IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 4 Ser. IV (Jul. – Aug. 2021), PP 17-27
www.iosrjournals.org

Comparison between Different Methods of Slender Column Jacket under Eccentric Loading

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***Abstract**:*
*The use of the concrete jacketing method for reinforcing and strengthening concrete columns has been shown to be a successful procedure for improving load eccentricity performance. For a long time, the concept of jacketing has been investigated to provide such strengths. The study's goal is to investigate the behaviour of slender concrete columns under eccentric loading with and without jacket. The most important parameters considered in this study were Ultra high strength Concrete (UHSC) with 220 N/mm2 and Fibre reinforcement ratio 1 percent cement quantity. In this study, four main groups were used: the first group was columns 370*170mm, known as the control group, the second group was ordinary columns 400*200mm, the third group was columns with ultra high strength concrete 220 N/mm2, and the fourth group was columns 400*200mm with a fibre reinforcement ratio of 1%. Four groups were compared in terms of ultimate loads and displacements. In this study, an analytical analysis was performed using the nonlinear finite element programme ANSYS11[1] to improve the quality of high strength concrete slender columns and to study the effect of the previous parameters on the column ultimate load, mid-height displacement. By increasing the compressive strength of the concrete, the column load capacity increases and decrease displacement .*

***Keywords:** Nonlinear, finite element, Ultra High Strength Concrete (UHSC), Strengthening.*

Date of Submission: 06-08-2021 Date of Acceptance: 20-08-2021

I. Introduction

Over the years, engineers have used different methods and techniques to strengthen columns by Providing external confining stresses. The material from FRP is elastic to a brittle failure. However, in modelling the fibre guidelines must be carefully considered and treated. Here, brief reviews on the use of FEA in modelling RC confined with an external confining device such as FRP are presented. .Karabinis et al.. Doran et al. [2] modelled concrete confined with FRP using the finite element package LUSAS. In One of the materials developed in recent years is Ultra-High Strength Concrete (UHSC) also known as reactive powder concrete (RPC). This material possesses a compressive strength greater than 21,750 psi (150 MPa) [3] Richard and Cheyrezy, [4] reported that the compressive strength greater than 200 Mpa was achieved. One of the materials developed in recent years is UHSC also known as reactive powder concrete (RPC). This material possesses a compressive strength greater than 150 MPa. The greatest compressive strengths obtained were 165.6 MPa for UHSC with steel fibres and 161.9 MPa for UHSC without fibres [5]. Although high-strength concrete is often considered a relatively new material, its development has been gradual over many years [6-8]. Using fibres for improving ductility and avoiding brittle behaviour is a general way that has been widely investigated in the last few decades. Also it was found that the fibre plays a critical role in the ductile behaviour of a structure until flexural failure and it is addition in the H.S.C at any of the tested fibre contents did not increase the ultimate load of the column [9] Azadeh Parvin and Wei Wangstudy [10] studied the behaviour of fibre-reinforced polymer (FRP) jacketed square concrete columns subjected to eccentric loading. The effect of strain gradient on the behaviour of concrete columns confined by the FRP jacket was investigated through experimental and numerical analysis methods. Nine (108 108 305 mm) square concrete column stubs with zero, one, and two plies of unidirectional carbon FRP fabric were tested under axial compressive loading. In addition to the FRP jacket thickness, the effects of various eccentricities were examined.

II. Description of studied columns

This paper presents the results of an analysis programme designed to investigate the various parameters that influence the behaviour of slender reinforced concrete columns under eccentric loads with and without jacket. The main parameters were as follows: Ultra high strength concrete (UHSC) 220 N/mm2, fibre reinforcement ratio 1 percent cement quantity. The analysis programme used 16 Rectangular columns divided into four groups: the first was columns 370*170mm, known as the control group, the second was ordinary columns 400*200mm without any jacket, the third was columns with ultra high strength concrete 220 N/mm2, and the fourth was columns 400*200mm with a fibre reinforcement ratio of 1%.as shown in table 1. As shown in Fig. 1, all specimens contain 6 longitudinal reinforcement bars 12mm in diameter and stirrups 8mm in diameter at a spacing of 150mm and length of (3000) mm. All of the columns are hinged - hinged. All columns are subjected to eccentric load until failure.

