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Precast Connection Behaviour Using Finite Element

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Abstract. Precast concrete structure is not a new system in construction industry. Despite the several of advantages offer like ease in installation process, there is still a weakness especially on the stability of the whole structure where critical area at joint and connection. This issue has been a huge barrier in construction industry and become continuous topic for researcher. The connection strength is the most important part in precast system. Due to lack of standard, there are two common approaches in identifying strength and behaviour of connection, which is through experimental work and computational modelling. In this study, corbel connection at beam-column are chosen as a model for conducting a 3-dimensional finite element analysis using ABAQUS and results were validated with theory and experiments from previous study. Results of load-displacement show that the precast corbel have bending stiffness range to 4.5 kN/mm and found with ±10% different when compare to the experiment and theory. By establish the analysis and parameters; finite element analysis is an economical way to replace with tedious laboratory testing in identifying the behaviour of other precast connection. In future, researcher may gather all precast connection data for design purpose and standard development for precast system.

1. Introduction
The definition of connection and joint are the action of forces such as tension, shear and compression and it also moment such as bending and torsion through an assembly comprising interfaces. The design of the connection is therefore a function of both the structural elements and the joint between them [1]. Precast failure mostly due to design error on connections. The weakness of connection or joint between precast concrete components are the factor in precast concrete failure. Failure of connection to sustain load not only effect on the safety of occupant but also to the damage of underneath and adjacent structures due to the effect of impact. There are lot of experiments that had be done on identify connection behaviour of precast concrete [2-4]. However, the real size of structure experiment caused of cost, time and accuracy. It is difficult to do when it comes to try with different sizes and element, which is more costly compared to the theoretically design [5]. Therefore, this study are investigate on the usage of finite element analysis using software in order to analyse the precast connection. It is prove nowadays that software able to produce accurate results as experiment.

1.1. Model Precast Corbel Connection
In this study, design of corbel connection implemented by Rohani (2017) was adapted in this research. Rohani (2017) has conducted an experiment on corbel connection to determine main characteristic and classification. The connection was design based from the recommendation of BS8110 Part 1: Code of Practise for Design and Structure [6].

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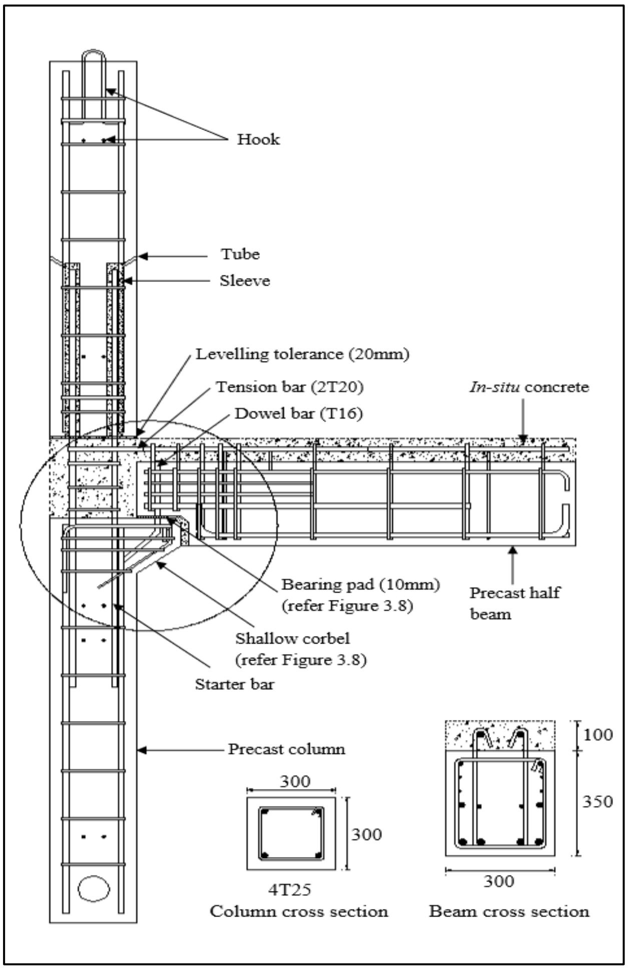

Figure 1. Corbel connection of precast concrete (Rohani, 2017).

