Palestine Polytechnic University

Deanship of Graduate Studies and Scientific Research

Master of Civil Engineering

Comparison study between slender columns and short columns of reinforced concrete circular cross-section supported using carbon fiber polymer fully scale .

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Thesis submitted in partial fulfillment of requirements of the degree

Master of Civil Engineering

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The undersigned hereby certify that they have read, examined and recommended to the Deanship of Graduate Studies and Scientific Research at Palestine Polytechnic University:

[Comparison study between slender columns and short columns of reinforced concrete circular cross-section supported using carbon fiber polymer fully scale .]

[Alaa Loiuy Al karaki]

in partial fulfillment of the requirements for the degree of Master in Renewable Energy & Sustainability.

Graduate Advisory Committee:

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[Comparison study between slender columns and short columns of reinforced concrete circular cross-section supported using carbon fiber polymer fully scale].

[Alaa Loiuy Al karaki]

Abstract

Many researchers studied and used different materials to strengthen and rehabilitate the concrete column , we know that the concrete column is a structure element that can be deformed from applying loads to it. And there are two types of columns the short and slander. Examples of such materials include carbon polymer fiber concrete (CFRP), glass polymer fiber concrete (GFPR), shape memory alloy (SMA) and ultra high performance concrete (UHPC)... etc.

In this thesis, analysis, comparing and investigation to strengthen concrete crucial columns topical scale sample using CFRP from practical experience, comparing results with finite element method.

The study of parameters in this research is the type of column short or sender is the main parameter to compering , the strength of concrete using at beginning 24 Mpa and increased to 28 Mpa ,at last we covered the circular column with Carbon Fiber Reinforced Palomar(CFRP) so we can choose the orientation of layer CFRP horizontal, vertical and combined between vertical and horizontal orientation. The results of tested circular column showed the beneficial effects of strengthening the RC column using CFRP, as evident from enhancement of the axial capacity and shifting of the failure mode from brittle to ductile with more stiff behavior.

دراسة المقارنة ما بين الاعمدة الطويلة والأعمدة الخرسانية المسلحة القصيرة دائرية المقطع المدعمة باستخدام اللايف الكربونية على القياس الكامل

علاء لؤي سفيان الكركي (بعباش)

المستخلص

قام العديد من الباحثين بدراسة واستخدام مواد مختلفة لتقوية وإعادة تأهيل العمود الخرساني، ونحن نعلم أن العمود الخرساني هو أحد العناصر الهيكلية التي يمكن أن تتشوه نتيجة تطبيق الأحمال عليه.
وهناك نوعان من الأعمدة للقصر والطويلة . ومن أمثلة هذه المواد خرسانة ألياف البوليمر الكربوني (CFRP)، والخرسانة المصنوعة من ألياف البوليمر الزجاجي (GFPR)، وسبائك ذاكرة الشكل (SMA)، والخرسانة فائقة الأداء (UHPC)... إلخ.
في هذه الرسالة ، تم التحليل والمقارنة والتحقيق في تقوية عينة الأعمدة الخرسانية باستخدام مادة CFRP من التجربة العملية، ومقارنة النتائج بطريقة العناصر المحدودة. دراسة العوامل في هذا البحث هي أن نوع العمود القصير أو الطويل هو المقياس الرئيسي للمقارنة، وكانت قوة الخرسانة تستخدم في البداية 24 ميجا باسكال وزادت إلى 28 ميجا باسكال، وأخيراً قمنا بتغطية العمود الدائري بألياف الكربون المقوى بوليمر. CFRP) حتى نتمكن من اختيار اتجاه طبقة CFRP أفقيًا وعموديًا ودمجها بين الاتجاه الرأسي والأفقي. أظهرت نتائج العمود الدائري الذي تم اختباره الآثار المفيدة لتقوية عمود RC باستخدام CFRP، كما هو واضح من تعزيز السعة المحورية وتحويل وضع الفشل من الهش إلى اللدن مع سلوك أكثر صلابة.

Declaration

I declare that the Master Thesis entitled" Comparison study between slender columns and short columns of reinforced concrete circular cross-section supported using carbon fiber polymer fully scale" is my own original work, and herby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

Student Name :Alaa Loiuy Sofiane Alkaraki

Signature:—————————— Date:——————

Dedication

Thanks be to Allah Who is always helping us to success

To my loving parents that are a great support in the life

To my brothers and sister

To all friends and colleagues

To my teachers

To my precious persons

To my wife I don’t see it but ISA

To all of them

TO me

Acknowledgement

I would like to thank my supervisor Ph.D. Maher Amer for his continuous support and motivation while preparing this work. Ph.D. Belal Almassri the head of the Civil Engineering Department who worked hard to establish the plan for the Master's Degree in Civil Engineering. Ph.D. Haitham Ayyad and Ph.D. Naser Abboushi who I learned so much from their knowledge.

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Chapter 1 : Introduction

1-1 Background

Nowadays most buildings are concrete structures consisting of reinforced concrete . These buildings are designed based on different loads depending on the nature of use and based on global codes, but sometimes there is a shortage of construction or the durability of these structural elements resulting in an unexpected increase in loads, changes in conditions of service or the eating of steel rods as a result of chemical or other conditions. Where there are many ways of strengthening such as concrete jacket, carbon polymer fiber concrete (CFRP), glass polymer fiber concrete (GFPR), shape memory alloy (SMA) and ultra high performance concrete (UHPC).

Fiber Reinforced Polymer Material (FRP) is a composite material that is typically composed of strong fibers embedded in the resin matrix. Fiber provides strength and hardness to the compound and generally carries most of the applicable loads. The matrix connects and protects fibers and provides stress transfer from fibers to fibers through shear pressures. The most common fibers are glass, carbon and synthetic fibers. FRP compounds have strong and good properties as FRP is corrosion resistant. When steel comes into contact with water, oxygen or other powerful oxidizing material or acids, it rust. , Easy to transport, can be easily rolled, high resistance to fatigue, light weight, and then, the ratio of strength to weight is very high. Low weight makes handling and installation much easier than steel. This is particularly important when installing materials in narrow locations., composite fiber materials are available in very long lengths while steel panels are generally limited to 6 meters. The availability of long length and flexibility of the material simplifies the composition, joints and coils are also not required. There is a need for a very lower period of time. does not affect the details or shape of historical structures. Generally for FRP rap, no screws are required, in fact the use of bolts would seriously weaken the material unless additional cover plates are attached. Moreover, since there is no need to drill in the structure to repair bolts or other mechanical anchors, there is no risk of damaging the current reinforcement, low unit weight (150-900 g/m2). , Composite fiber reinforcement materials have higher absolute strength and less density than steel. Low power consumption during raw material manufacturing and structure, real time monitoring capability. There are also features of FRP that also have defects. One such defect is that the main defect of external reinforcement of composite materials is the risk of fire, sabotage or accidental damage, unless the reinforcement is protected, under temperature 5 ℃ We cannot use FRP, lack of expertise in techniques and suitably qualified personnel to carry out the work and lack of acceptable design standards

1-2 Problem :

There are three types of failure of concrete column , compression failure When columns are axially loaded, the concrete and steel will experience some stresses. When the loads are greater in amount compared to the cross-sectional area of the column, the concrete and steel will reach the yield stress and failure will be starting without any later deformation.

Buckling failure Buckling failure generally occurs in long columns. Because they are very slender and their least lateral dimension is greater than 12. In such condition, the load carrying capacity of the column decreases very much.

and Shear failure Shear force tends to produce sliding failure on a material along a plane that is parallel or slightly parallel (diagonal) to the direction of the force. When shear force exceeds the shear capacity of column then this failure occurs.

