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Study on Progressive Collapse of Precast Beam-Column Assembly

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ABSTRACT *: Progressive collapse of building is a major threat to structural engineering community for the past few decades. Buildings are vulnerable to progressive collapse due to loss of one or more columns due to accidental events such as blast attacks. Out of which precast structures are extremely vulnerable to progressive collapse due to lack of structural continuity and redundancy in the load paths. In the event of a column removal under progressive collapse, beams are immediately affected due to transfer of load paths. This paper focuses on the performance evaluation of partially encased and fully encased beam in a precast beam-column assembly under progressive collapse. The performance is compared with reinforced concrete beam having same volume of steel. The performance is evaluated in terms of load-deflection characteristics. The beam-column joint consists of a corbel with a bent-up rebar grouted with the beam. The analysis of precast beam-column assembly is done using finite element software ANSYS 19.0*

KEYWORDS – *Finite element analysis, fully encased beam, partially encased beam, precast beam-column assembly, progressive collapse*

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I. INTRODUCTION

Progressive collapse is the spread of an initial local failure from element to element, which eventually result in the collapse of an entire structural system or a disproportionately a large part of it [1,2]. The factors that contribute towards progressive collapse are design mistake, faulty construction, abnormal loadings such as internal gas explosions, blast, aircraft impact, vehicular collision, earthquake etc. It is one of the most disastrous building failures, most often leading to possible loss of life, multiple injuries, and costly damages. The Ronan Point apartment tower collapse in England (1968), The Murrah Federal Office Building collapse in Oklahoma City (1995), The World Trade Center collapse in New York (2001) are some of the major progressive collapse events which occurred in the past few decades [3]. These incidents are evident that buildings are vulnerable to progressive collapse no matter whether it is a reinforced concrete or precast constructed structure. But compared to reinforced concrete structures precast structures are extremely vulnerable to progressive collapse due to lack of redundancy in the load transfer path and continuity of structures [4].

Over the last few decades, numerous tests on steel structures and composite structures, including the beam-column substructure, plane frame structure, and space-frame structure have been conducted under an internal column-removal scenario [5]. In the event of a column removal during a blast, all the forces acting on the beam get transferred to the connected beam, thus when the beam gets collapsed total structure gets collapsed. However, if the beam withstands the load acting on it, then progressive collapse can be stopped. Until recently, studies of the collapse-resistant mechanism of frame structures have mainly focused on slab effect, joint behaviour, and boundary conditions but no systematic studies of composite beam-column assemblies under progressive collapse exist.

This paper focus on the study of partially encased (PE) and fully encased beam (FE) on progressive collapse resistance. A partially encased beam [6] is a beam in which web portion is covered by reinforced concrete for which maximum strain will develop in steel flanges. A full height rectangular opening castellated steel beam is used for the development of partially encased beam. The main objective of making castellated steel beam is to increase the steel section flexural stiffness and strength without increasing the steel self-weight. A fully encased beam is a beam in which the whole steel section is covered by the reinforced concrete so that the top and bottom flanges are not in outermost position. In this case the maximum strain developed in the steel is less than the one in the concrete.

II. PRECAST BEAM-COLUMN ASSEMBLY

The primary objective of this study was to conduct a finite element analysis of progressive collapse on a precast beam column assembly. In order to achieving this objective, experimental test results conducted on a 2D precast beam-column assembly under progressive collapse by Al-Salloum et al. [4] for middle column-removal scenario has been studied.

2.1 Test specimen details and assembly

The specimen consists of a two-bay beams and three columns as shown in Fig. 1. The beam and column were 350 x 350 mm size square cross-section. The column height was 1070 mm up to the soffit of the beam and the corbel section was 350 × 250 mm. The shear reinforcement in the beam was in the form of two legged stirrups of 8 mm diameter rebars provided at a spacing of 100 mm center-to-center.

The longitudinal reinforcement of the column consists of 8 numbers of 16mm diameter rebars and 8 mm diameter ties were provided at a spacing that varied along the column height. The beam-column joint consisted of a 16 mm diameter rebar which protrude from the corbel. The beam had a circular hole of 60 mm diameter at the beam ends for the corbel rebar to pass through and the connection is finally grouted with non-shrinkable cementitious mortar. To support the beam on the corbel a 20 mm thick neoprene pad was used to cushion the assembly. The reinforcement details of the beam-column assembly are provided in Fig. 2.