2. Finite Element Analysis Procedure

The Finite Element Analysis (FEA) is a numerical method for solving problems of engineering and mathematical physics. It is useful for problems with complicated geometries, loadings, and material properties where analytical solutions could not obtain. ABAQUS offers the technologies necessary to include fracture and failure in the syringe design process. The extended finite element method (XFEM) allows for the analysis of crack initiation and propagation along an arbitrary, solution dependent path without the need for remeshing [7]. As in any FEA model, optimization of computational resources is one of the engineer's key philosophies. Through the discretization of not only of the topology of models, but undoubtedly through the application of approximated equations, it able to solve for even the most complex system achieving an answer within a finite, but known margin of error – suitable in industry and academia in many applications. Figure 2 shows dimension of precast beam-to-column connection considered in this analysis. The beam-to-column connection has main dimension, length of 1800 mm, height of 3000 mm and width of 300 mm. The beam has dimension of 1500 mm x 450 mm x 300 mm and column has dimensions of 300 mm x 3000 mm x 2142 mm.

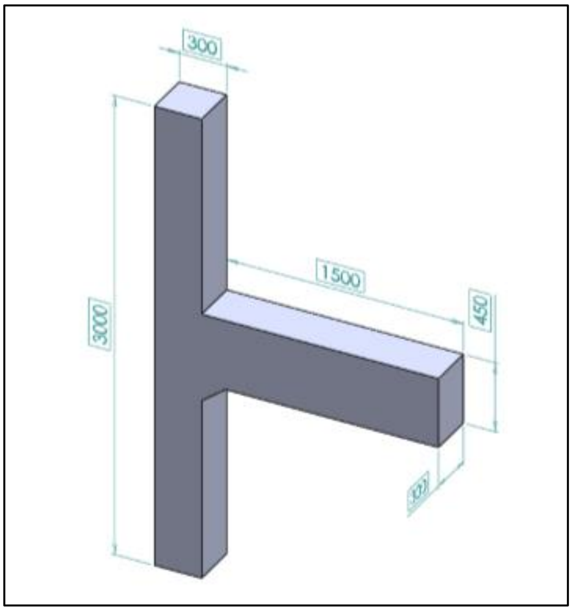

Figure 2. Dimension of beam-to-column connection used in FEA analysis (unit mm).

Figure 3 shows boundary condition of beam-to-column connection used in this study. The beam, top and bottom column was prepared using precast concrete and has steel as reinforced material. The load of 95kN applied at distance 1350 mm from root of the beam. The material properties used in this analysis was show in Table 1 and 2 for concrete and steel reinforced respectively was take from Rohani [1].

