Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 6, Issue 06, June -2019

FLEXURAL BEHAVIOR OF REINFORCED CONCRETE SANDWICH WALL L-JOINT

[1]Ismail Zaman Khan, [2]Mohammad Adil, [1]Afnan Ahmad, [3]Zia Ur Rehman, [1]Inam Ullah
[1]*Researcher, Department of Civil Engineering, UET Peshawar*
[2]*Assistant Professor, Department of Civil Engineering, UET Peshawar*
[3]*Researcher, Department of Civil Engineering, CECOS University, Peshawar*

Abstract — *Structural joints are usually sensitive to risky conditions and show failure in such situations prior to any damage in members connected through them. In Reinforced Concrete Sandwich Panel (RCSP), wall joint behaviour has not been studied which plays very important role in overall safety of these structures. Flexural, axial and shear behaviour of the RCSP has been tested experimentally. While the joint behaviour of RCSP has not been investigated in detail as in Reinforced concrete (RC) frame structures. In typical RC structures the joints are required to be stronger with heavy reinforcement, which makes the system uneconomical and difficult to construct. In this research, the L-joint of RCSP wall has been studied under quasi static cyclic loading along with numerical modelling in ABAQUS to have in depth understanding of bending behaviour of such joints. The load- displacement behaviour shows that L-joint in wall is highly ductile and can resist the maximum moment of 4.4 KN-m with maximum lateral drift of 145 mm for 0.9144 m long wall, also energy dissipation and initial stiffness are calculated based on experimental results. The experimental results and numerical model will help the designer to confidently design RCSP wall joints against lateral forces either due to earthquake or wind etc., economically.*

Keywords: *RCSP, RC, Cyclic loading, ABAQUS, PCS.*

I. Introduction

Reinforced concrete Sandwich Panels (RCSP) is composed of expanded polystyrene (EPS) foam as a core which is surrounded by welded wire galvanized mesh. This mesh is covered in the sprayed on concrete layer on both sides called wythes. RCSP has already been used in North America for more than 50 years [1]. In the early stages, it had been used as Precast panels but now the panels are erected on side and then sprayed with concrete on site. This makes the construction easy and quick. According to [1]–[3] that the result of the combination of RCSP has high energy efficiency along with excellent noise and thermal insulation. It has with relatively high bending stiffness and strength-to-weight ratios, which is desirable in many applications. [4] studied the behaviour of different core material having variation in thickness and densities. The tested materials show that RCSP with densities from 15 kg/m3 to 25kg/m3 shows increased in stiffness by about 40% for 160 mm thick core EPS than that of 80mm and the ultimate strength also increased to 62kN than 35kN. [5] investigates that in Chile, 1985 earthquake which is considered as one of the strongest, shows that the structural walls constructed with precast sandwich panels perform relatively better. In the 1988 Armenia Earthquake, the precast concrete panel wall which were constructed as poorly designed but has the main function of resisting the lateral force had a better performance than the building constructed with other structural systems[6].

In case of Reinforced Concrete RC the joints between walls are studied which shows that opening corners or positive bending moment tends to have low performance in cracking and load carrying capacity and there is need for the special care in the design. Efficiency of corners is usually defined as the ration of failure moment of the corner to the moment capacity of the adjoining members. Nilson said that the effect of reinforcement layout, steel content and the bar diameter on the behaviour of knee or right-angle corners which is normally between the walls. Others test of 60 degree and 135 degree were also conducted.

[7] tested these two main types of the corner angle but that is on the reinforced concrete. He stated that the flow of forces is the main consideration for the layout of reinforcement and another one is the distribution of the stress which shows that there is the need of the inclined splay bars which resist the tensile force causes at the inner angle of the corner. Corner failure is normally due to these diagonal forces and there is need for some reinforcement in the upper portion of the corner which make it U type shaped in fabrication. Finally, the best results is obtained by combining U shaped with diagonal bars in corner joint.