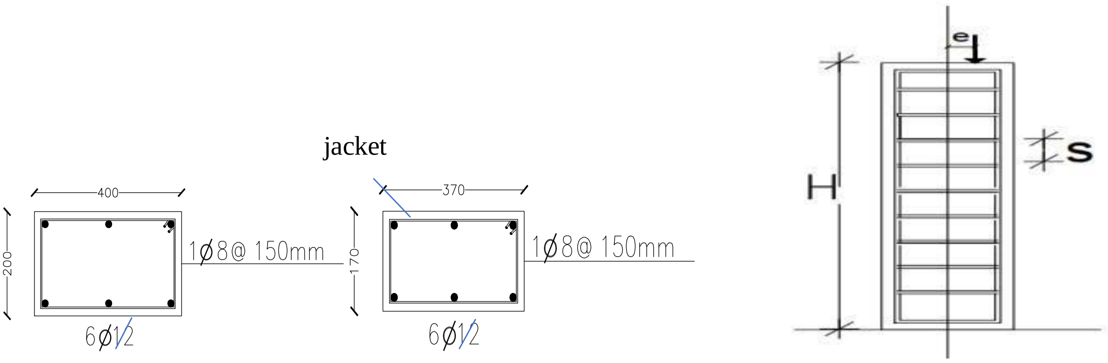

Fig .1 typical concrete dimensions in mm and reinforcement details

Table.1 Description of Models

Col name	Type of concrete jacket	Studied of concrete dimension mm	Concrete jacket mm	Specimen name	ECC (e/t)
Group A	Control	370*170	No	C1	0.05
		370*170	No	C2	0.20
		370*170	No	C3	0.35
		370*170	No	C4	0.5
Group B	ordinary	400*200	15 from every side	C5	0.05
		400*200	15 from every side	C6	0.20
		400*200	15 from every side	C7	0.35
		400*200	15 from every side	C8	0.5
Group C	Ultra	400*200	No	C9	0.05
		400*200	No	C10	0.20
		400*200	No	C11	0.35
		400*200	No	C12	0.5
Group D	Fibre	400*200	15 from every side	C13	0.05
		400*200	15 from every side	C14	0.20
		400*200	15 from every side	C15	0.35
		400*200	15 from every side	C16	0.5

III. Mesh configuration

The size of the finite element mesh used in the model was divided to suit the locations of steel and stirrups and eccentricity for all cases e 10,40,70,and100 mm as shown in Fig2.

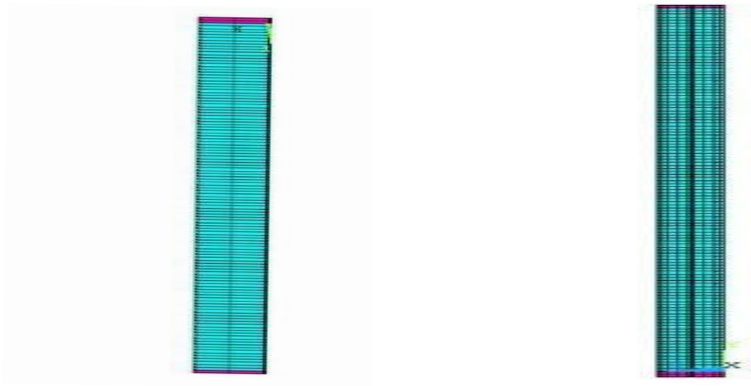

Fig.2 the finite element mesh's

3.a.Model restraints

The details of Column restrains are hinged-hinged as shown in Fig 3.

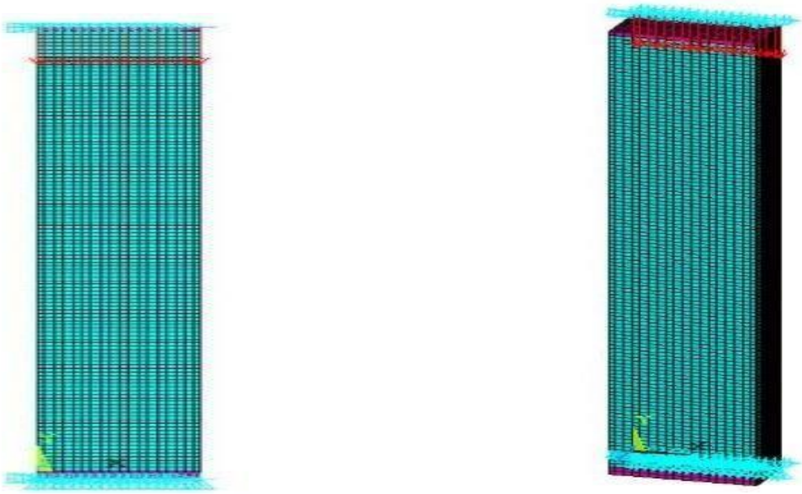

Fig.3 The Column restrain

3.b.Loading scheme and loading increments

The (ANSYS) solution requires the user to define a maximum number of iterations for each load increment. Within this number of iterations the solution will continue to the next load step if the out of balance forces are within a prescribed limit. For the analysis under hand only one load step was used to define the load on the columns. The load on the slabs was gradually increased until failure occurred. The size of the load increments was chosen to help achieve convergence and at the same time attains an acceptable level of accuracy. Small load increments usually lead to better accuracy and improved convergence with the penalty of more computational cost.

