Comparative Study On Behavior Of Reinforced Concrete Frames With Different Beam-Column Joints Types

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Abstract- *A beam-column joint is a very critical zone in reinforced concrete framed structure where the elements intersect in all three directions. There are practical difficulties involved in the construction of reinforced beam-column joints. In this review to focus on the general behavior of reinforced concrete Beam-Column joints (BCJ) exterior, interior and at top floor. Previous research work presented studying BCJ under gravity and seismic loads in addition to the effect of many parameters on the mechanical behaviour of BCJ the effect of reinforcement configuration, eccentricity, the joint aspect ratio (hb/hc), concrete compressive strength, and the compressive column axial load. BCJ classification was introduced according to ACI 318-02 (2002) and Egyptian code (2007), the equations and recommendations related with BCJ in national codes were reviewed. This study presented a comparison between the deflection and the static load capacity that can be received by the connection of reinforced concrete beam-column which is monolithically connected and non- monolithic.*

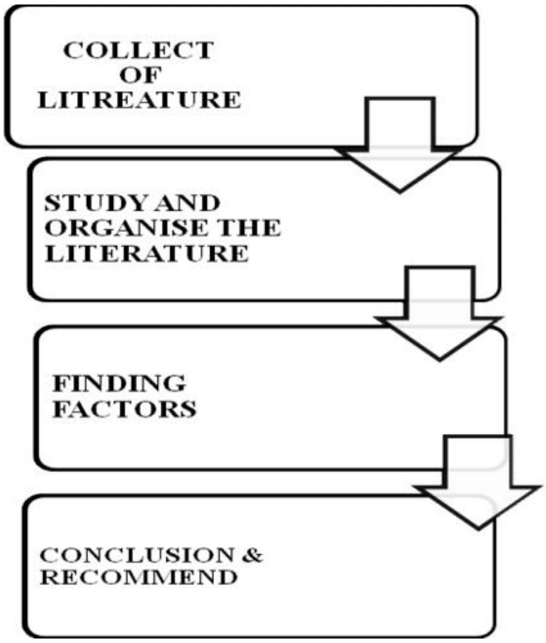
I. INTRODUCTION

According to the stiffness of the beam-column joint, the frames can be classified into three main types;

- Rigid Frames
- Flexible Frames
- Semi-rigid Frames.

Rigid frames are specified by the resistance of the shear, moment and torsion more effectively than other types of frames. Flexible frames are specified by the free rotation of the joint to load. Semi-rigid frames are specified by that the actual stiffness of connections lies between the rigid and flexible connections .A beam-column joint is defined as that portion of the column within the depth of the deepest beam that frames into the column. Structural connections are classified into two categories; Type 1 and Type 2 based on the loading conditions for the connection and the anticipated deformations of the connected frame members when resisting lateral loads. A Type 1 connection is composed of members designed to satisfy ACI 318-02 strength requirements for members without significant inelastic deformation. A Type 2 connection, frame members are designed to have sustained strength under deformation reversals into the inelastic range. The beam-column joints were classified.regarding to their positions into six categories according to ACI 352R-2

II. METHODOLOGY



III. LITERATURESURVEY

BEAM COLOUMN JOINT

Alva, G. M. S., Ferreira, M. A. and El debs, A. L. H. C., December, 2009 presented an experimental and theoretical study to discuss the effect of concrete compressive strength and the joint transverse reinforcement on degree of restriction of the joint.

Based on the analysis of five reinforced concrete beam-column joint, it can be concluded that the concrete compressive strength clearly contribute to the changing the behaviour of joint from rigid to semi-rigid through increasing the relative movement of beam-column joint by decreasing the concrete compressive strength of the frame.

Maya, L.F. and Albajar, L.," 2012 conducted high performance fiber reinforced cement composite beam-column connections. The structural behaviors for the frame were evaluated based on the load-deflection response, flexural strength of the concrete beams and crack pattern at the joint. Subsequent analysis of the test data showed that there is a good response of steel fiber high performance concrete frames to loading in comparison with NC frames. Good structural performance of steel fiber high performance concrete frames comes through reduction in the mid span deflection.

Several researchers Aly M. August 2004 Said and Moncef L. Nehdi and Ali E. Yeganeh October 2013 showed extensive investigations on fresh and mechanical properties of concrete (compressive strength, splitting tensile strength, and flexural strength) through using new concrete types such as self compacting concrete and ultra-high strength concrete. Compared to normal concrete frame, the load capacity, initial stiffness and energy absorbing capacity of self compacting concrete and ultra high performance concrete frames were improved.