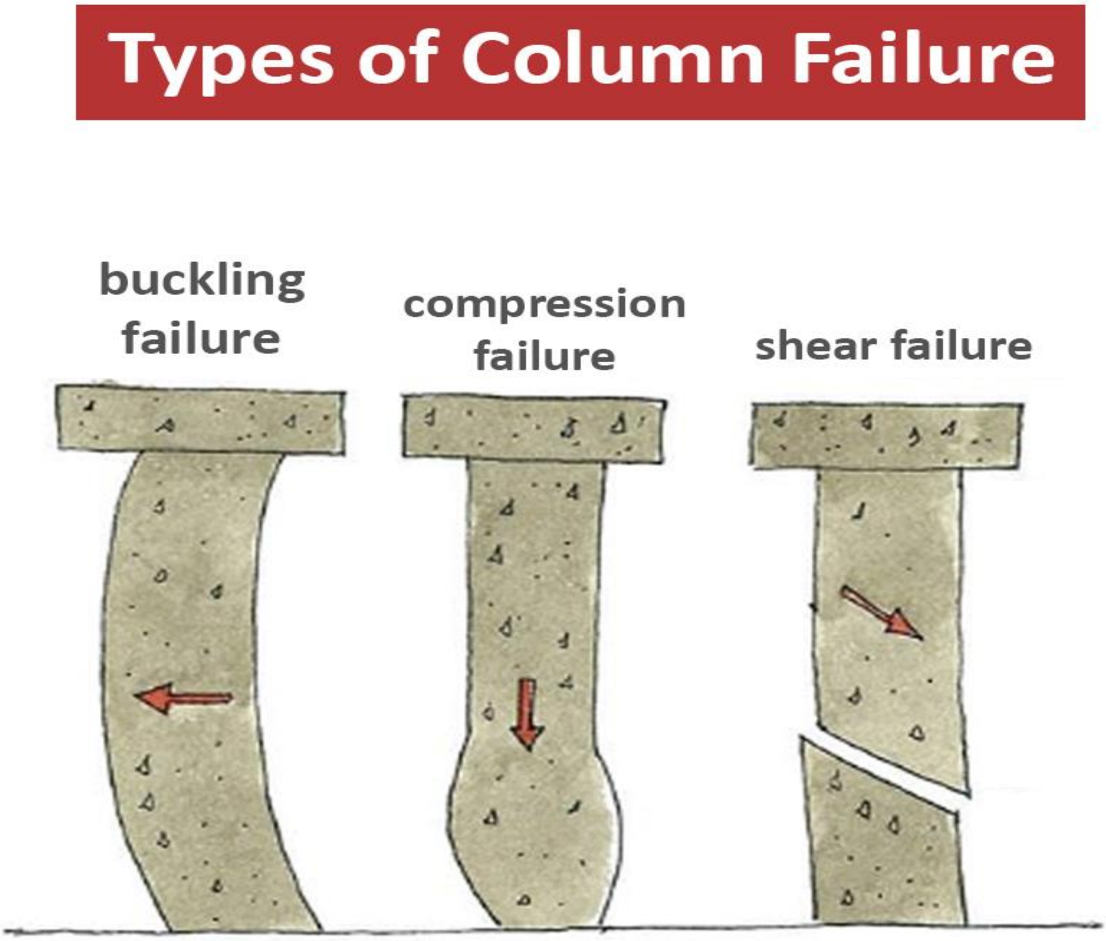


Figure 1 : Types of failure in beam

1-3 Research Significance and objectives:

The work done in the thesis is to investigate the use of CFRP material for strengthening for reinforced concrete crucial column by comparing between short and long columns using one layer of CFRP study impact on concrete columns and identify an effective approach to strengthen it.

1-4 Methodology

In this study the analysis and numerical investigation of a concrete column ABAQUS software will be hired to model a beam subjected to loads cause some deformation, this deformation will be treated and analyzed by Finite Element Method compared and verified with laboratory work done by Hu and Zhongjun et al (2021) and then will be some upgrades and different parameters to be studied.

Chapter 2 : Literature Review

This chapter will contain a summary of previous experiences and studies exploring the use of reinforcement strategies for construction elements in general and addressing reinforcement of construction elements and concrete column using CFRP.

In recent years, fiber-reinforced polymer (FRP) composite material has been applied to improve the strength and ductility of concrete columns extensively (Barros and Ferreira 2008; Realfonzo and Napoli 2011; Wei and Wu et al 2012; Teng et al. 2013; Garyfalliaet al. 2015; Yin et al. 2016; Eid and Paultre 2017).. There are many techniques to strengthen structural elements, and these techniques include mineral fibers, FRP, which is used to strengthen various elements such as columns, beams, etc. These fibers have different types that are strips, wires, rods.

Carbon fiber FRP consists of a mixture of two or three materials to form a matrix of reinforced polymer fibers. There are different types of mineral fibers, such as AFRP, CFRP and GFRP.(B. Benmokrane et al 2000) . (N. Attari et al 2012) . (T. Uomoto et al 1995) .(G. Tumialan et al 2000).

The best types mentioned are CFRP, which offers the best performance among them due to their attic endurance compared to the other two. WFP has also been used largely to strengthen and reform various structural elements. There are many advantages, including its high endurance and increases hardness, durability and maximum load capacity. (A. Nanni et al 2003). (M. Samaan et al 1998). (M. Ameli et al 2007). (F. Bencardino et al 2002) . (F. Katsuki et al2004).

Strengthening the Near Surface Structural Element (NSM) which also works with composite materials such as FRP is being studied and used in scientific research. **(**Bilotta A el al 2011) .(De Lorenzis L et al2007). (Al-Mahmoud F et al2010).

Where in this way, grooves are made in the concrete cover, and then improved materials such as FRP are introduced. After that, the grooves are filled with adhesive materials such as epoxy. (Kreit A et al2011).

Core concrete confined with lateral FRP sheets under axial pressure will be in a triaxial compression state and therefore strength and ductility of concrete columns can be improved significantly. However, the effectiveness of FRP confinement would be weakened for the stress hysteresis of the resin impregnated FRP strips. An early experimental research (Ali et al. 2003)**.**

Investigated the behavior of repaired and strengthened reinforced concrete (RC) rectangular columns by flexible near surface mounted –carbon fiber reinforced polymer (NSM-CFRP) cord Obaidat et al. (2020). The study showed that significant enhance in axial strength can be achieved by using larger width to depth ratio and smaller spacing between CFRP cords. The restoration of column strength through longitudinal and transverse CFRP repairs was mostly successful, except for the column with fractured bars near the base, which faced limitations in CFRP anchorage. For columns with fractured longitudinal bars, adding longitudinal and transverse CFRP in the plastic hinge region partially restored flexural strength. Ruili He et al. (2013). Researchers used many materials for rehabilitee and strengthening such as fiber reinforced polymer FRP , carbon fiber reinforced polymer CFRP , shape memory allow for strengthening and rehabilitate concrete member (Chen and Teng 2003) . The researchers found that CFRP and FRP have some shortcoming as low fire resistance , fading bonding ... etc.

Experimental investigations (Janke et al. 2009; Masoud et al. 2011) had shown that applying prestressed CFRP bands to a cylindrical concrete column had a very beneficial effect on the residual load-bearing capacity and load-deformation behavior. By using the combined results of the test study and two comprehensive experimental databases of actively confined and FRP-confined concretes, an expression has been developed for the prediction of the difference in the confining pressures that results in differences in the axial stresses between actively confined and FRP-confined concretes (Jian and Ozbakkaloglu 2014).

Improper repairs significantly reduced the lateral strength, stiffness, ductility, and energy dissipation of the columns. Concrete core damage in the later stages caused considerable stiffness reduction in strengthened columns. Lateral strengths remained mostly unchanged, but cumulative energy dissipation increased. Ductility improvement varied due to stiffness loss Hasan Elci et al. (2020) In the related research of Li and Wu (2016), a gap was found between the envelop curves of the two types of confined concrete, indicating that stress-strain behavior of actively and passively confined concrete under cyclic axial load was different significantly. Besides, a great number of studies have been conducted to optimize the mechanical performance of concrete columns by active confining methods instead of the traditional path (Pantelides and Yan 2007; Ciniņa et al. 2012; Vincent and Ozbakkaloglu 2015; Jian et al. 2016; Vincent and Ozbakkaloglu 2017) The confinement of concrete has a major effect on columns – its effect on axially loaded short squared and circular concrete columns has been demonstrated in numerous tests (also Olivová (2007)). The research on eccentrically loaded slender concrete columns is still quite limited, and there are few publications on this topic, which is why this application is not advanced. Mirmiran, et al. (2001) started the research in this field with concrete-filled fibre-reinforced polymer tubes (CFFT), which showed that as the slenderness ratio is increased, the columns' strength rapidly drops Pan, et al. (2007) and Tao and Han (2007)

Chapter 3: Finite element model Program

3-1 General

A previous laboratory experiment was done by Hu, Zhongjun et al (2021). Now we will do a simulation of the circular concrete column on the ABAQUS program used in finite element method, and verify the results of this simulation with the result of the laboratory so that we can study new parameters for development from the concrete Column.

3-2 Geometry of columns

We used two specimens of circular concrete column shortly and slender used in the Abaqus verification program obtained from paper (Hu, Zhongjun et al (2021)), the slender column is a circler section with a length of 2800 mm, a Dimitri of 200mm and, strengthened by a one layer of 100 mm CFRP coting shape and the attached figure shows the shape and dimension of the sample.