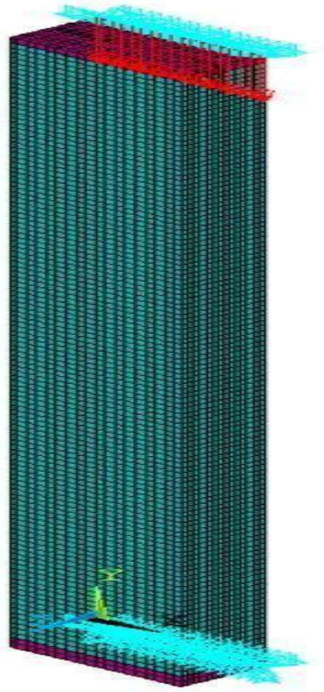

Fig4. The column loads

IV. The elements which used to represent finite element model

4.1 Concrete element

The concrete material is subjected to two possible failure modes. Cracking in tension and crushing in compression. The 3D solid element (SOLID65) was selected to perform this analysis using "ANSYS version 11", because it is capable of both cracking in tension and crushing in compression. (SOLID65) allows for four different materials within the element, one matrix material and a maximum of three independent reinforcing materials. In concrete applications, the solid capability of the element is used to model concrete. The element (SOLID65) is defined by 8 nodes having three degrees of freedom each. Eight integration points were used for evaluating element stiffness. The geometry, node location, and the coordinate system for this element are shown in Fig. 5. The element material is assumed to be isotropic and the most important aspect of this element is the treatment of nonlinear material properties where concrete is capable of directional cracking and crushing besides incorporating plastic and creep behaviour. In the previous paragraph, we noted that the element (SOLID65) had the capability of cracking and crushing. The cracking and crushing are the most significant factors contributing to nonlinear behaviour of the concrete. If the material at an integration point fails in compression, the material is assumed to crush at this point. For the concrete element used (SOLID65), crushing is defined as the complete deterioration of the structural integrity of the material, i.e. under the crushing conditions, the material strength is assumed to be degraded to an extent such that the contribution of the element stiffness at the integration point in question can be ignored. There are two techniques of crack representation in any finite element program. Smeared crack modelling and the discrete modelling. The first type occurs by adjusting of the material properties to introduce a plane of weakness in a direction normal to the crack face. While the second type occurs by separation of appropriate nodes of adjoining elements. The crack modelling adopted by (ANSYS) program is the smeared crack representation.

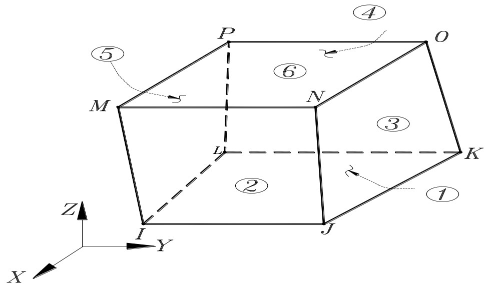

Fig5.Three Dimensional Reinforced Elements

4.2 Internal reinforcement element

To model the reinforcing steel bars, the 3D spar element (LINK 180) available in the element library of the (ANSYS) program was used. The three dimensional spar elements (LINK 180) is a uniaxial tension compression element with three degrees of freedom at each node. No bending is considered for this element. The element is also capable of plastic deformation, creep, swelling, and stress stiffing. The geometry, node location, and the coordinate system for this element are shown in Fig. 6 the element is defined by two nodes, the cross-sectional area, an initial strain, and the material properties. The X-axis of the element is oriented along length from node I towards J. the solution output associated with the element is the nodal displacements included in the overall nodal solution and some other additional element output as shown in Fig6

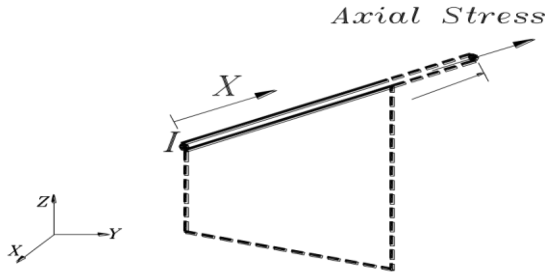

Fig6. Solution output associated with element (LINK 180)

4.3 Supporting element

SOLID185 is used for 3-D modeling of solid structures. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials as shown in Fig7