Amanat, K. H. and Enam, B., 2016 proposed a finite element model to investigate the effect of beam depth and steel reinforcement ratio on the degree of restraint of reinforced concrete beam-column joint. This study reported that, the rotational stiffness of beam-column joint increased when increasing the beam depth and reinforcement steel ratio.

THE SHEAR STRENGTH OF BEAM-COLUMN JOINT

YasuakiGotoand Osamu Johstudied experimentally influence of eccentricity on the shear strength of reinforced concrete interior beam-column joints. 4 specimens were tested and the test results show that as the eccentricity increased, the joint shear strength decreased. The failure mechanism of joints were studied analytically. The analytical results show that the concentration of the shear stress of joint concrete is on the eccentric side and in the region of concrete failure.

Hideo Murakamiand et al.(2000) collected available 332 test data about interior R/C beam-column joint sub assemblage. They studies a lot of parameters acting shear strength of interior R/C beam-column joint connection. It was showed the concrete compressive strength had biggest influence on Joint shear strength. However, column axial force ratio and joint shear reinforcement ratio were not major influencing factors
Jaehong Kim and James M. LaFave (2007) collected and database of reinforced concrete (RC) beam–column connection test specimens and the specimens failed in joint shear failure.

Jung-Yoon Lee and et al. (2009) proposed a method to predict the deformability of RC joints failing in shear after plastic hinges develop at both ends of the adjacent beams. The proposed method is capable of estimating the effect of longitudinal axial strain of a beam in the plastic hinge region of the beam on the joint longitudinal strain. The estimated value of joint longitudinal strain was used to obtain the potential shear strengths of joint.

Sangjoon Park, Khalid M. Mosalam (2012) presented key parameters to determine the shear strength of exterior beam–column joints without transverse reinforcement. It showed that the shear strength of unreinforced exterior joints reduces with increase of the joint aspect ratio. The shear strength of unreinforced exterior joints is not affected by the compressive column axial load until 20% of nominal capacity.

THE EFFECT OF REINFORCEMENT IN THE BEHAVIOUROF BEAM-COLUMN JOINT

F. Kusuhara1 and H. Shiohara(2008) tested a ten half-scale reinforced concrete beam-column joint sub-assemblages loaded to failure by statically cyclic loading simulating earthquake loading, to obtain fundamental data including stress in bars after yielding and joint deformation**.** The amount of joint shear reinforcement is 0.3 %, which is the minimum requirement of the AIJ Guidelines (1999).It was found that the story shear capacity of the specimen with transverse beams, in which the damage of the joint was severe, was improved. Also in case of damage of joints were severe, bond actions of beam bars passing through the joints kept lower level than the bond strength specified in the AIJ Guideline. Poor anchorage length of beam bars in exterior joints led lower story shear capacity, yielding of column bars and severe damage in the joint.

Leslie M. Megget(2004) tested a four external reinforced concrete beam-column sub-assemblages under pseudo seismic cyclic loading.

It was found that the maximum beam elongations between 2.7 and 3.8% of the beam depth were measured in all the units tested with 500 Grade beam reinforcing, about 35% greater than those measured for the same sized beams with Grade 430 reinforcing at the same level of ductility.

The added transverse bars within the 90-degree bends to allow a reduction in the development length appear to work well as no beam bar slip was apparent.

Constantin E. Chalioris and et al.(2008) investigated the effectiveness of crossed inclined bars (X-bars) as joint shear reinforcement in exterior reinforced concrete beam–column connections under cyclic deformations. The experimental study consisted of 20 joint sub assemblages with various reinforcement ratios and arrangements including X-bars in the joint area. They focused full loading cycle curves, energy dissipation values and a categorization of the observed damage modes.

it is reported that specimens with crossed inclined bars and stirrups showed enhanced hysteretic response, excellent performance capabilities and the cracking was mainly localized in the beam–joint interface creating a distinct flexural hinge.

ECCENTRIC BEAM-COLUMN JOINT

The concrete cracks, caused by the earthquakes, appeared spirally upwards round the surface of the columns, or developed obliquely along the whole length of the columns. These cracking patterns show that the column failure is a kind of the torsional failure caused by the combination of torsion and shear.

As a result, a particular consideration should be given to the influence of the eccentricity of beam - column joints on the shear capacity of columns, both in seismic evaluation of existing structures and in seismic design of new reinforced concrete structures.