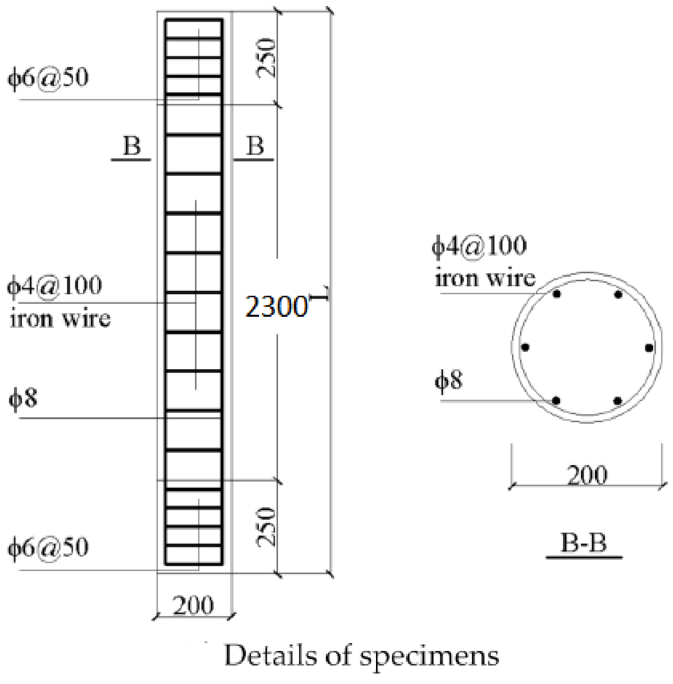


Figure 2:shape of slender specimens

3-3 Specifications of material

The concrete damage-plasticity (CDP) model used to represent the plastic behavior of concrete in compression and tension. plasticity theory is only appropriate in compression zones . This model employs two basic failure criteria: compressive crushing and tensile cracking of concrete. Furthermore, the yield function used in the plasticity model founded by Lubliner et al. (1989) and modified by Lee and Fenves (1998) . The damage variables are dt and dc where indicate to tension and compression damage parameters respectively **.** Fig3.showed damage variables . Based on the formulae supplied by Birtel and Mark (Birtel 2007) , the compressive and tensile damage parameters are determined from the following equations :

- Compressive damage parameter (d_c):

$$d_c = 1 - \frac{\sigma_c E_c^{-1}}{\varepsilon_c^{pl}(1/b_c - 1) + \sigma_c E_c^{-1}}. \quad (1)$$

- Tensile damage parameter (d_t):

$$d_t = 1 - \frac{\sigma_t E_c^{-1}}{\varepsilon_t^{pl}(1/b_t - 1) + \sigma_t E_c^{-1}}. \quad (2)$$

where d_c and d_t are compressive and tensile damage parameters, σ_c and σ_t are compressive and tensile stresses of concrete, E_c is the modulus of elasticity of concrete, ε_c^{pl} and ε_t^{pl} are plastic strains corresponding to compressive and tensile strengths of concrete. b_c and b_t are constant parameters, $0 < b_{c,t} \leq 1$.

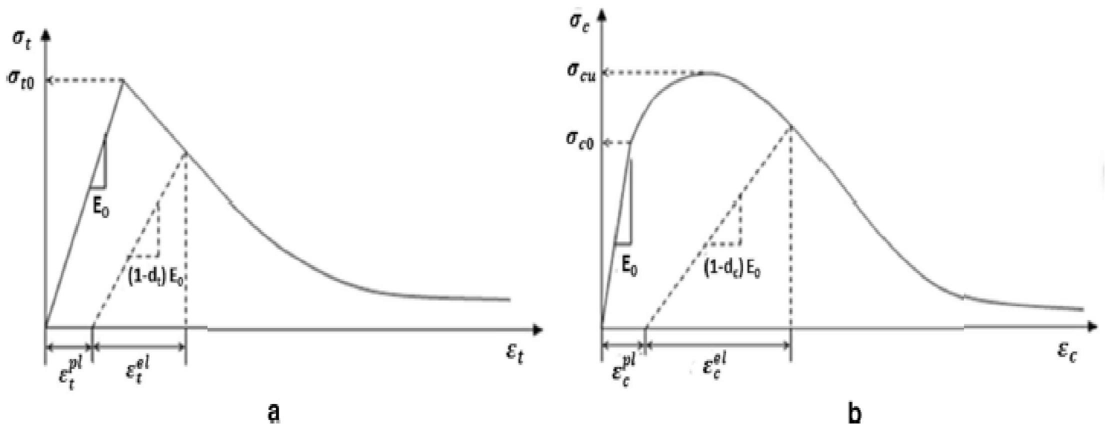


Figure 3 Damage variables: a in tension, b in compression (Bahraq, Ashraf Awadh et al (2019)

The mechanical properties of normal concrete , steel reinforcemenr , CFRP proprortions, are shown in Table 1 , Table 2 , Table 3 , Table 4 , respectively.

And Fig. 4 showed stress strain behavior for normal concrete and shear reinforcement

Table 1: Mechanical properties of normal high grade concrete.

Compressive Strength (MPa) FOR CONORET ON 28 DAYS 21.1 MPa and the Modulus of elasticity 19.8 GPa

Table 1: Mechanical properties of steel reinforcement.

Material	**Property**	**Average value**
Steel rebar used as stirrups	Yield strength (MPa)	240
	Modulus of elasticity (GPa)	200
	Ultimate strength (MPa)	300

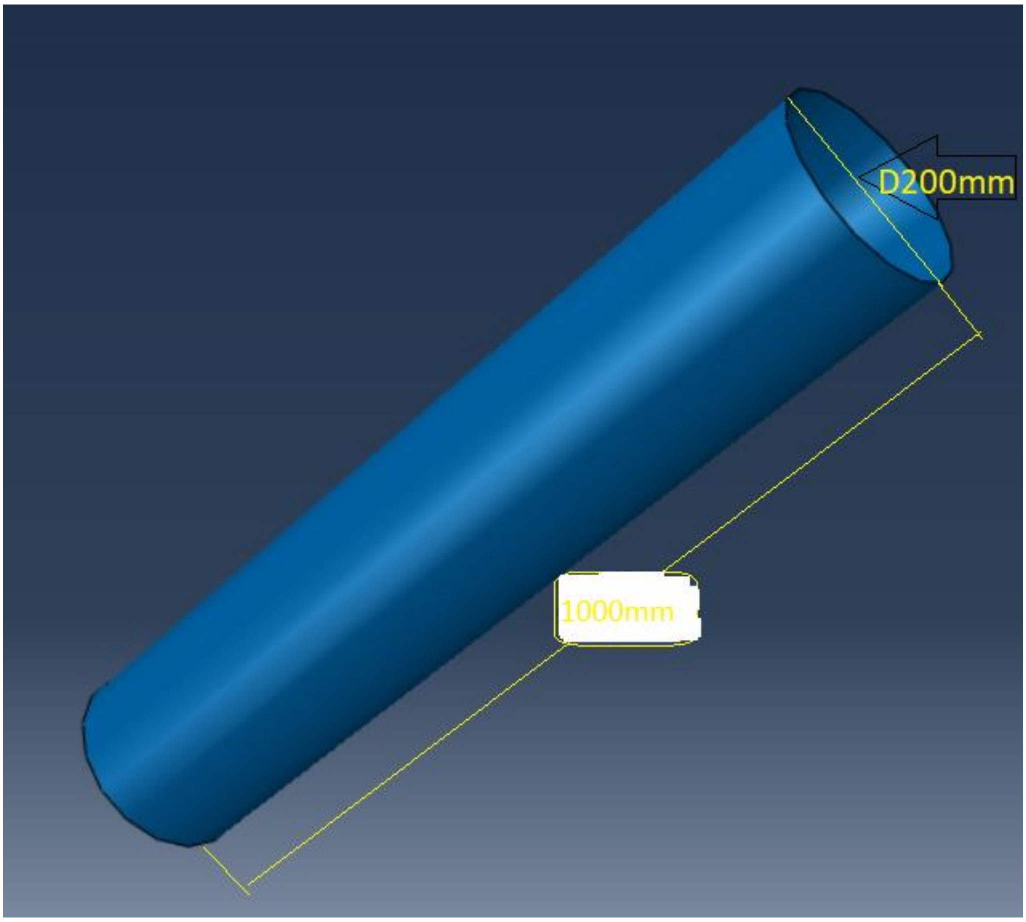
Table 2: Mixture proportions of CFRP end epoxy for one layer (Hu, Zhongjun et al (2021))

Material	Thickness t_f(mm)	Density (g/m2)	Tensile Strength, f_{fu} (MPa)	Elastic Modulus, E_f (MPa)	Fracture Strain, "fu (%)
CFRP	0.167	300	4330	237000	1.7
Epoxy adhesives			41.1	3068	1.57

The explicit dynamic technique is the most reliable way of applying the load in Abaqus. This approach is said to be successful for two reasons: first, it produces consistent findings with less convergence issues, and second, it is the most appropriate for materials like concrete in terms of capturing concrete fractures and general failure behavior (Mercan 2011). All data from F.E model compared with experimental data included load curve , ultimate failure load and cracks . this comparison showed that F.E model capturing most failure mode with good accuracy .

3-5 Modeling of CFRP

CFRP and epoxy where modeled in Abaqus program as one layer as a shell material with 3D dimensional with thickness 100 mm along the column slender and short (2800mm slender and 1000 mm short length) Fig.7 ,



3-6-Numerical modelling

In addition to the experimental examination, the comprising strengthen of the reinforced circle column was studied numerically using the finite element approach. The primary goal of the numerical modeling in this work was to confirm the adequacy of the experimental data for capacity of loudening crucial column , which included depicting load against deflection graphs, failure loads, and cracking pattern. Abaqus finite element analysis software was used to create the numerical models. All element are defined as 3D modeling , steel reinforcement (longitudinal and transverse) modeling as wire with tow nodes 3D truss elements , normal concrete , CFRP and steel plate modeling as solid extrusion with three nodes . The concrete-reinforcement-steel bond was represented as an embedded region , with the concrete as the host element. concrete and CFRP , and Concrete and steel plate was bonded by tie-bond .