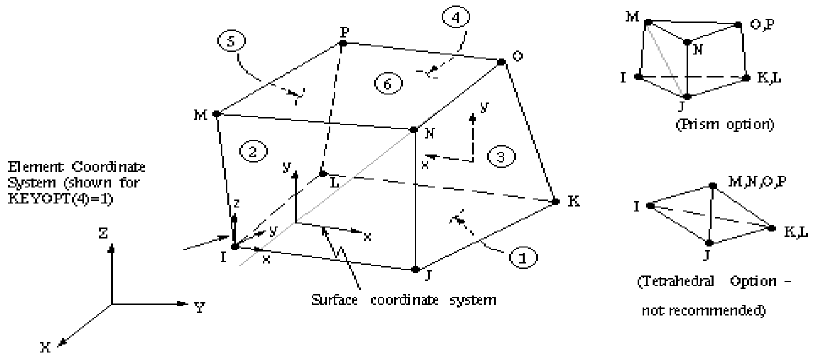

Fig7. Solid185 element in 3-D

V. Test Results

This section presents analysis of the test results to clarify the variation in compressive strength, different eccentricity, and ratio of fibre of the analysis specimens. Moreover, measures are defined to quantify this variation of each specimen. Table 2 summarizes the results of the analysis, the maximum load Pmax, and corresponding displacements .In general, the displacement can be defined as the sudden large deformation of structure due to a slight increase of an existing load under which the structure had exhibited little, if any, deformation before the load was increased.” No failure implied as shown in figure 8 .

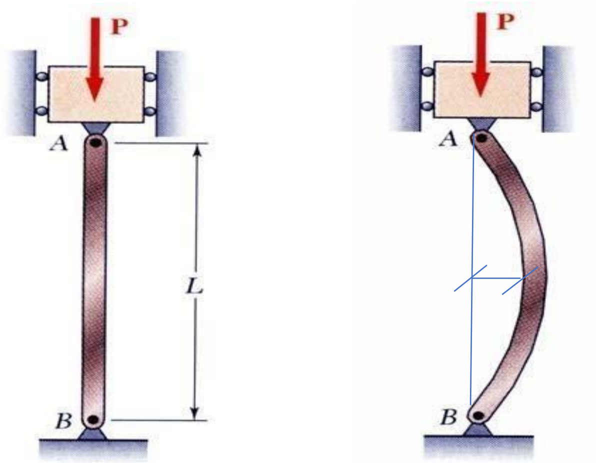

Fig. 8 Displacement

x Dx

VI. Discussion of test results

Evaluation of the major test variables on the behaviour of the analysis columns is discussed in the following subsections. Variables covered in this evaluation include different eccentricity ,Ultra high strength Concrete (UHSC) 220 N/mm2, and fibre reinforcement ratio 1%.

6.1Effect of Load Eccentricity

Variation of different Eccentricity had a significant effect on the performance of the analysis columns under eccentric loading. This effect can be presented by comparing the behaviour of columns C2, C3, C4with C1in group A. The ultimate loads of columns C2,C3and C4 were 34.21%, 55.07%, and 73.36% of that of column C1 respectively. This means that increasing the eccentricity decreases the maximum load of the columns and increases the displacement 70.35%,97.63%,and 152.56%, respectively. Group B (Concrete), is designed to study the effect of load eccentricity. As eccentricity of the applied loads increased, the ultimate load decrease . The ultimate loads of these columns C6 ,C7 C8,were 34.81%, 58.69%, and 75.01%. of that of column C5 respectively . This means that increasing the eccentricity decreases the maximum load of the columns and increases the displacement 70 %,100%,and 150%, respectively. Group C (Concrete only with cover fibre under effect of ultra compressive strength), is designed to study the effect of load eccentricity when compressive strength 220 N/mm2.. As eccentricity of the applied loads increased, the ultimate load decrease . The ultimate loads of columns C10,C11and C12 were 34.65%, 58.50%, and 74.38% of that of column C9 respectively. This means that increasing the eccentricity decreases the maximum load of the columns and increases the displacement 44.97%,53.02%,and 104.02%, respectively. . Group D (fibre with cover fibre when fibre ratio 1% The ultimate loads of columns C14,C15and C16 were 33.88%, 57.72%, and 66.53% of that of column C13 respectively. This means that increasing the eccentricity decreases the maximum load of the columns and increases the displacement 66.58%,97.97%,and 116.55%, respectively. This assured the previous conclusions mentioned by many researches earlier, as load eccentricity increases, column undergoes greater mid height displacement. When comparing between column without jacket and column with jacket we show that the column with jacket increase load about without jacket as shown in table 2 ,Figure 9 shows comparison between the load -displacement curves for groups A,B,C and D from the curve the cover fibre improve behaviour of columns and decreases loads and increase displacement little increase, .Figure 10 shows comparison between the ultimate load and eccentricity.