@IJAERD-2019, All rights Reserved

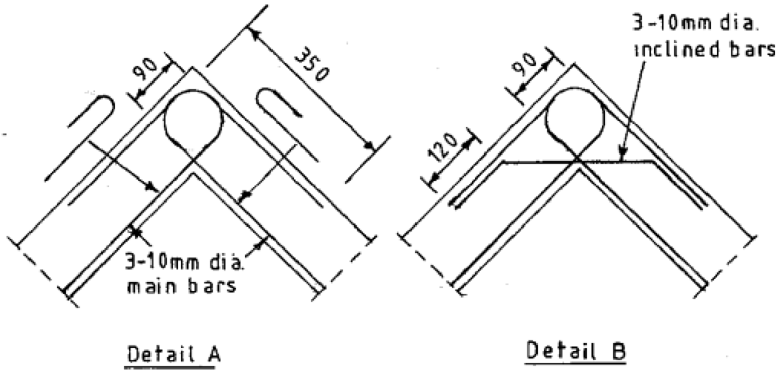

Figure 1. Details of the corner joint reinforcement

The structural behaviour cannot be fully understandable without the development of suitable and reliable numerical models and the advantages of PCSPs cannot be best utilized and their safety is not guaranteed due to a lack of confidence in their design[1]-[8]**.** According to Nilsson, 90-degree corners are the weakest amongst 60, 90, and 135 degrees. Also similar limits were recommended by [9]. We chose to model 90-degree angle instead of 120 degree which have the lowest efficiency because 90-degree joint is the most practical in today's construction.

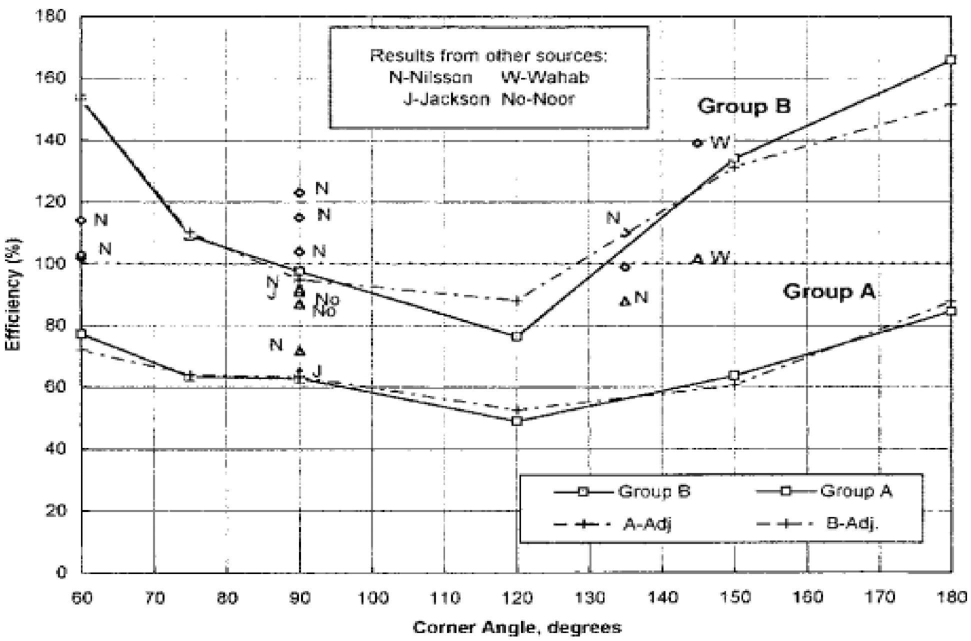

Figure 2. Efficiency versus corner angle

[10] conducted an experimental and analytical study to investigate the behaviour of reinforced concrete corner joints under monotonically increasing loads which tend to increase the right angle between the two joint members. The effect of reinforcement details at the corner joint was studied for commonly used detailing systems, and the nonlinear response was traced throughout the entire load range up to failure.

The RCSP joint has not been studied till now due to its different behaviour however its flexural, shear and axial properties has been studied and modelled. But as the joint is the sensitive region in the structure, their behaviour needs to be studied in RCSP. However, RC structural joints has been extensively studied with different designs. Instead of making the RCSP joints more reinforced to make it stronger, there was a need for the RCSP wall joint to be studied to make the economical design of RCSP wall joint.

II. Methodology

The joint between walls to wall has been casted based on the test setup and their bolting was decided on girder hole spacing of the straining frame in order to have fixity. 3 feet high wall on one side which was placed on 3 feet long horizontal wall. The total width is 12 inches having total thickness of each wall as 7 inches. The sample has 4 inches thick EPS core which is surrounded by concrete layers. The 2.6 mm galvanized wire mesh is provided at the joint in order to join the two walls. An extra reinforcement of 6 #3 bars each on the end of two walls because of the stress concentration. Making the supports region stronger will transfer the stresses to the joint. The full details of joint with mesh and reinforcements are shown in figure 4.