2.2 Properties of materials

A ready-mix concrete of compressive strength 37.3 MPa, whose compressive strength measured as per ASTM C39/C39M was used for casting of the test specimens. The yield strength for 8mmϕ and 16mmϕ rebars were 525 and 526 MPa and the average value of tensile strength was 550MPa and 651 MPa respectively. The tensile test for steel rebars were carried out according to ASTM E8/E8M.

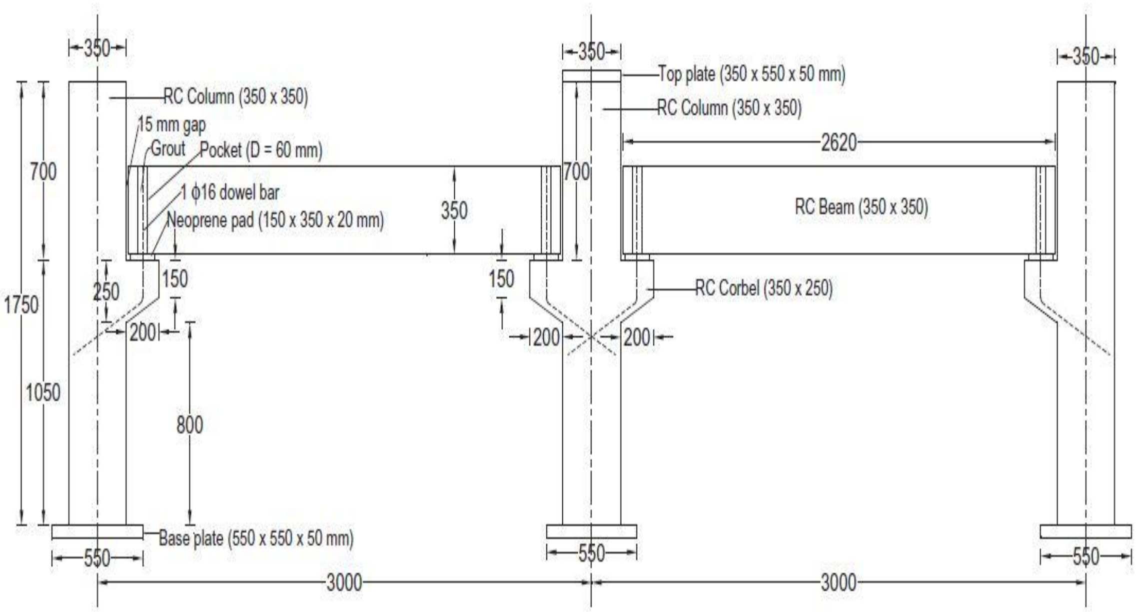

Fig 1: Details of PC-C specimen [4]