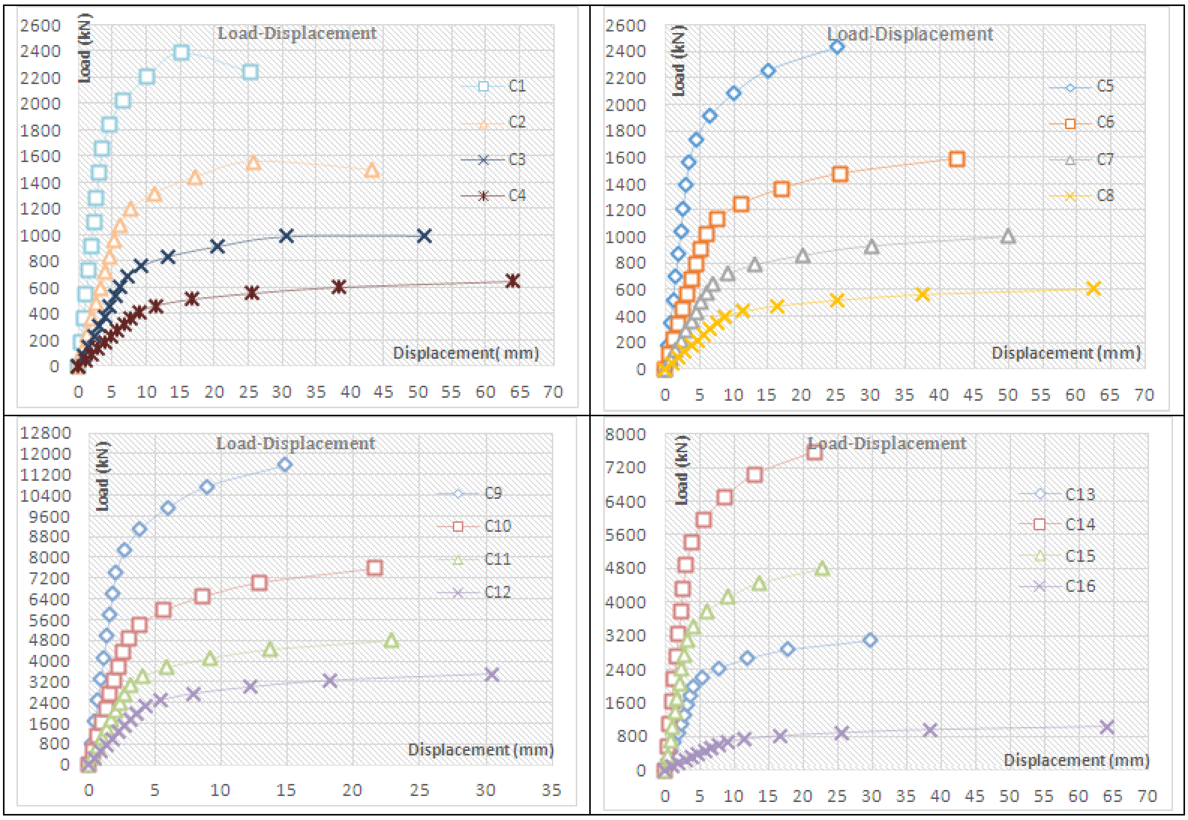

Fig9. The ultimate loads (Pu) for the studied columns

Col name	Parametric study	Specimen name	ƒcu (N/mm2)	ECC (e/t)	Pmax (kN)	Dx (mm)
Group A	Control	C1	30	0.05	2237	25.3
		C2	30	0.20	1494	43.1
		C3	30	0.35	994	51
		C4	30	0.5	596	63.9
Group B	ordinary	C5	30	0.05	2433	25
		C6	30	0.20	1568	42.5
		C7	30	0.35	1005	50
		C8	30	0.5	608	62.5
Group C	Ultra	C9	220	0.05	11577	14.9
		C10	220	0.20	7565	21.6
		C11	220	0.35	4805	22.8
		C12	220	0.50	2908	30.4
Group D	fibre	C13	30	0.05	3089	29.6
		C14`	30	0.20	2043	49.9
		C15	30	0.35	1306	58.6
		C16	30	0.50	1034	64.1