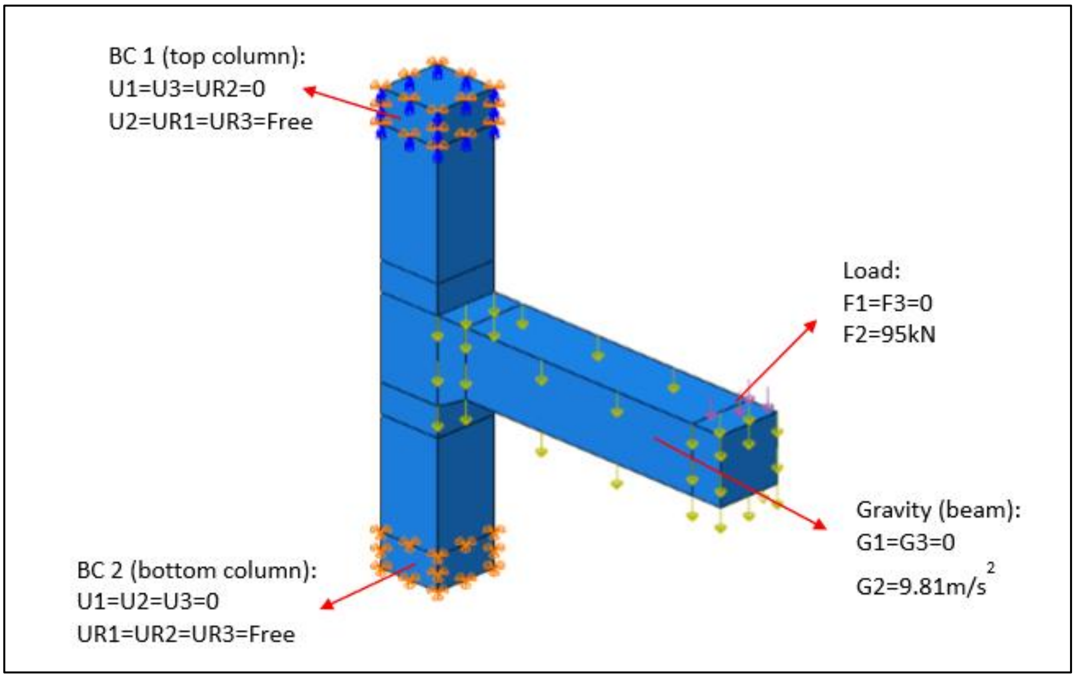

Figure 3. Boundary condition of beam-to-column connection used in FEA analysis.

Table 1 and Table 2 shows that the material's parameter that used in FEA. It include the main component in structure, which is concrete, and steel reinforce.

Table 1. Material properties of concrete used in this analysis.

Material's Parameters		The parameters of Concrete	
		β	38°
Concrete elasticity		m	1
E [GPa]	31.0	F=fb0/fc	1.12
ν	0.22	γ	2/3
Concrete compression hardening		Concrete compression damage	
Stress [MPa]	Crushing strain [-]	Damage C [-]	Crushing strain [-]
15	0	0	0
30	0.0000988	0	0.0000988
40	0.00015	0	0.00015
20	0.0056	0.56	0.0056
5	0.012	0.9	0.012
Stress [MPa]	Cracking strain [-]	Damage T [-]	Cracking strain [-]
2800000	0	0	0
56000	0.00108	0.9	0.00108

Table 2. The material properties of steel reinforce used in this analysis.

Steel Reinforce elasticity			
E [GPa]	200	ν	0.3

3. Results and Discussion

Figure 4 shows result of displacement at distance of 450 mm from root of precast beam. Result shows gradual decrease in load-displacement slope at point A due to propagation of crack from precast beam root as shown in Figure 5. Point A shows that with 30kN load, the beam displacement are 0.459mm. Propagation of this crack caused degradation in bending stiffness of precast beam concrete. Figure 6 shows further propagation of existing crack from beam root and propagation of new crack from beam structure, which caused further decreased in bending stiffness and further decrease in load-displacement slope after point B as shown in Figure 4.