@IJAERD-2019, All rights Reserved

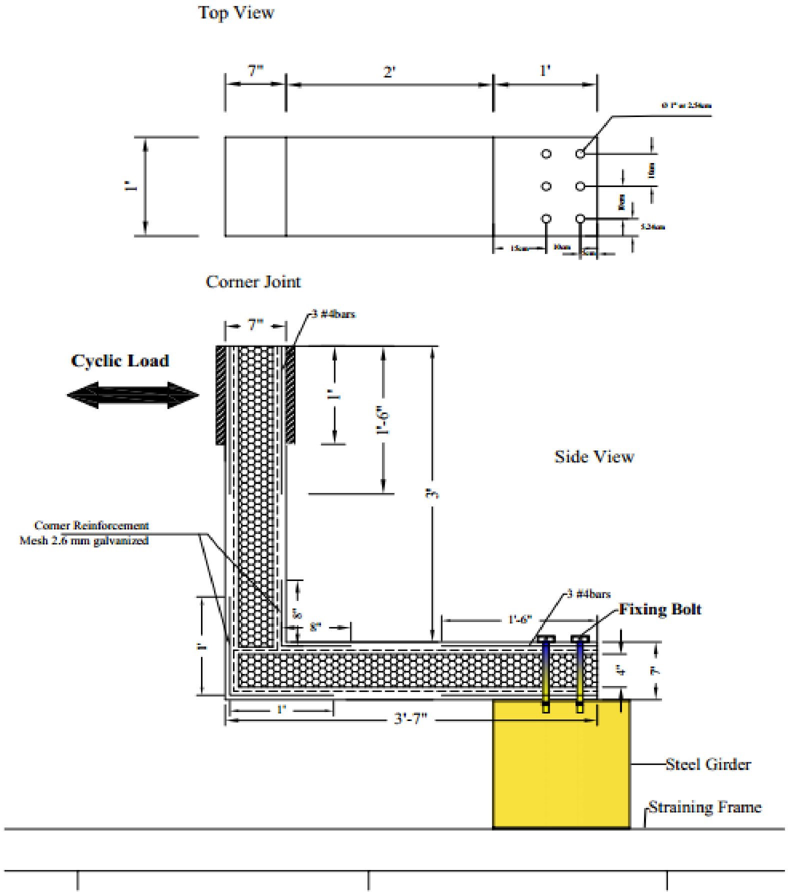

Figure 3. Wall joint Details

III. Sample casting and concretion

The sample with extra wire mesh and reinforcement is shown in figure 5. The sample was casted with the shotcreting the mix ratio of 1:2:1 where zero pane crush was used with addition to polypropylene fiber. The strength recorded was 17.23 MPa (2500 psi) on average. The shotcreting was done up to 1 inch which after 7 days of curing the concrete, the plaster of 0.5 inches was applied on the surface. The final sample is shown in figure 6. The sample was cured for 28 days and then shifted to structural testing lab at UET Peshawar.

Figure 4. Samples before Concreting

@IJAERD-2019, All rights Reserved

Figure 5. Sample after Concretion

IV. Test Setup

The testing setup was quasi static cyclic loading in which one wall end was fixed to the girder while the other end was displaced according to the displacement control. Initially, the test was decided to be load controlled but later when the top displacement reaches to 2mm, it will be changed to displacement control. The load applied was recorded by load cell places at the actuator while displacement was recorded in UCAM 70 by Linear Variable displacement Transducer. The displacement control plan was three cycles of each [2,4,9,13,18,36,54,73,91,128,145] millimetre displacement at the actuator position.

V. Cracks and Results:

The crack of the L wall joint are shown in figure [7, 8 and 9] which shows crack at the EPS, joint and at the outer edge of the wall.

Figure 6. EPS cracked

@IJAERD-2019, All rights Reserved

Figure 7. Back portion crack and spalling of concrete

Figure 8. Joint Crack at the perpendicular walls

The crack patterns occur at the joint which then increases at the higher displacement. The EPS also crack at 91mm displacement cycle which is shear type of failure. Also, the outer edge concrete spalling has been observed at the higher cycle.