Tab2. Comparing between groups of columns

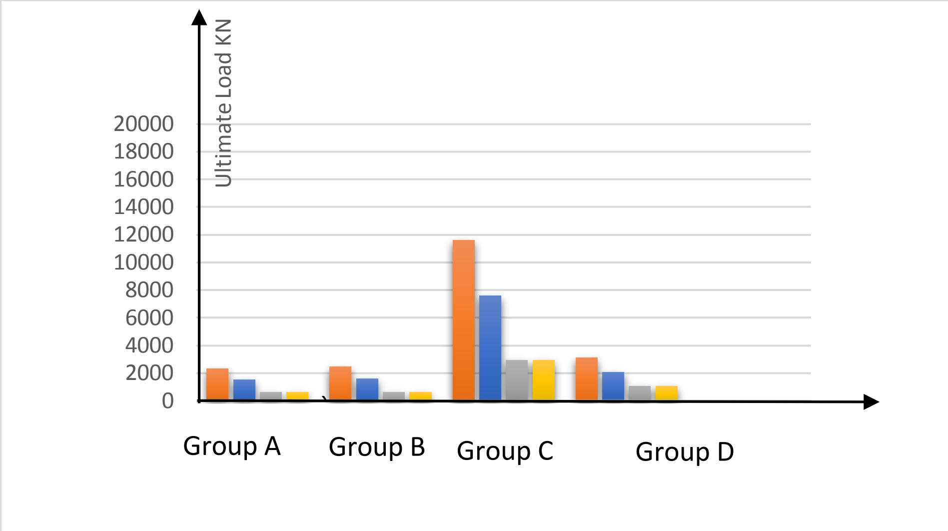

Fig10. Effect of eccentricities on the maximum displacement of the columns at ECC0.05,0.020,0.35,and 0.5.

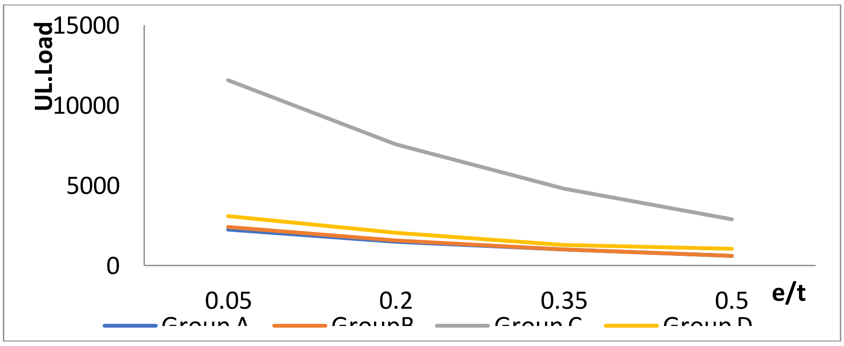

Fig 11. The relation between ultimate load and eccentricity

6.2 Effect of concrete jacket

In order to study the effect of the concrete jacket, the behaviour of columns C1,C2,C3,and C4 (Group A)which had no jacket is compared with columns C5,C6,C7,and C8 with concrete jacket 15 mm at every side (Group B). All these columns had the same compressive strength, stirrups ratio, and steel fibre ratio. It was clarified that adding jacket the ultimate load decrease and increase displacement. Figure 12 shows comparison between load – displacement of Group A and Group B, Figure 13 shows the relation between ultimate load and eccentricity.

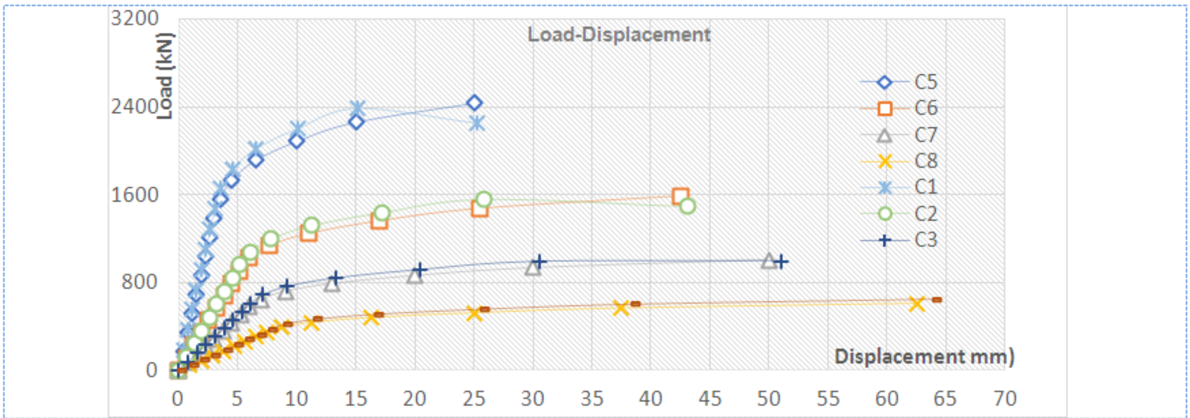

Fig 11.comparing between column without jacket C1,C2,C3,C4 and column with cover fibre C5,C6,C7,C8 in term of load displacement