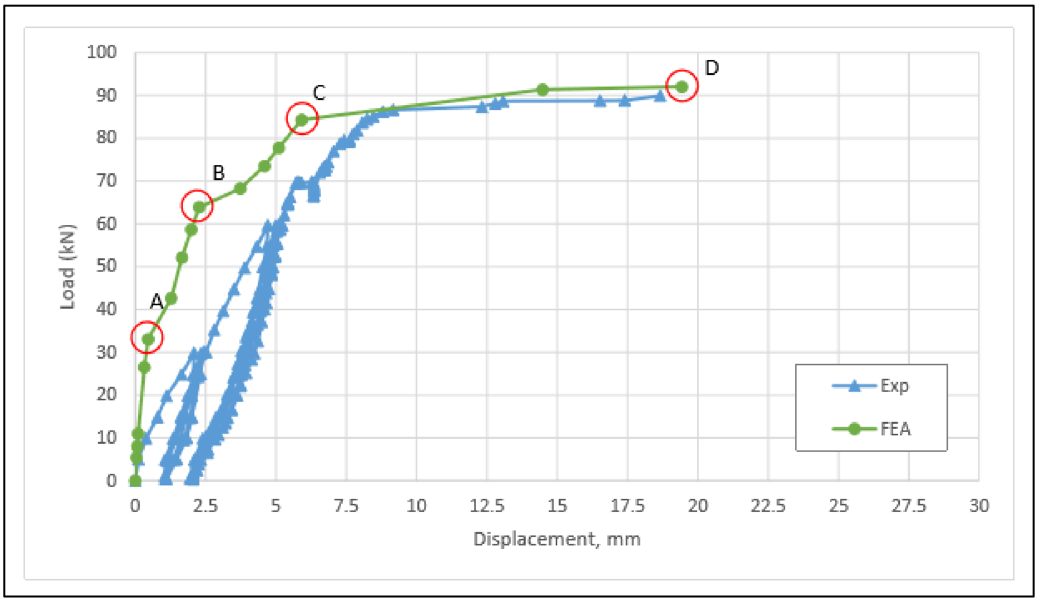

Figure 4. Load-displacement analysis slope.

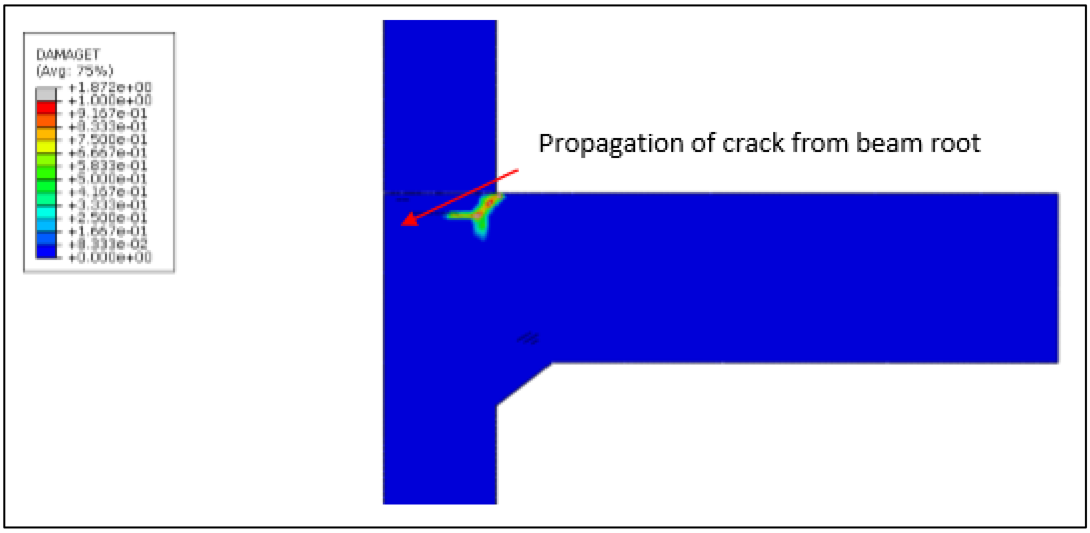

Figure 5. Propagation of crack from root of precast beam.