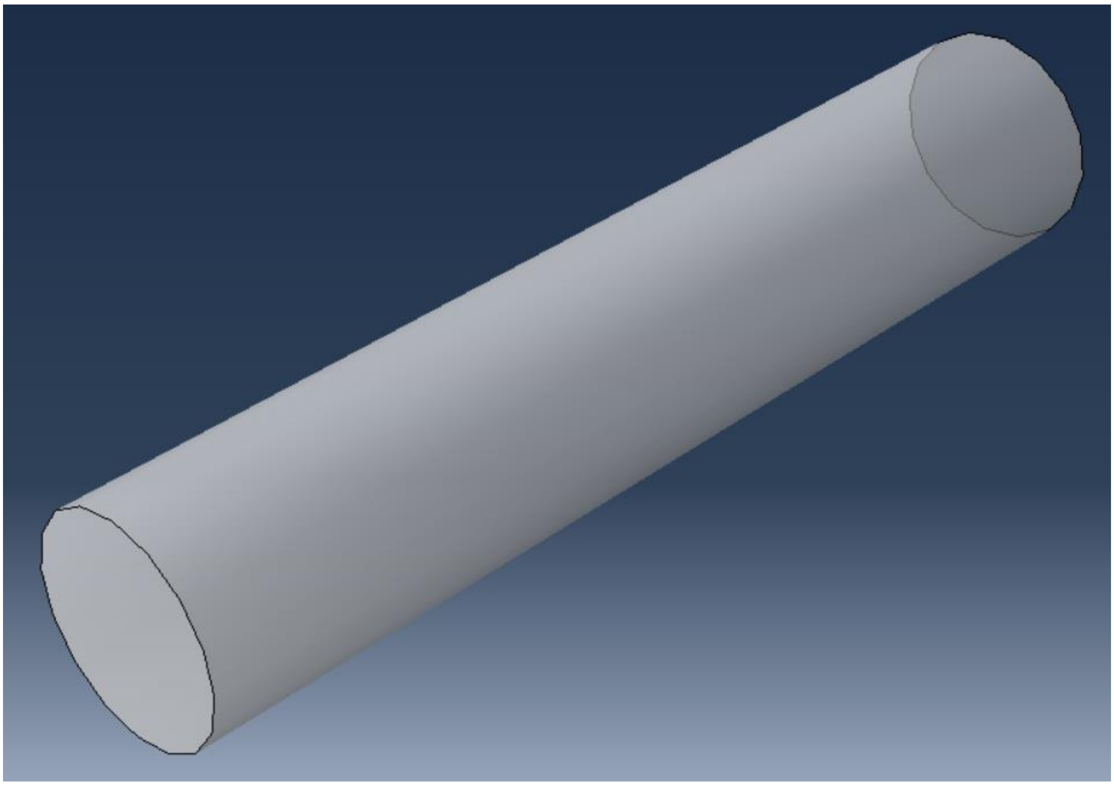


Figure4：Column part.

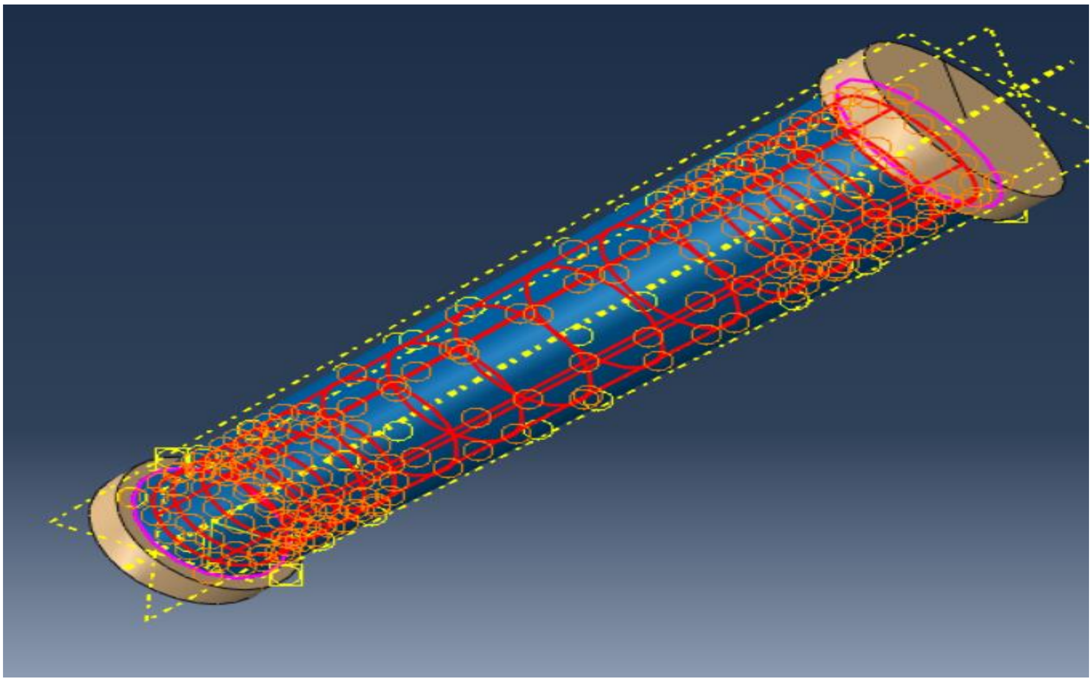


Figure 5: Embedded constrain between concrete column and steel reinforced.