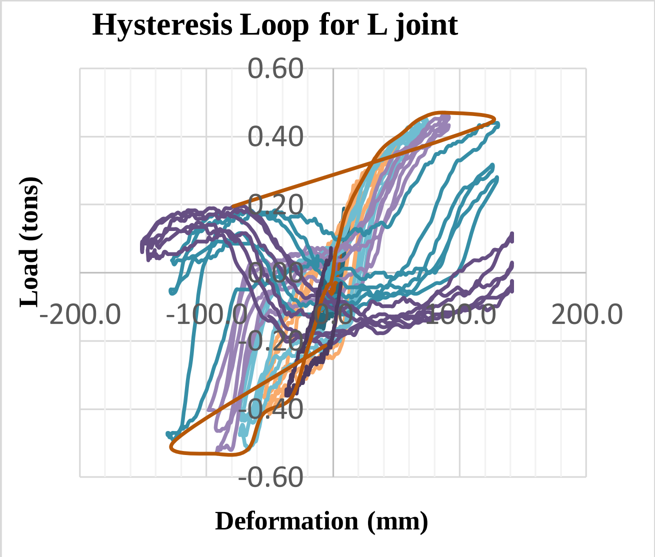

Figure 9. Hysteresis Loop for L joint

The hysteresis loop for sample one in figure 10 shows that it can resist the maximum load of 0.49 tons in cyclic loading at the displacement of 100 mm and then it dissipates its energy while move freely with minimum load taken at 145mm. The sample then decreases its resistance capacity by making plastic hinge but still it was attached.

The backbone and energy dissipation of L joint is shown in figure 12. The energy dissipation for L joint is 3 KN-m as shown in figure 13.

@IJAERD-2019, All rights Reserved

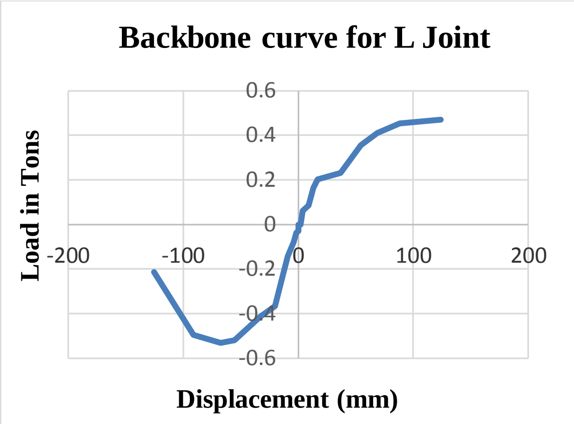

Figure 10. Backbone Curve

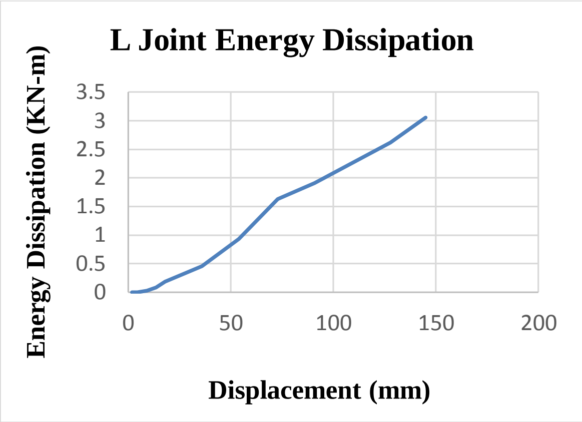

Figure 11. Cumulative energy dissipation

VI. Numerical Modelling

The Numerical Modelling of L joint was conducted in Abaqus in which the same model size and details were analysed.