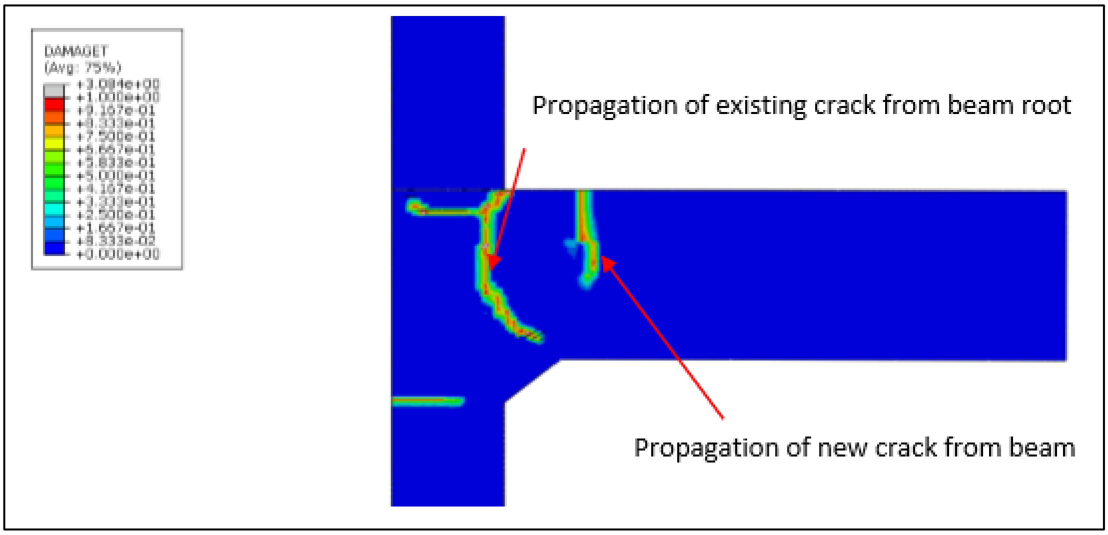

Figure 6. Propagation of existing and new crack from root of precast beam.

Figure 7 and Figure 8 shows extensive propagation of crack at beam to top column connection from point C to point D. Point D shows that the load are 92kN while the displacement are 19.433mm.
It is because there are very small crack propagation in the beam degrade load carrying capability in the beam which then manifested by lowest load-displacement as shown in Figure 4. Figure 8 shows crack propagation in the beam from FEA that has almost similar crack pattern in experiment as shown in Figure 9.

Comparison between the experimental and modelling show trends of curves in a similar manner as illustrated in Figure 4. Comparison between crack by experimental and modelling also show the same pattern of cracking in connection section. Hence, connections are in a ductile manner. Besides that, ductility factor defined by the ratio of ultimate displacement to displacement at yielding of tensile reinforcement [8].

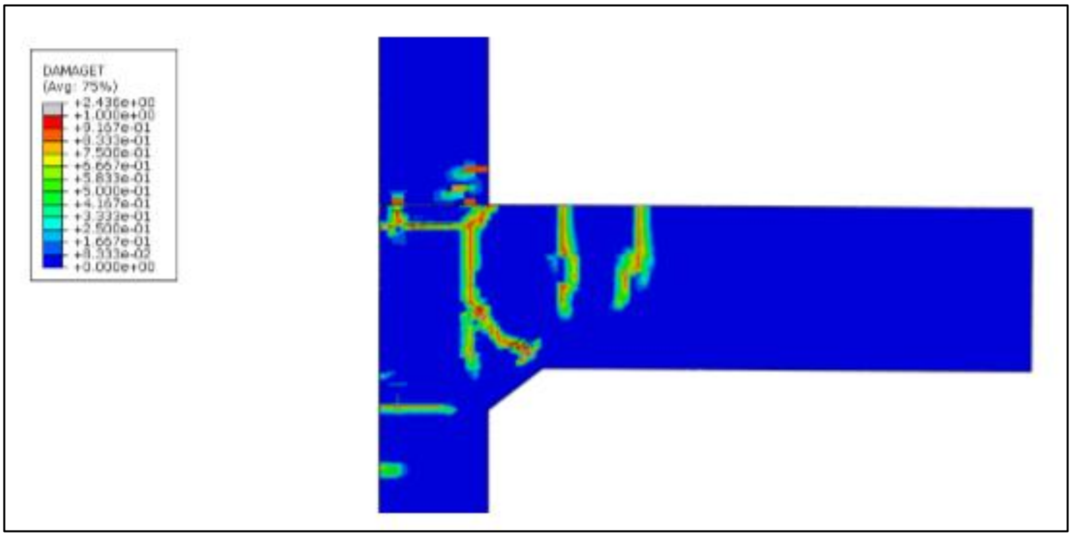

Figure 7. Propagation of existing and new crack from root of precast beam.