IV. AREA NEEDING RESEARCH

The following list identifies areas needing further research: Effect of eccentric beams on joints, Lightweight aggregate concrete in joints, Limit on joint shear, Behavior of indeterminate systems, Distribution of plastic hinges, Innovative joint designs, Special joint configurations and loadings, and Joints in existing structures. Beam column connection in joints of the structure plays vital role in the strengthening part of the structure. So further studies is to determine the behavior of column beam joint with monolithic and non-monolithic connections

V. COMPARATIVE STUDY BETWEEN MONOLITHIC AND NON MONOLITHIC

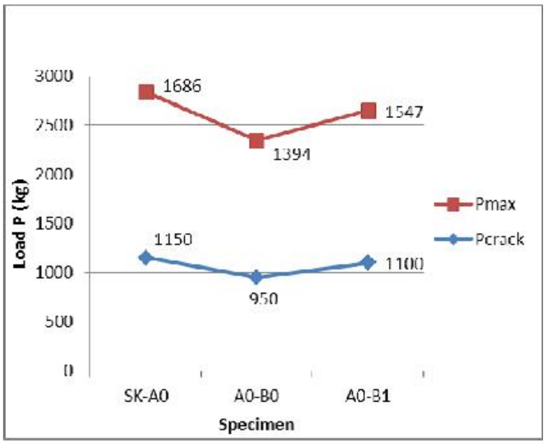
This study presented a comparison between the deflection and the static load capacity that can be received by the connection of reinforced concrete beam-column which is monolithically connected and non- monolithic.

3 sets of specimens were made to represent monolithic and non-monolithic specimens.

The beam-column connections were tested experimentally and compared to the monolithic beam-column connection.

LOAD CAPACITY

Based on the result of the test, it was found that in the non-monolithic beam-column joint connection without notches, the maximum acceptable load capacity decreased compared to the monolithic connection. The magnitude of the decline was 17%, i.e. 1686 kg for monolithic connection and 1394 kg for non-monolithic connection without notches . The same phenomenon also occurs in the load capacity as the first crack occurs. The first cracks occur at 1150 kg, 950 kg, and 1100 kg loads for monolithic connections, non-monolithic connection without notches and non-monolithic connections with notches

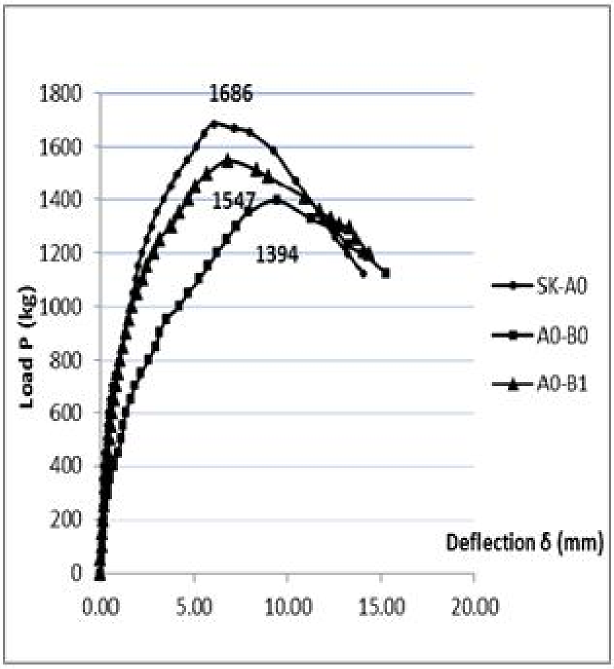


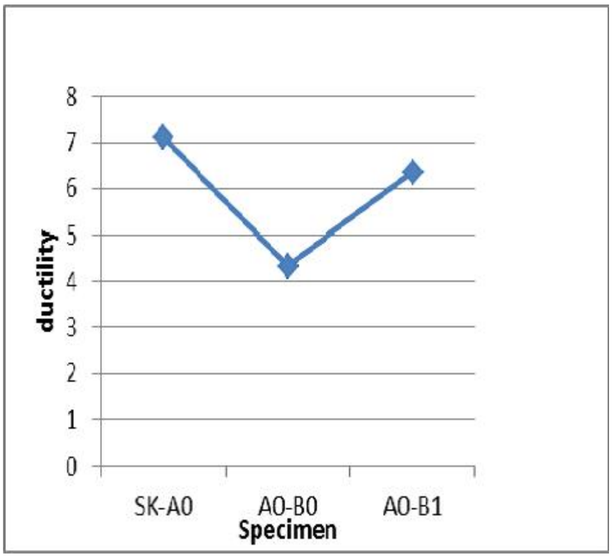
DEFLECTION AND DUCTILITY

Based on the test results, it can be seen that the deflection that occurs in non-monolithic connection without notches has a considerable increase compared to the monolithic connection.