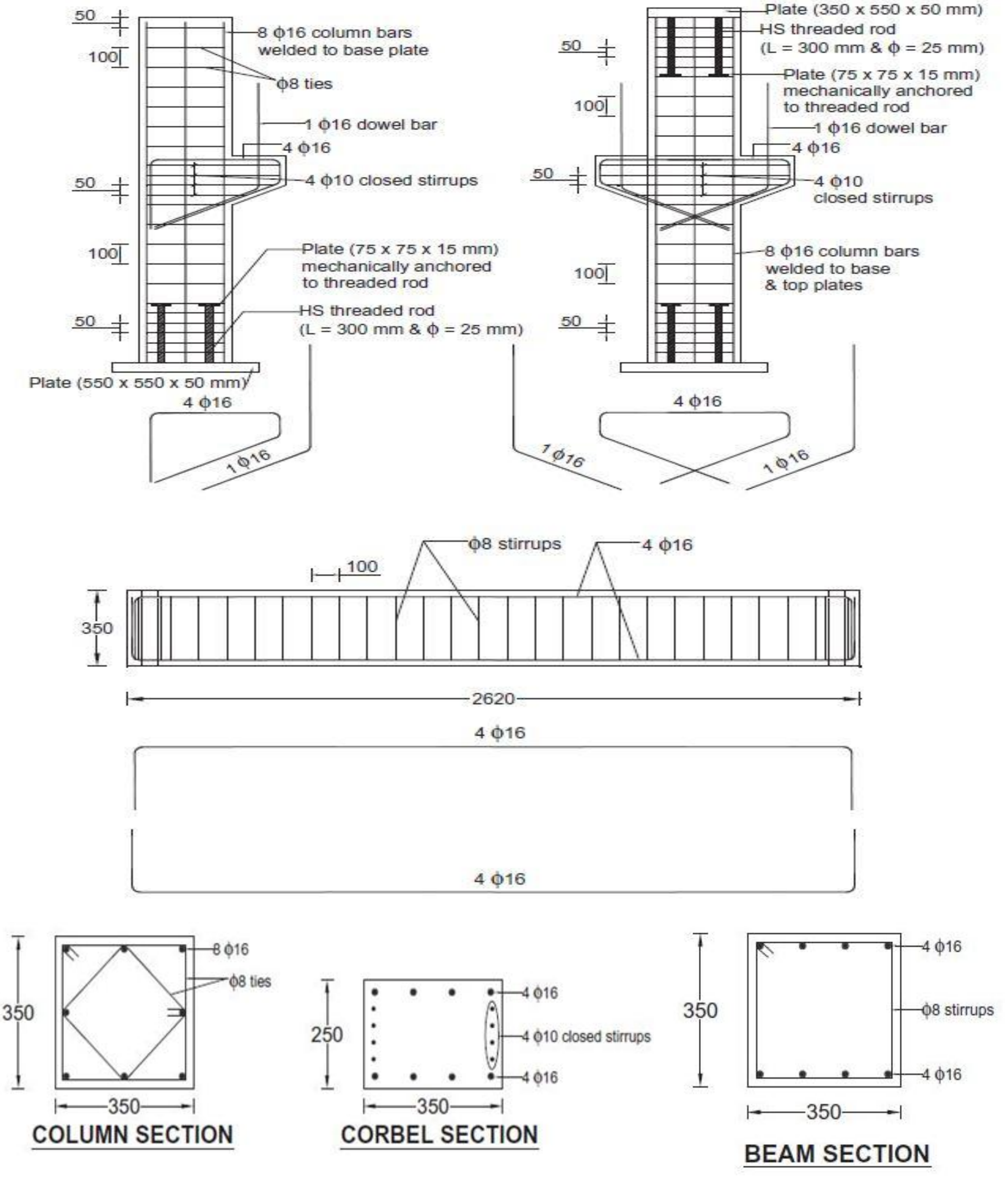

Fig 2: Reinforcement details of the specimen [4]

III. FINITE ELEMENT ANALYSIS

Finite element analysis has been carried out using ANSYS 19.0 package to predict the behaviour of precast beam-column assembly. Static structural tool in ANSYS Workbench was used in the modelling procedure. For the simplicity of modelling only ¼ th model was modelled due to geometry of the assembly. The symmetry option was used to make the entire assembly. The concrete was modelled using extrude option in the design modeller option. The longitudinal reinforcement and stirrups were modelled using lines from sketches option and were patterned to required spacing and number. Square shaped meshes were used for finite element. Load was applied as displacement-controlled loading.

3.1 RC beam

Finite element analysis of RC beam in precast beam column assembly was done from an experimental study conducted by Al. Salloum et al. [4] on progressive collapse on precast beam-column assembly.

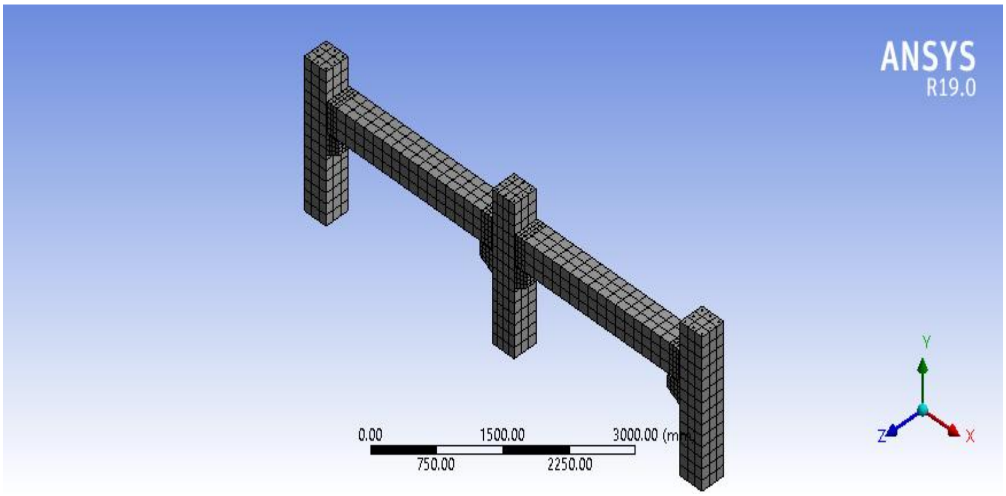

Fig 3: Meshing of precast beam-column assembly

3.2 Partially encased beam

Finite element analysis of partially encased beam is done by designing a new partially encased beam by making volume of steel same as that of RC beam. The volume of steel is obtained by multiplying the total weight of steel with density of steel which is 7860 kg/m^3. Fig. 4 shows the partially encased beam.