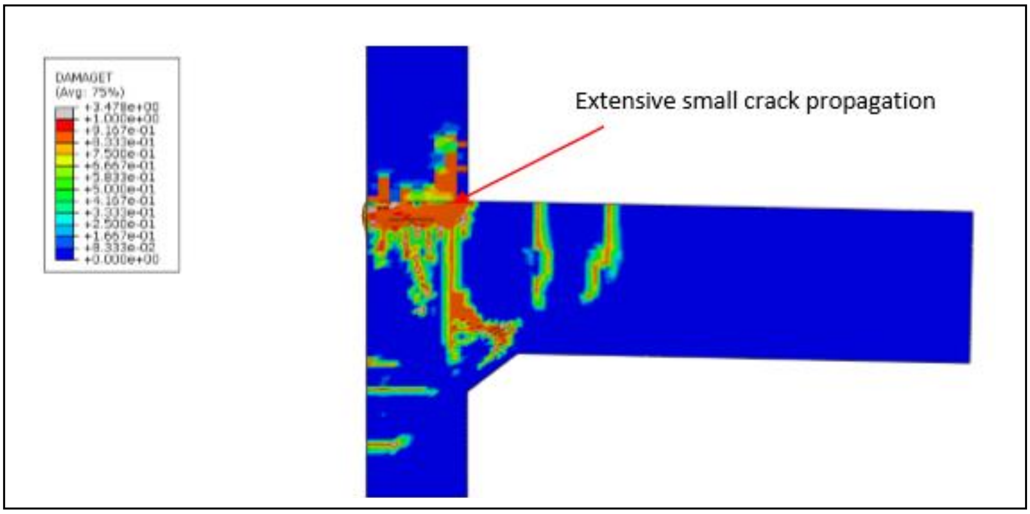

Figure 8. Propagation of existing and new crack from root of precast beam.

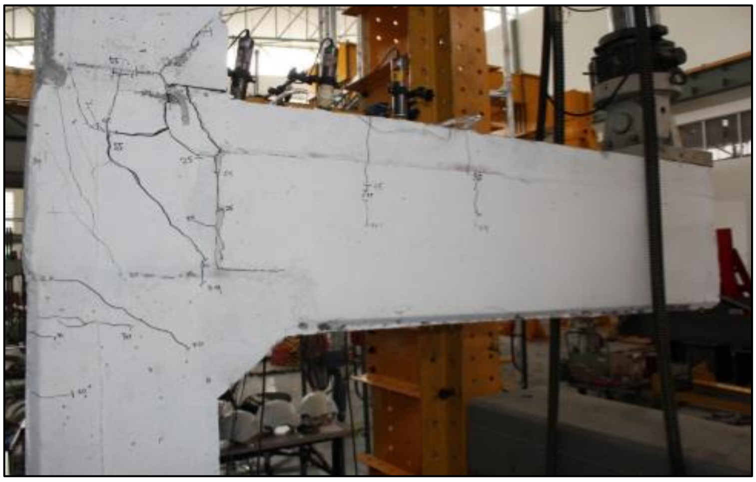

Figure 9. Failure mode of precast beam [2].

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4. Conclusion

The conclusion for this study is the cracking pattern of precast beam from FEA similar to experimental done previously. It also shows that the curve in graph between FEA and experimental increasing linear to non-linear. As it, the FEA modelling design can use to determine the displacement and cracking pattern, which is more reliable and cheaper than experimental method. For future, there will be design and parametric changes done in order to get the 7ehavior of connection. The cracking are mostly at the connection between column and beam. It mean connection section are the stress area of structure.

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