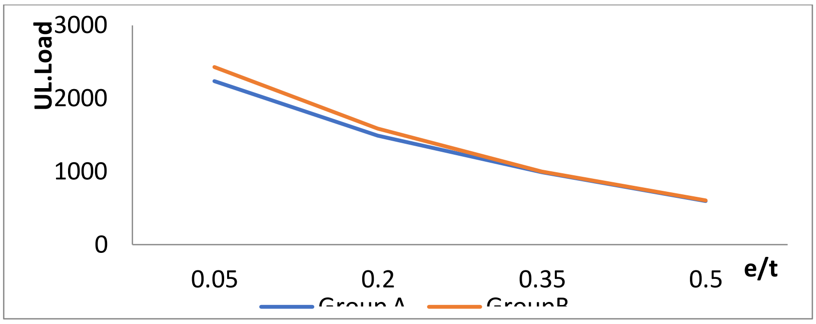

Fig 12.comparing between column without jacket C1,C2,C3,C4 and column with jacket C5,C6,C7,C8in term of eccentricity

6.3 Effect of Ultra high strength Concrete (UHSC)

The effect of the ultra compressive strength on the performance and behaviour of the columns under eccentric loading is studied by comparing C1,C2,C3 andC4 which had a compressive strength of 30 Mpa by columns C9,C10,C11,and C12 but with different compressive strength 220 Mpa. All these columns had the same stirrups ratio, and steel fibre ratio. The behaviour of these columns can be compared by examining the load -displacement The ultimate loads of columns C1 is 80.68% of that of column C9, The ultimate loads of columns C2 is 80.25% of that of column C10, The ultimate loads of columns C3 is 79.31% of that of column C11, The ultimate loads of columns C4 is 79.50% of that of column C12. This is means that increasing the compressive strength has a considerable effect on increasing the maximum load of the column under eccentric loading. .Table (3) show the Ultimate load and decrease in column carrying capacity at different eccentricity e/t =0.05, 0.20, 0.35and 0.5. figure (13) shows the increase in column carrying capacity when increase compressive strength . Figure (14) show the effect of eccentricities on the maximum displacement of the column.

Col name	Parametric study	Specimen name	*f*cu (N/mm2)	ECC (e/t)	Ratio of fibre	Pmax (kN)	Dx (mm)
Group A	Control	C1	30	0.05	NO	2237	25.3
		C2	30	0.20	NO	1494	43.1
		C3	30	0.35	NO	994	51
		C4	30	0.5	NO	596	63.9
Group C	Ultra	C9	220	0.05	NO	11577	14.9
		C10	220	0.20	NO	7565	21.6
		C11	220	0.35	NO	4805	22.8
		C12	220	0.50	NO	2908	30.4

Tab 3. comparing between column C1,C2,C3,C4 and column C9,C10,C11,C12

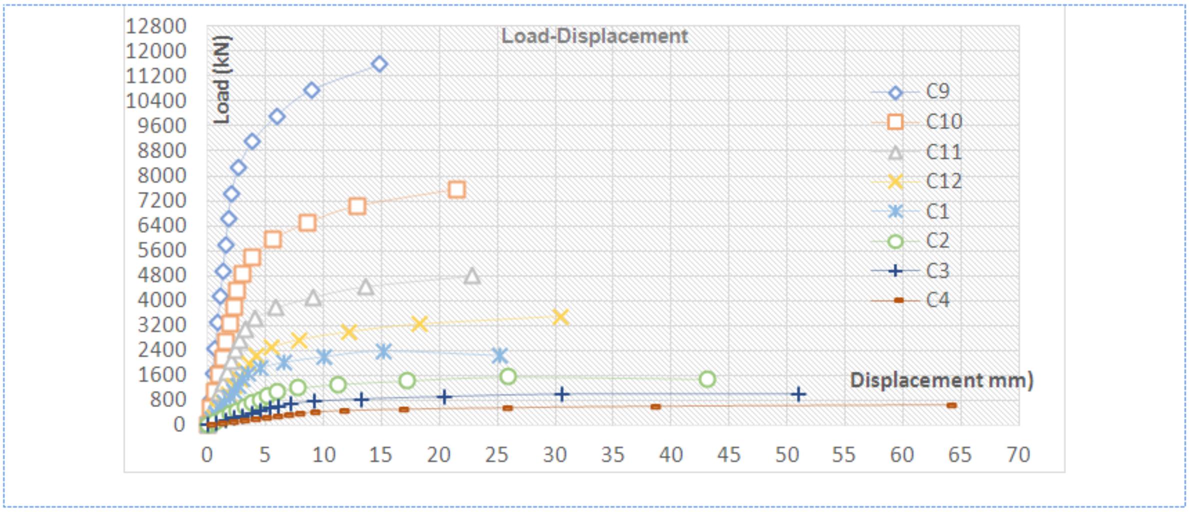

Fig 13.comparing between column without jacket C1,C2,C3,C4and column with jacket C9,C10,C11,C12 in term of load displacement