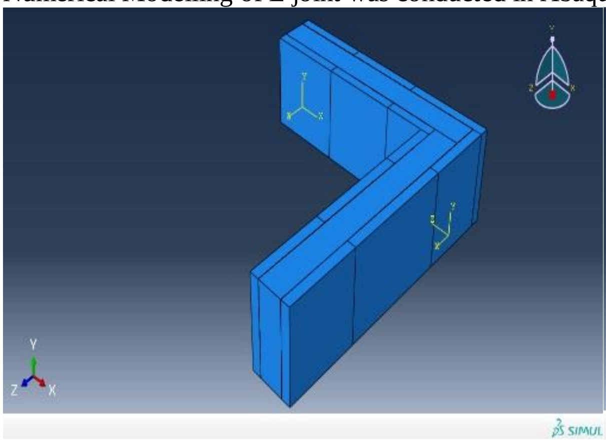

Figure 12: L joint modelling in Abaqus

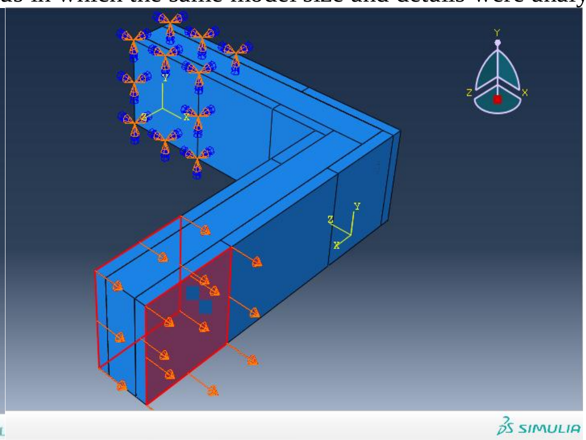

Figure 13. Boundary conditions

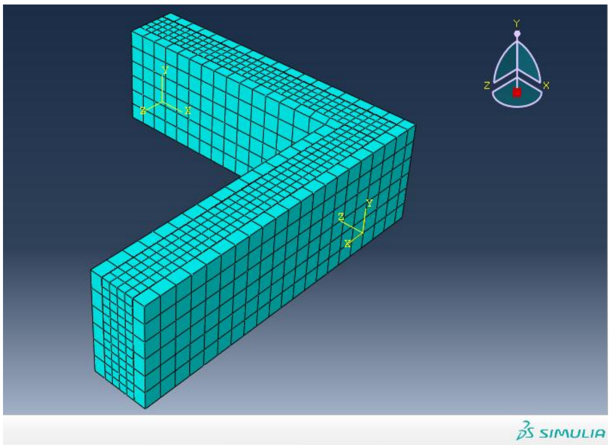

Figure 14. Sample Meshing

The results of the Numerical modelling is compared with the experimental data which is stated as sample 01 in figures where the hysteresis loop is shown in figure 17, backbone curve in figure 18 and cumulative energy dissipation is shown in figure 19. The hysteresis loop in the numerical modelling takes 2 tons of load at the displacement of 145mm. The numerical model deals in elastic condition and did not apply the adaptive condition.