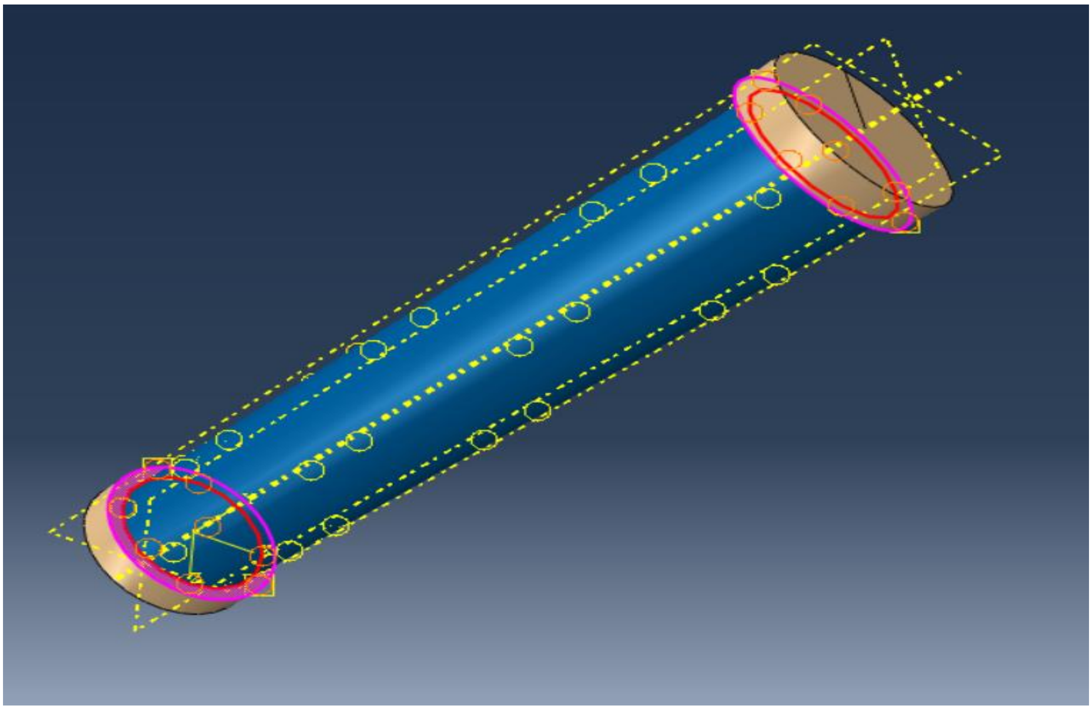


Figure 6: Tie constrain between concrete and steel plat

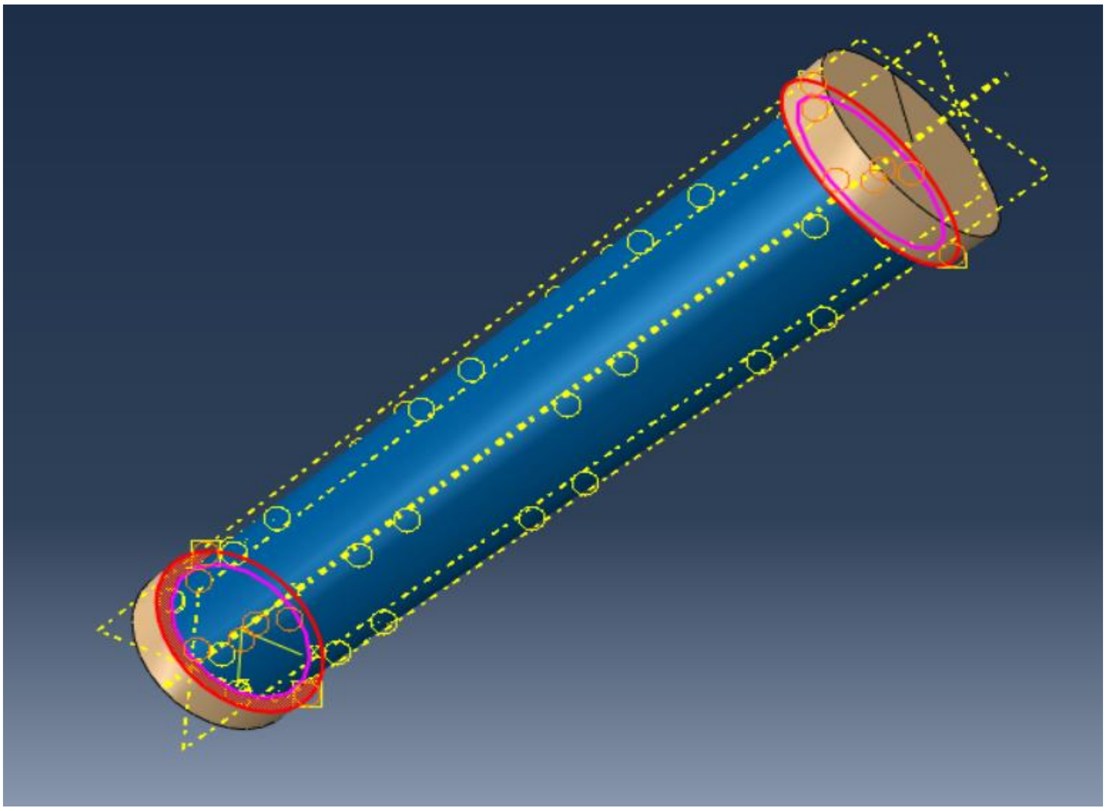


Figure 7:Tie constrain between CFRP and steel plat

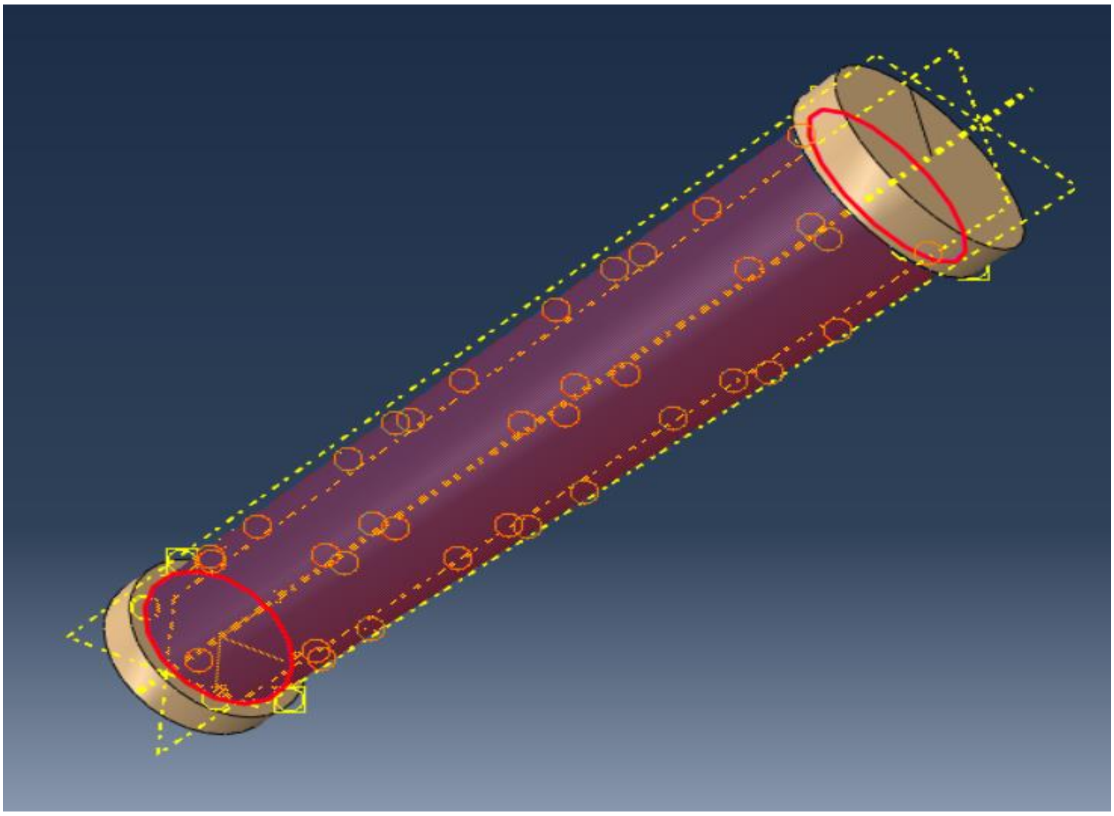


Figure 8:Tie constrain between CFRP and concrete

3-7 loading and boundary conditions

The boundary conditions were utilized in modeling are the same ones that were used in experiments. Fig. 8 shows the arrangement of boundary conditions , the bottom of the column have two supports , a pin support at bottom to restrain translation of the point in the three orthogonal directions (X, Y, Z). At the top end, a roller is assigned to prevent translation along only (X and Z) directions. One load plate and the same time it's a supported are placed at top of the column at . the load applied as a displacement load (50 mm) .Three spotting points (LVDT) , one for displacement and the rest for load. Fig.8 show the experimental column with load , Fig. 8 show Abaqus detailing

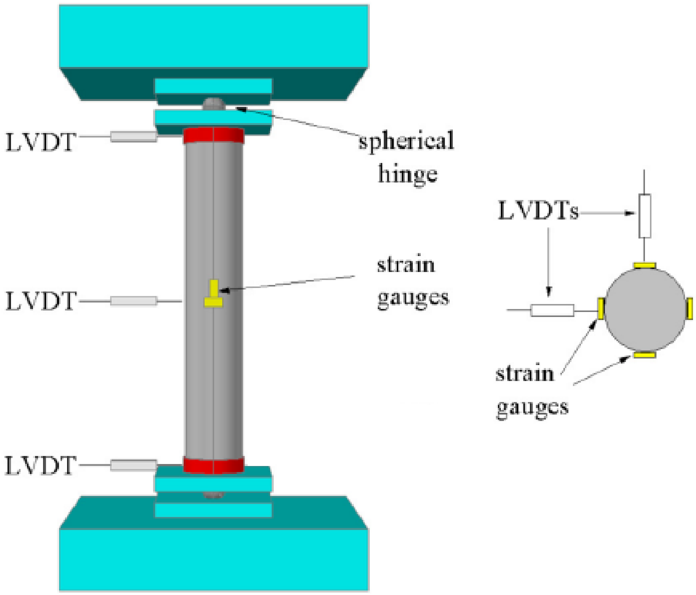


Figure 9:the experimental column with load

3-8 Verification of model data
3-8-1 Control short column (without CFRP)