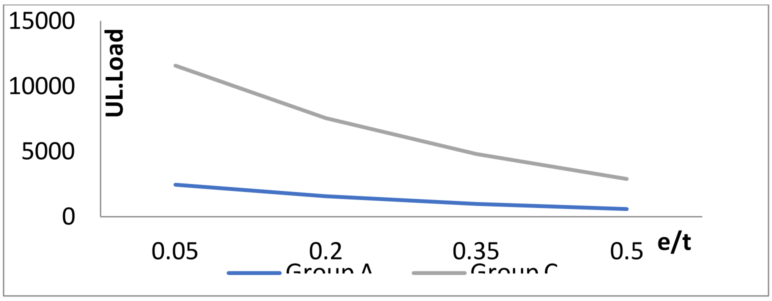

Fig14.comparing between Group A and Group C in term of eccentricity

6.4 Effect of steel fibre ratio in cover

Variation of steel fibre ratio had a significant effect on the performance of the columns under eccentric load .This effect can be presented by comparing the behaviour of columns of Group A which had Zero% and Group D which had 1% steel fibre. All these columns had the same compressive strength, stirrups ratio

Col name	Parametric study	Specimen name	ƒcu (N/mm2)	ECC (e/t)	Ratio of fibre	Pmax (kN)	Dmax (mm)
Group A	Control	C1	30	0.05	NO	2433	25
		C2	30	0.20	NO	1586	42.5
		C3	30	0.35	NO	1005	50
		C4	30	0.50	NO	608	62.5
Group D	Fibre	C13	30	0.05	1%	3089	29.6
		C14`	30	0.20	1%	2043	49.9
		C15	30	0.35	1%	1306	58.6
		C16	30	0.50	1%	1034	64.1

Tab4. comparing between Group A and Group D

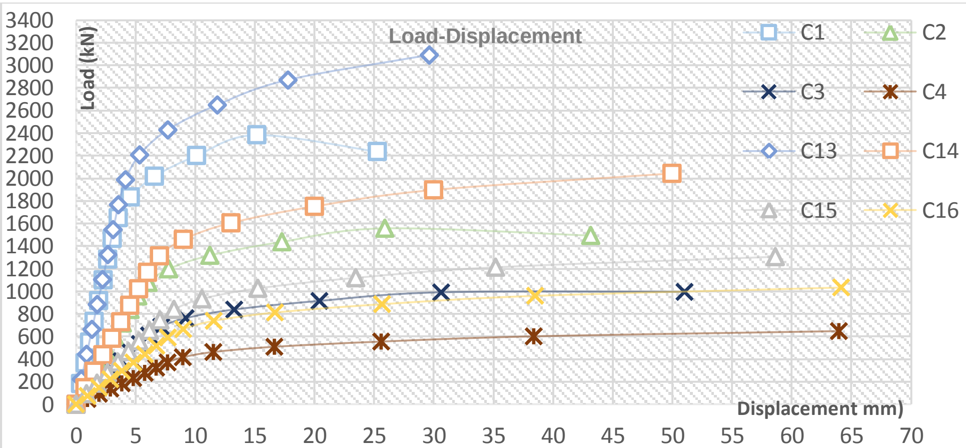

Fig 15.comparing between column without jacket **C1,C2,C3,C4** and column with jacket C13,C14,C15,C16 in term of load displacement

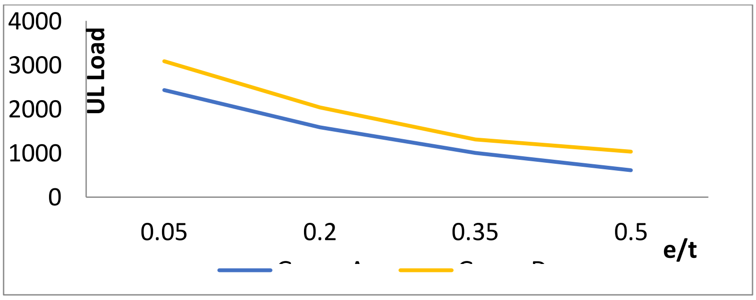

Fig 16. comparing between column C1,C2,C3,C4 and column C13,C14,C15,C16 in term of load displacement in term of eccentricity

VII. Conclusions

Based on the analytical results for the studied columns under eccentric load:

1.Increasing eccentricity leads to increase of displacement, but decreases load capacity.

2.Increasing the ultra compressive strength resulted increase of load capacity.

3.Incorporation of 1% steel fibre had a significant effect on the columns ultimate load, it improved the column ultimate lateral load by and % respectively.

4. Increasing column slenderness ratio results in decrease in load capacity, but increase in both mid height displacement at failure and concrete compressive strain.

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Alaa Ali Elsayed. "Comparison between Different Methods of Slender Column Jacket under Eccentric Loading." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(4), 2021, pp. 17-27.