@IJAERD-2019, All rights Reserved

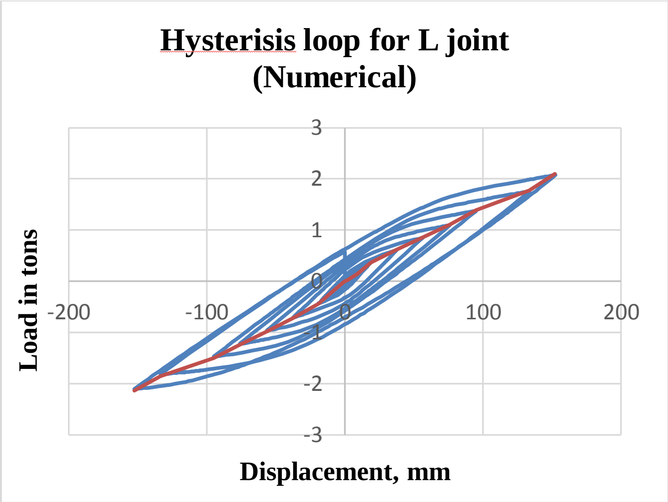

Figure 15. Numerical model Hysteresis Loop

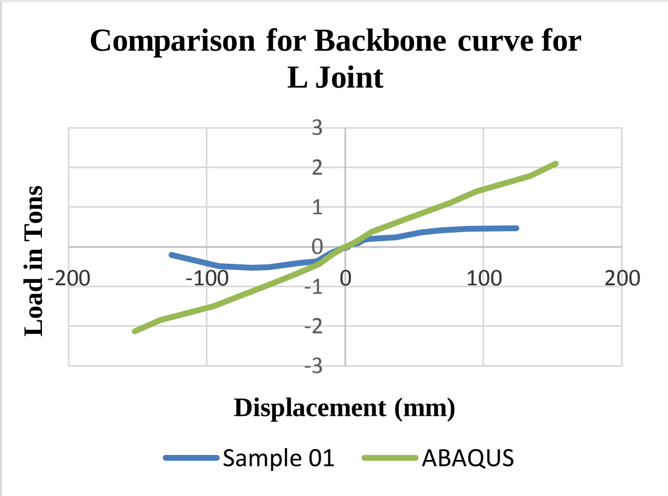

Figure 16. Backbone comparison of Experimental and Numerical

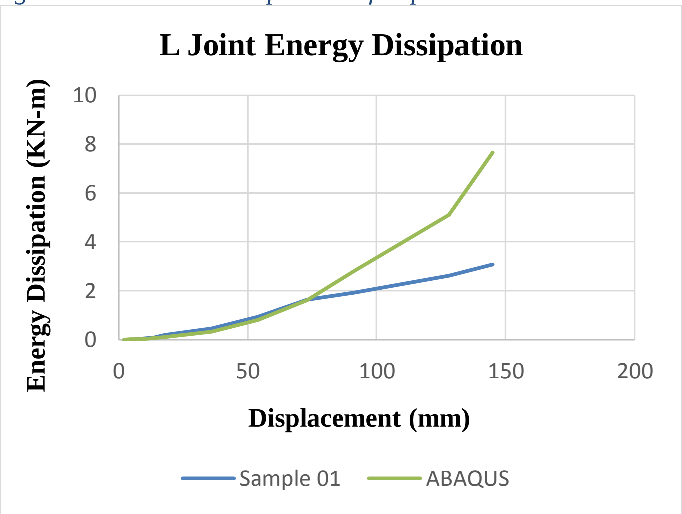

Figure 17. Energy Dissipation of Numerical and Experimental Comparison

VII. Conclusion

- The load-displacement behaviour shows that L-joint in wall is highly ductile and can resist the maximum moment of 4.4 KN-m with maximum lateral drift of 145 mm for 0.9144 m long wall.
- It can resist 0.49 tons of maximum load at 100mm which then drop it capacity gradually so giving the ductile behavior.
- The EPS in the joint fails in shears which should be made stronger by doing the suitable design.
- The sample has as rigid body motion in the 2mm cycle where the load was not taken due to the flexibility of the

@IJAERD-2019, All rights Reserved

EPS as it was absorbing the energy.

- The numerical model in Abaqus consider the L joint stronger than that of the experimental because the numerical modelling is done by using simplified technique where certain assumption is made which then effect the analysis.

REFERENCES

[1] E. D. Losch et al., "State of the art of precast/prestressed concrete sandwich wall panels," PCI J., vol. 56, no. 2, pp. 131–176, 2011.

[2] D. A. Bournas, "Experimental Investigation and Analytical Modeling of Prefabricated Reinforced Concrete Sandwich Panels," 2012.

[3] A. Einea, Salmon, M. K. Tadros, and D. T. D. Culp, C, "Full scale testing of precast concrete sandwich panels," ACI Struct. J., vol. 94, pp. 239–247, 1997.

[4] V. Toniolo, "Advanced Building System," no. 1010, 2014.

[5] S. L. Wood, J. K. Wight, and J. P. Moehle, "The 1985 Chile earthquake: observations on earthquake-resistant construction in Viña del Mar," University of Illinois Engineering Experiment Station. College of …, 1987.

[6] L. A. Wyllie and J. R. Filson, "Special supplement Armenia Earthquake reconnaissance report," Earthq. Spectra, pp. 1–175, 1989.

[7] H. M. S. Abdul-wahab and S. A. R. Salman, "Effect of Corner Angle on Efficiency of Reinforced Concrete Joints under Opening Bending Moment," no. 96, 1999.

[8] "No Title," https://www.pci.org/PCI/Resources/Building_Engineering_Resources/Connections/PCI/Design_Resources/Building_Engineering_Resources/Connections.aspx?hkey=fd42864e-0d84-4d95-ad38-32189ba01fc8&fbclid=IwAR1wVeYUSLTeEdPYpJJ6SsonbakmeUj4xEavuaXRfRhniWebrSy2OGj35p, 2014.

[9] M. Holmes and L. H. Martin, Analysis and design of structural connections: Reinforced concrete and steel. Halsted Press, 1983.

[10] L. N. Assi and D. A. M. Jawad, "Nonlinear finite element analysis of reinforced concrete corner joints subjected to opening moments," Basrah J. Eng. Sci., vol. 13, no. 1, pp. 16–33, 2013.

@IJAERD-2019, All rights Reserved