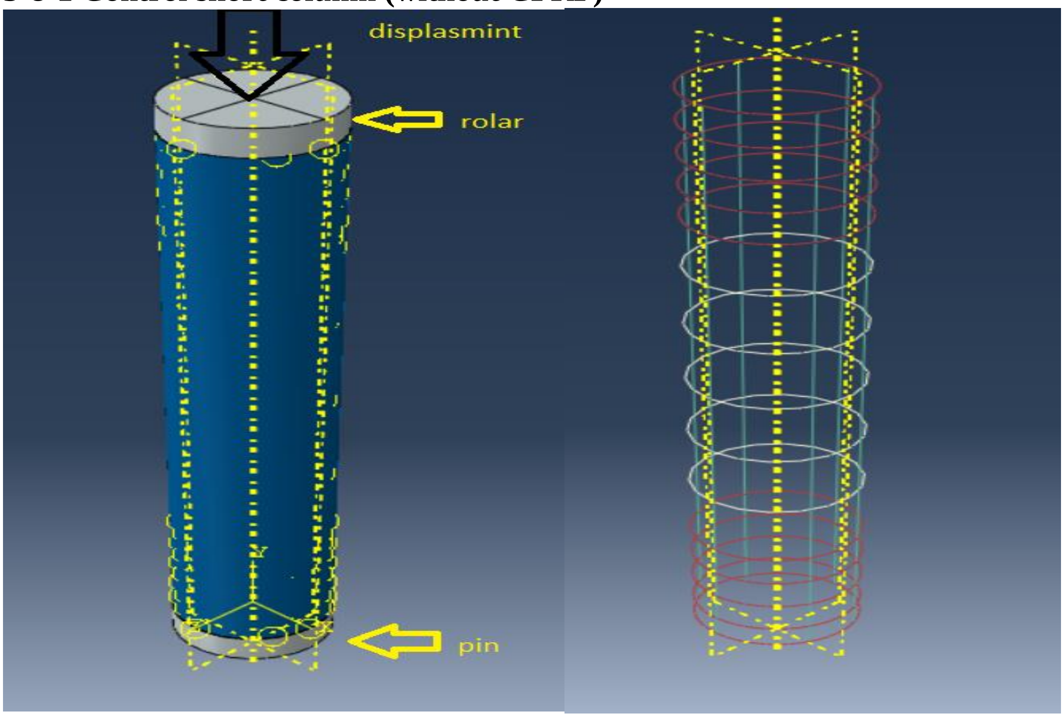


Figure10 :short column and reinforcement without CFRP

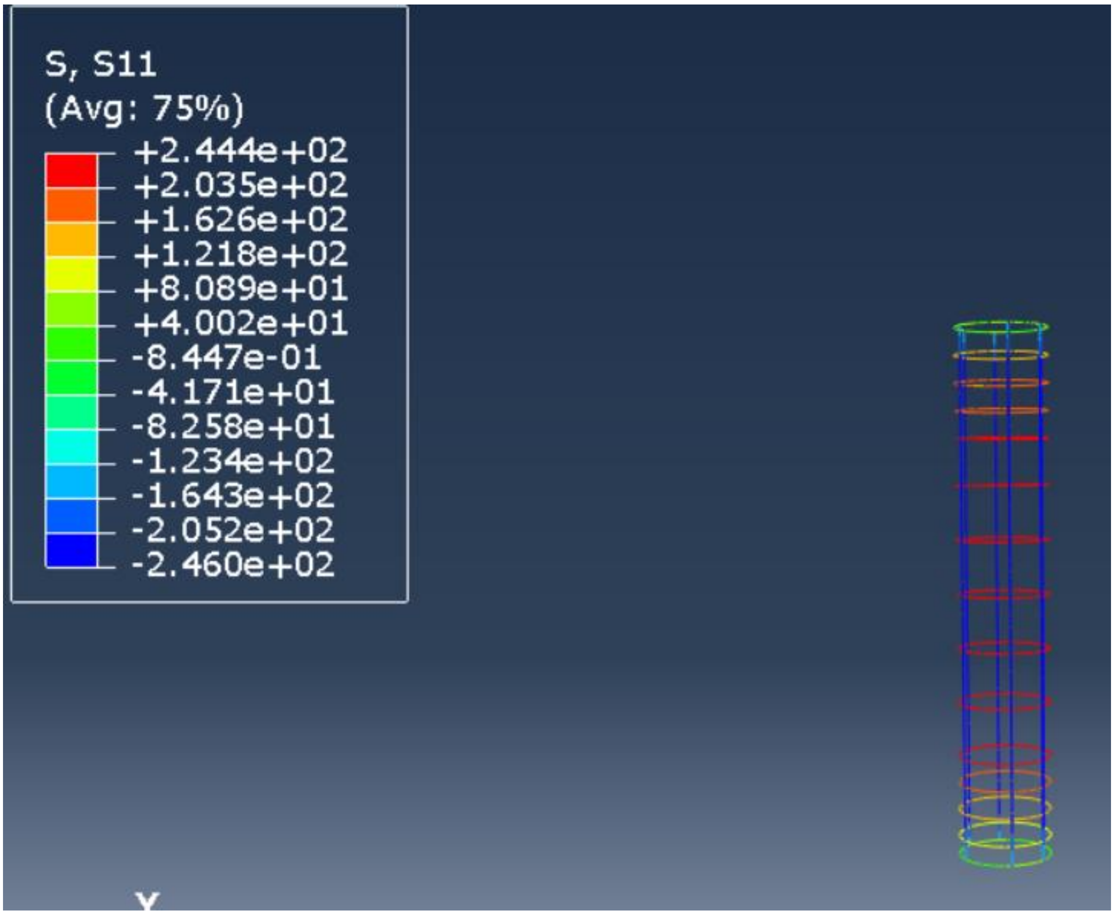


Figure 11: Without CFRP Model – Steel Normal Stress

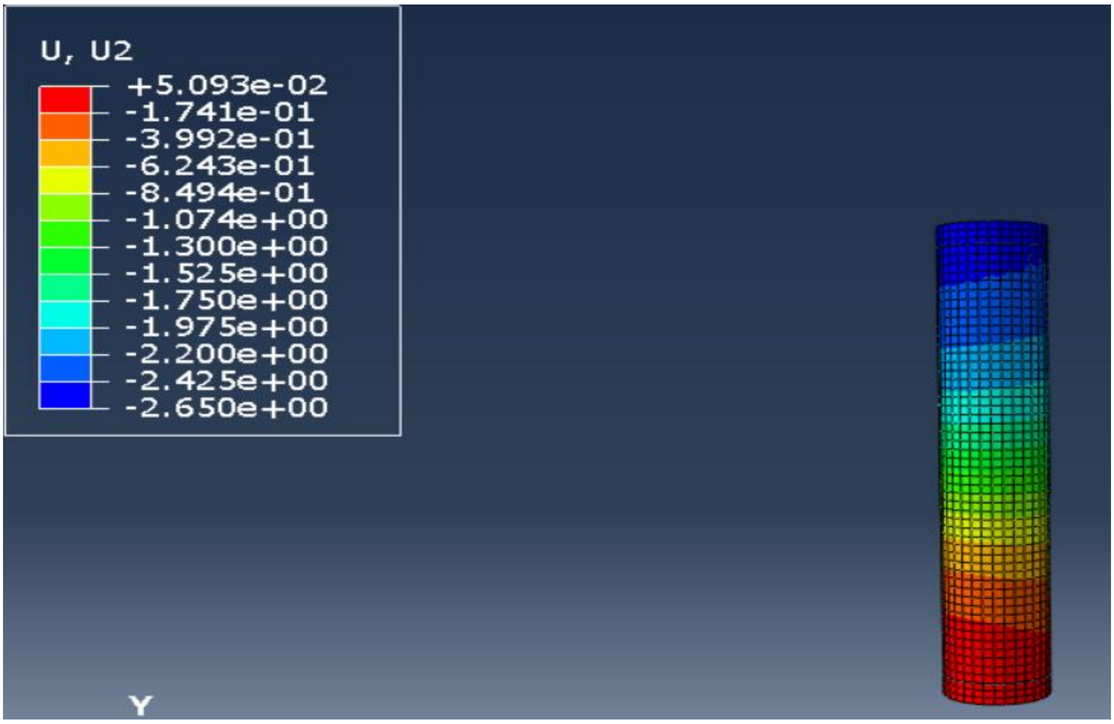


Figure 12: Without CFRP Model – U2 (Vertical Displacement)

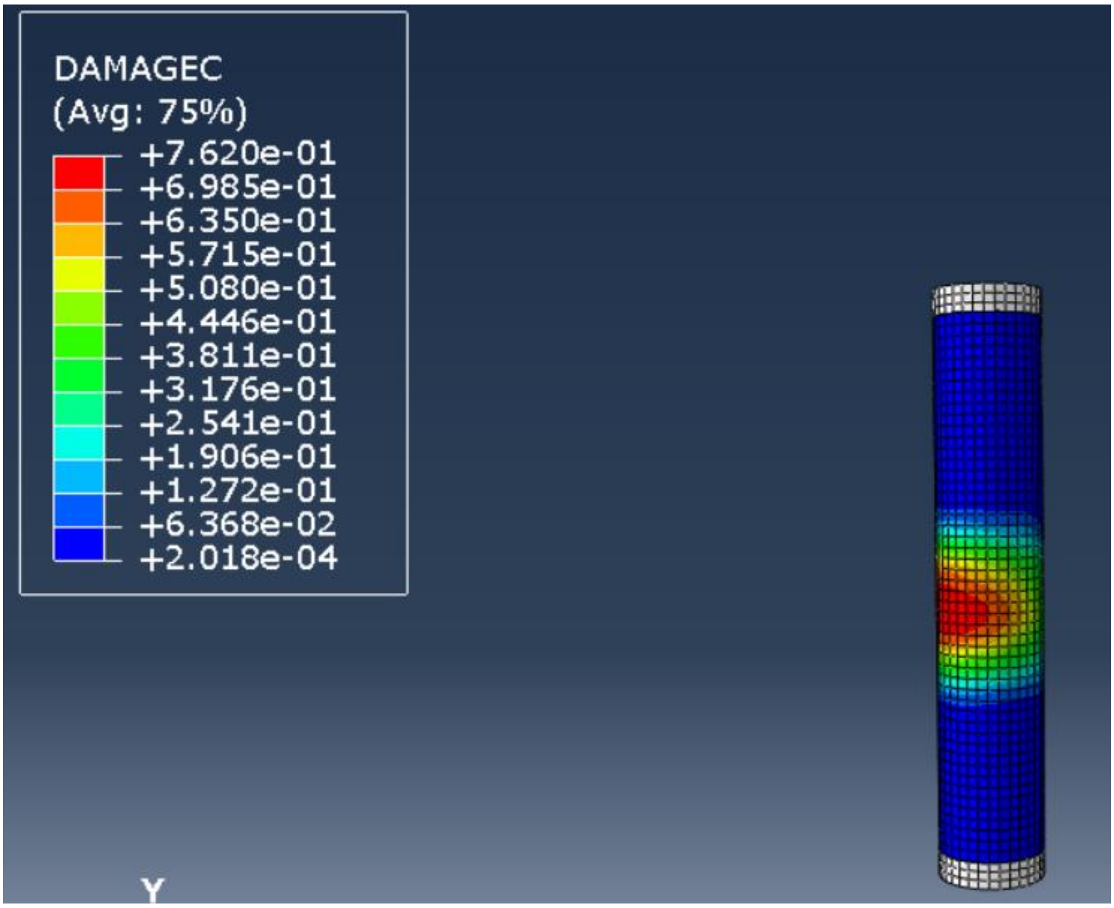
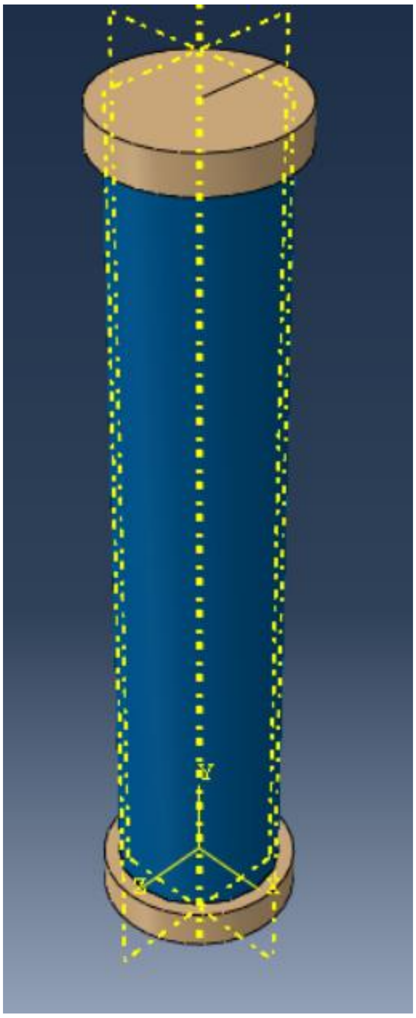