This clearly indicates that monolithic connections are more rigid than non-monolithic connections.

The presence of notch given to the non-monolithic connection has an effect on the increase in the visibleconnection stiffness of the deflection





CRACK PATTERNS

Crack patterns that occur after receiving a static load differ on each specimen. In the monolithic specimens, the crack propagation occurs slowly until the peak load and collapse occur.

Initial cracking occurs when working load of 1150 kg is applied. Crack propagation that occurs on the beam continues to grow and extend along with increasing load.

Crack propagation on the beam stops when cracking occurs at the interface of the beam and the column causing the opening.

The collapse occurs when the crack is very large and towards the column area and there is considerable damage to the beam compression area.

In non-monolithic specimens without notches, the crack propagation occurs very quickly until peak load and collapse occur.

Initial cracking occurs when a working load of 950 kg is applied.

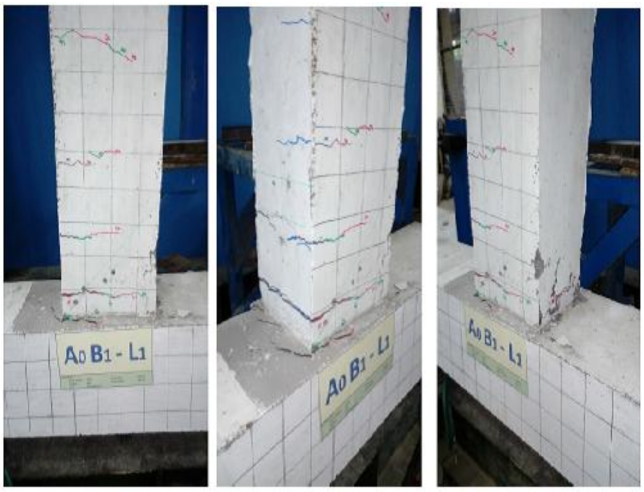
Crack propagation that occurs on the beam does not increase but extends along with the increase in load.

Crack propagation on the beam stops when cracking occurs at the interface of the beam and the column causing the opening.

In non-monolithic test specimens with notches, the crack propagation occurs slowly until the peak load and collapse occurred.

Initial cracks occur when working loads of 1100 kg are applied.

Crack propagation that occurs on the beam continues to grow and extend along with increasing load.



VI .CONCLUSION

The beam column connection is the most important region in reinforced concrete structures practically, in case of earthquakes. This research introduced a literature review on the beam column connection under gravity and seismic loads. This study included the previous works either experimental or numerical study in addition to recommendations of national codes.

Based on the results of this investigation, the following conclusions or observations can be drawn:

1- The beam column connection was classified to two types; type I designed to resist straining actions due to gravity loads, while type II designed to resist straining actions due to earthquake loads.
2- The concrete compressive strength had bigger influence on Joint shear strength than column axial force ratio and joint shear reinforcement ratio.
3- The compressive column axial load, that was lower than 20% of nominal capacity, did not affected on the shear strength of unreinforced exterior joints.
4- The minimum amount of joint shear reinforcement is 0.3 % according to the AIJ Guidelines (1999).
5- Use of X-bars as joint shear reinforcement enhance hysteretic energy dissipation.
6- The joint without stirrups fails in shear when the beam strength reached only 68% of the design flexural capacity, while it is shown that the joints with transverse reinforcement possess much better seismic behaviour and fail after the beam strength reaches more than 83% of its ultimate flexural capacity.
7- The eccentricity in the joints led to lower capacity in story shear and severe damage of concrete on the side to which the center line of beam shifted to.

The non-monolithic connection that occurs between the beams and columns lead to decreased load capacity, stiffness, and structural ductility compared with monolithic. The experimental results showed a decline of 17%, 23%, and 38%, respectively. The decrease in the performance of this beam-column joint can be improved by providing a notch in the column. This notch has a function as an addition to the shear area that can improve the stiffness of the beam-column joint. With the addition of this notch, improved performance of the beam-column joint was obtained in the form of increased load capacity, stiffness, and structural ductility compared with non-monolithic without notch. The increase was 11%, 18%, and 32%, respectively. The experimental results also show that the strength and performance of structural non-monolithic beam-column connections with notch are as good as those of monolithic beam-column joints.

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