. Asian J. Civ. Eng., 15: 41-59.

Vaghani, M., S.A. Vasanwala and A.K. Desai, 2015. Performanced of RC beam column connection subjected to cyclic loading. IOSR J. Mech. Civil Eng., 12: 48-53.

Zheng, W., D. Wang and Y. Ju, 2018. Performance of reinforced reactive powder concrete beam-column joints under cyclic loads. Adv. Civ. Eng., 2018: 1-12.