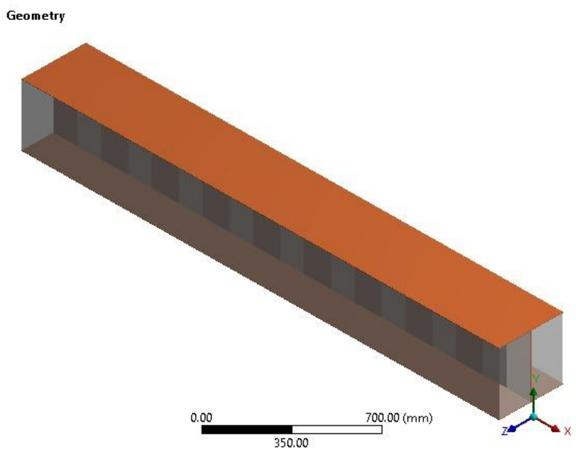

Fig 4 Partially encased beam

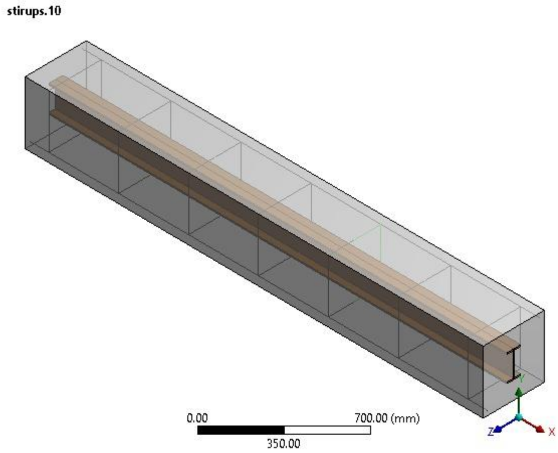

Fig 5 Fully encased beam

3.3 Fully encased beam

Fully encased beam is also designed by making volume of steel constant with that of RC beam which is 45 kg. Fig. 5 shows the fully encased beam.

IV. RESULT AND DISCUSSION

The finite element modelled precast beam-column assembly is validated against experimental data by Al Salloum et al. Table 1 shows the variation of the finite element analysis results with experimental results. It is observed that finite element analysis results have variation of less than 10%. The performance PE and FE beams are compared with respect to RC beam and are evaluated in terms of load-displacement behaviour. Table 4 summarises the test results of PE and FE specimen with respect to RC specimen. Load versus middle column displacements envelops are presented in Fig. 7 for all the test specimens.

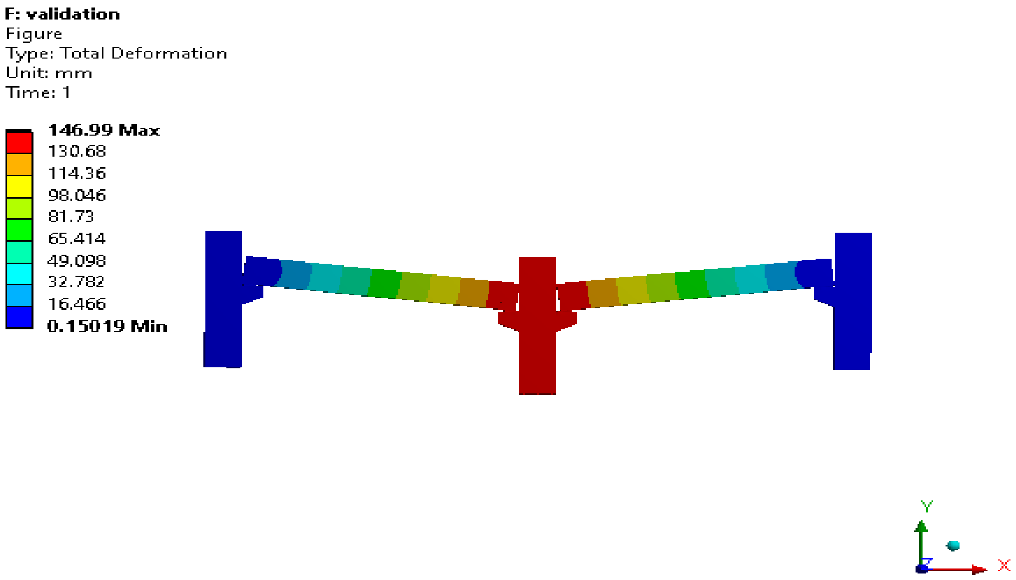

Fig 6 Total deformation of precast RC beam column assembly by FEA

Table 1 Results of FEA

Properties	FEA	Experiment	Variation (%)
Peak load	11.76kN	12.8kN	8.12%
Middle column displacement at peak load	146.99mm	145mm	1.37%