Figure 13:Without CFRP Model – Damage compression

Figure14：experimental short column without CFRP

The results of test to converting from experimental to numerical is the displacement and reaction force , the paper have just the reaction force (Hu, Zhongjun et al (2021)), Abaqus model showed a very similar behavior and reaction of the experimental column. Maximum load capacities were approximately 607 kN and 675 kN in Abaqus model and experiment respectively at top displacement of 2.5mm from Abaqus . The difference of the maximum load capacity obtained from Abaqus is decrease about 9.7% which is acceptable percentage.

3-8-2 Control short column (with CFRP)



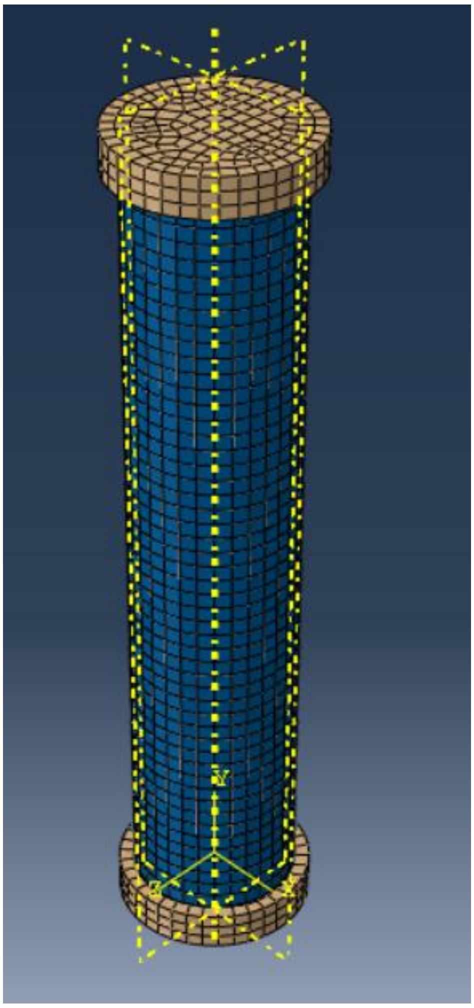


Figure 15: Short column – Mach Figure 16:short column with CFRP

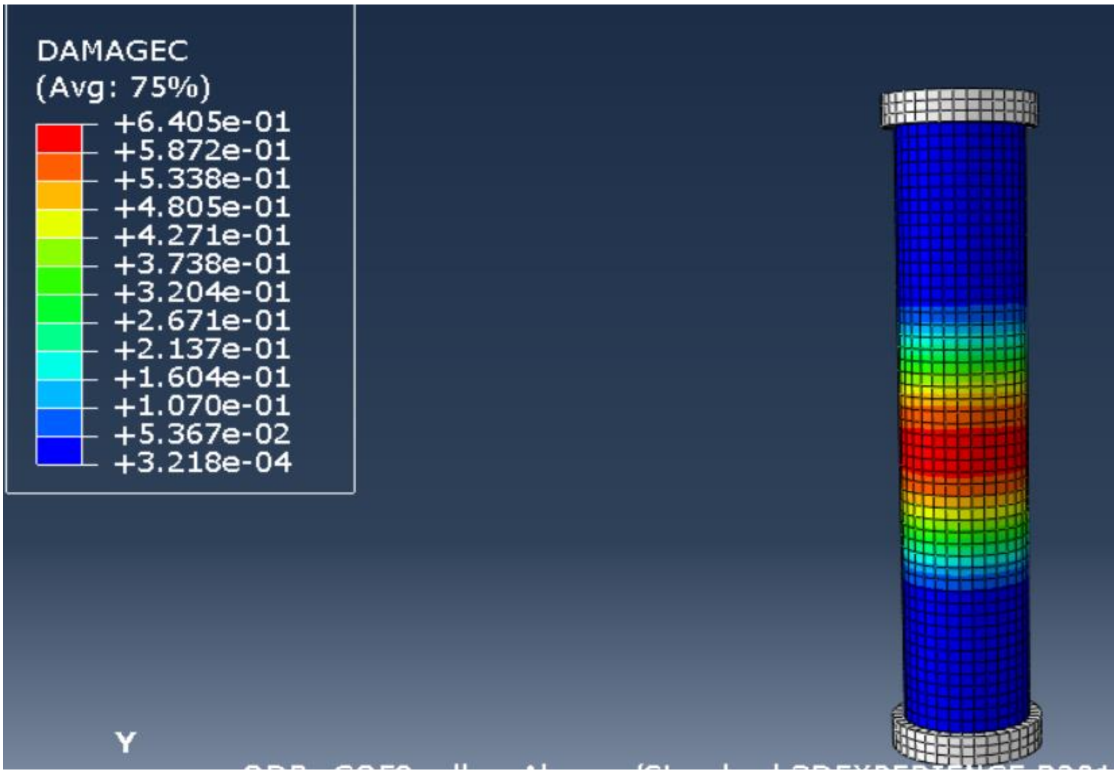


Figure17 :short column - damage c (whit CFRP)

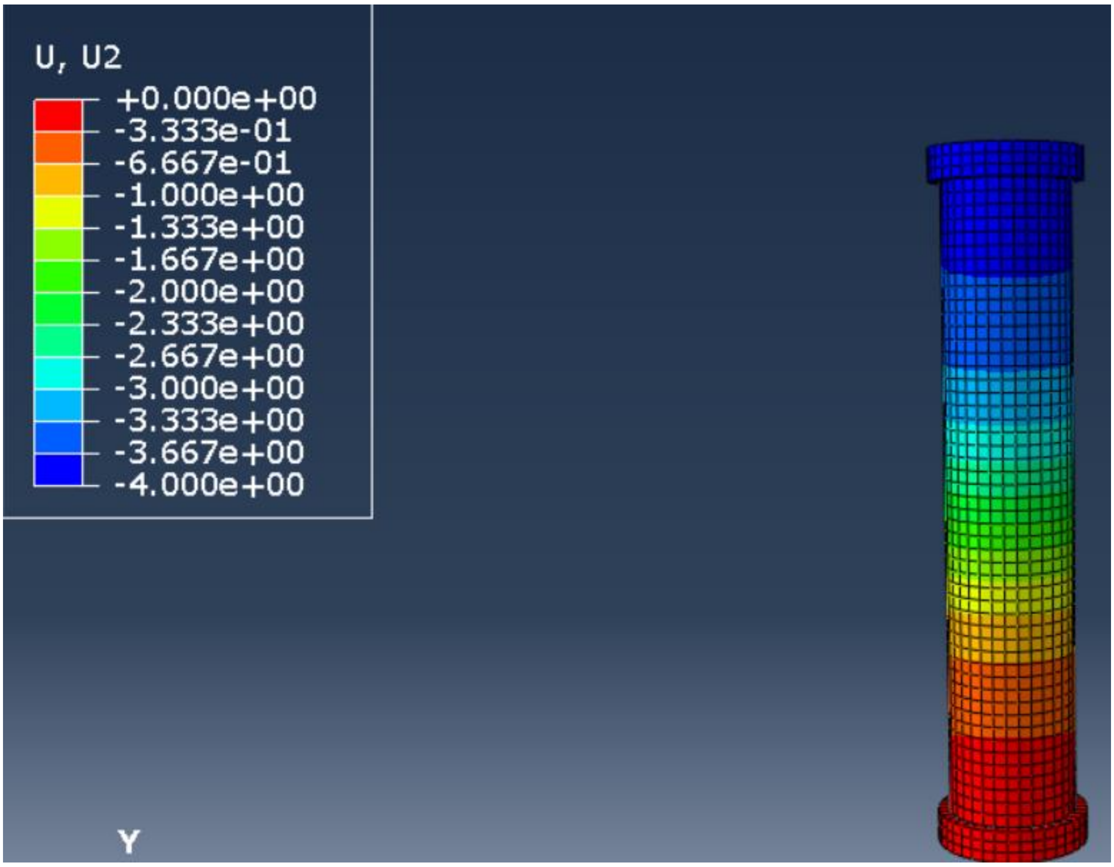


Figure 18: short column - displacement u2 (whit CFRP)