Table 2 FEA results of RC, PE and FE beams

Beam	Peak load (kN)	Displacement (mm)	% Increase in load
RC	11.76	146.99	1
PE	16.15	183.72	37.33
FE	16.38	204.36	39.28

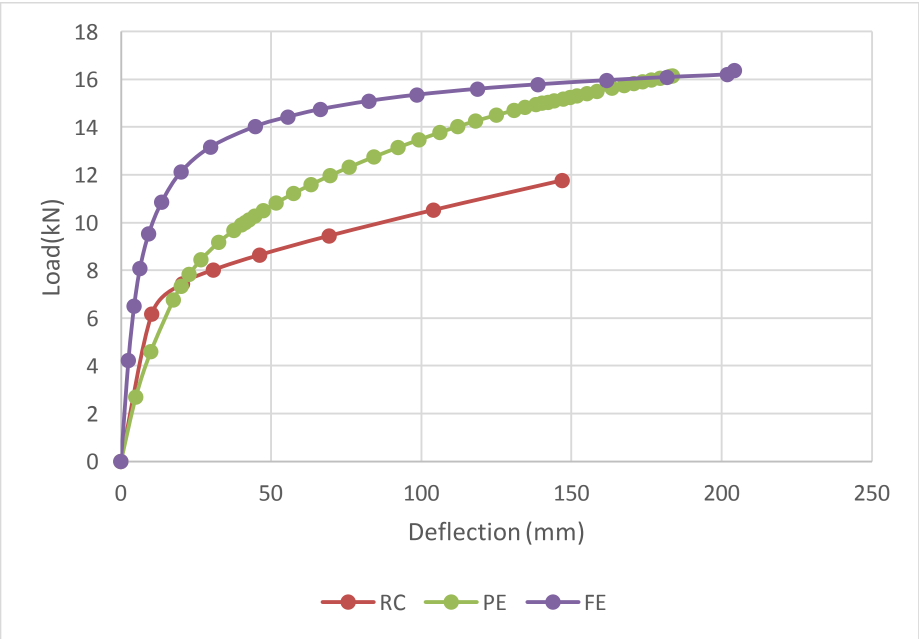

Fig 7 Load displacement envelope comparison of RC, PE and FE

V. CONCLUSION

Results of finite element analysis of precast beam column assembly falls within the permissible range of values of experimentally conducted data. Hence the finite element modelled can be used to conduct other studies. As a part of this, a partially encased (PE) and fully encased (FE) beams are studied. On comparing the results, it is evident that PE and FE beams shows better load resistance capacity compared to RC beam of same volume of steel. There is an increase in load resistance of about 39.28% for FE and 37.33% for PE beams compared to RC beam. FE encased beam shows highest displacement (204.36 mm) before failure compared to other specimens. Hence FE beam does not fail immediately after the column loss and it take sufficient amount of displacement before failure. Thus, FE beam section is found efficient in precast constructions.

REFERENCES

[1]. Ellingwood B, Leyendecker EV. Approaches for design against progressive collapse. J Struct Div ASCE 1978; 104(11):413-23.

[2]. Ellingwood B. Mitigating risk from abnormal loads and Progressive collapse. J perform Constr Fac 2006;20(4):315-23.

[3]. R Shankar Nair, Progressive collapse Basics, modern steel construction, NASCC proceedings 2004

[4]. Yousef A. Al-Salloum, Mohammed A. Alrubaidi, Hussein M. Elsanadedy, Tarek H. Almusallam, and Rizwan A. Iqbal, Strengthening of precast RC beam-column connections for progressive collapse mitigation using bolted steel plates, Engineering Structures 161 (2018) 146–160.

[5]. Ibrahim M.H. Alshaikh, B.H. Abu Bakar, Emad A.H. Alwesabi, and Hazizan Md Akil, Experimental investigation of the progressive collapse of reinforced concrete structures: An overview, Structures 25(2020)881-900

[6]. Iman Satyarno, Djoko Sulistyo, Dina Heldita, and A. Talodaci Corte Real De Oliviera, Full height rectangular opening castellated steel beam partially encased in reinforced mortar, Proceedia Engineering *171(2017) 176-184*

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