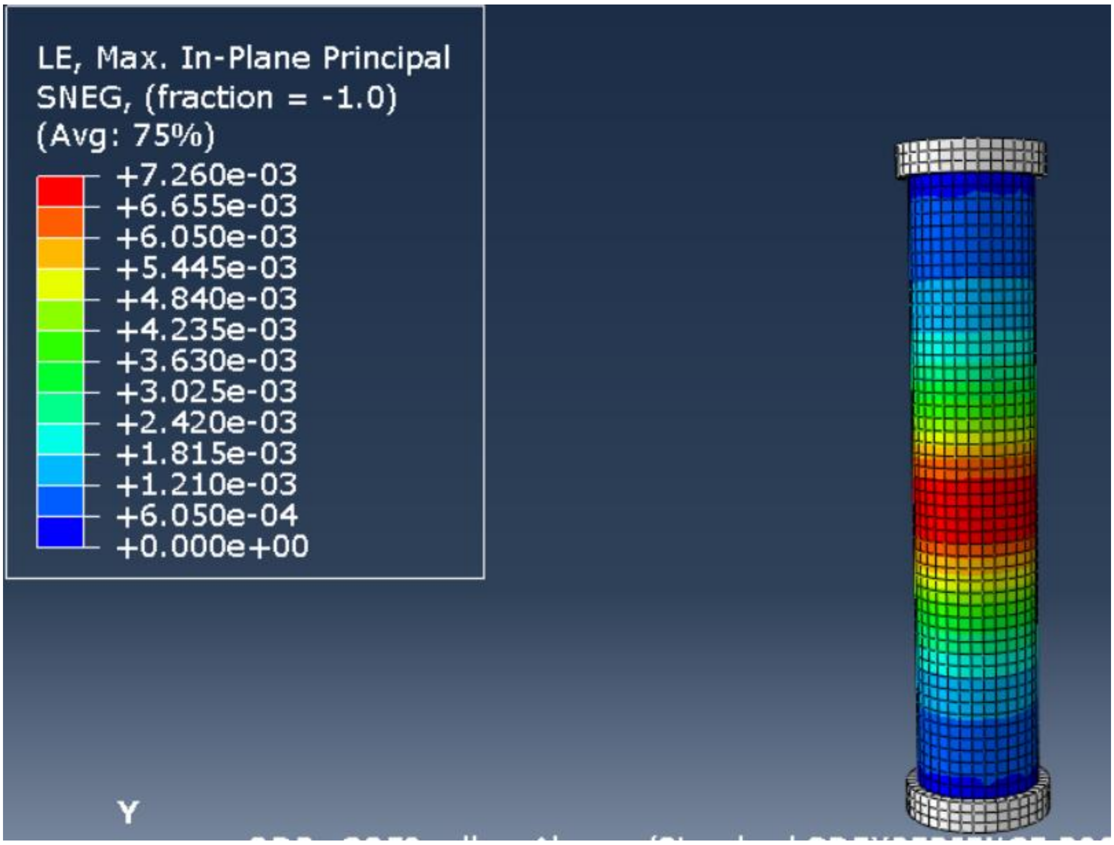


Figure 19: short column - CFRP (whit CFRP)

The figure below shows the relation between load and displacement on the TOP of the column(the converting point of the size of the column both given by the paper (Hu, Zhongjun et al (2021))and obtained from the Abaqus software. Abaqus model showed a very similar behavior and reaction of the experimental column . Maximum load capacities were approximately 1167 kN and 1214 kN in Abaqus model and experiment respectively at top displacement of 0.97 mm. The difference of the maximum load capacity obtained from Abaqus is decrease about 3.8 % which is acceptable percentage. We can see that using CFRP can increase the axial load capacity up to 539 kN, which means a development of more than 55%.

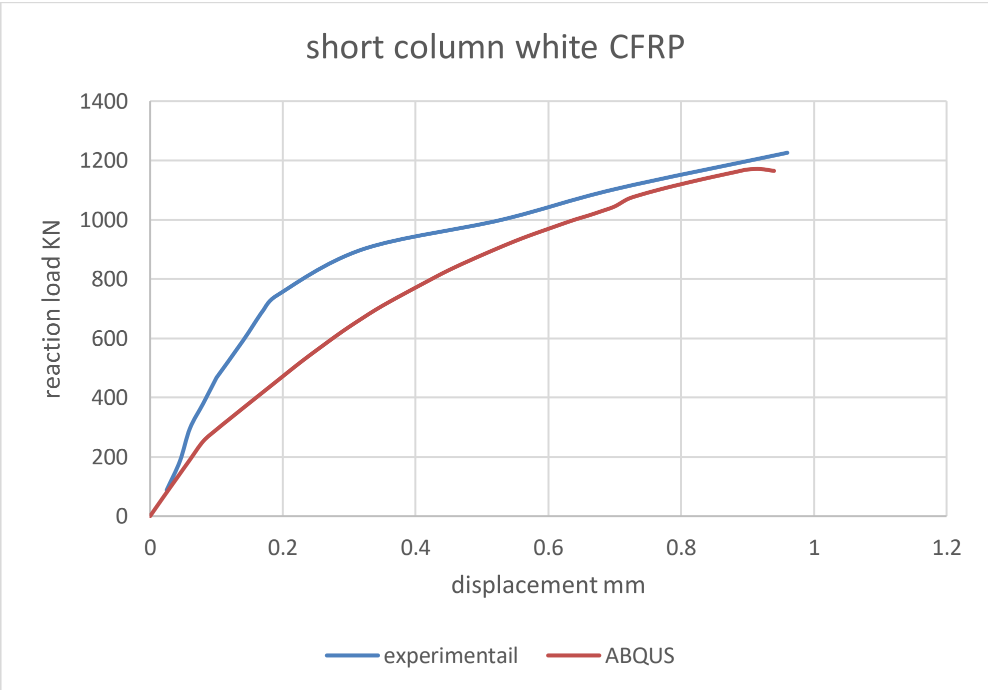


Figure 20:Load – Displacement Curve for CFRP model

3-8-3 Control slender column (without CFRP)

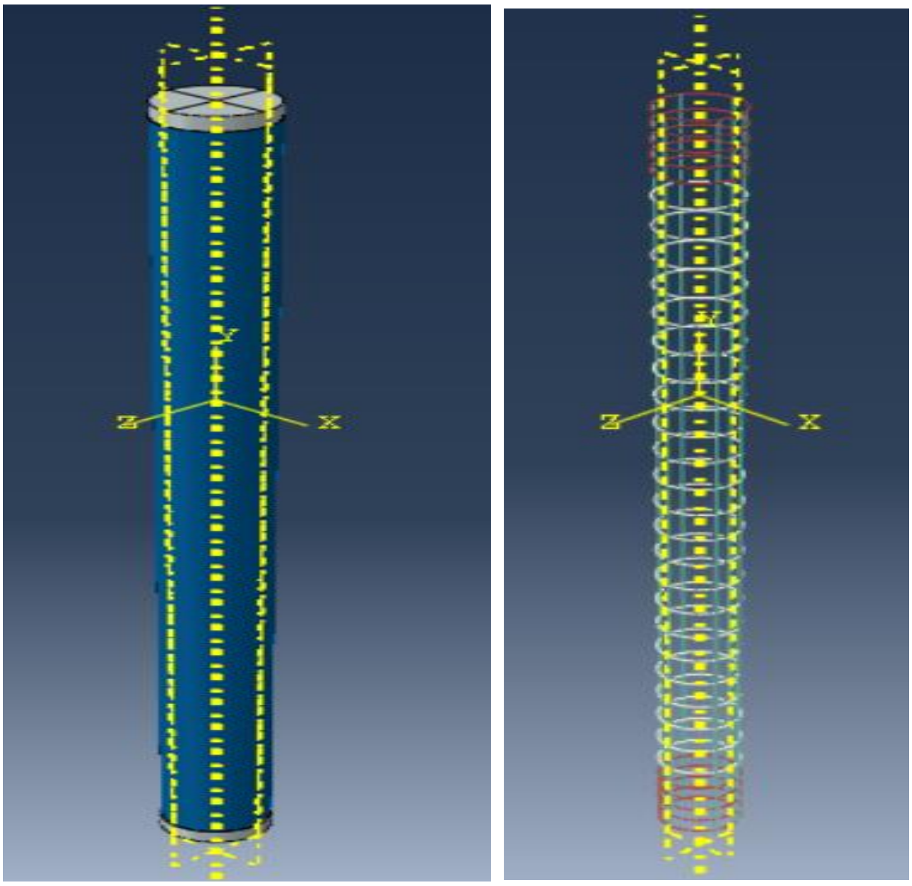


Figure21 : slender column

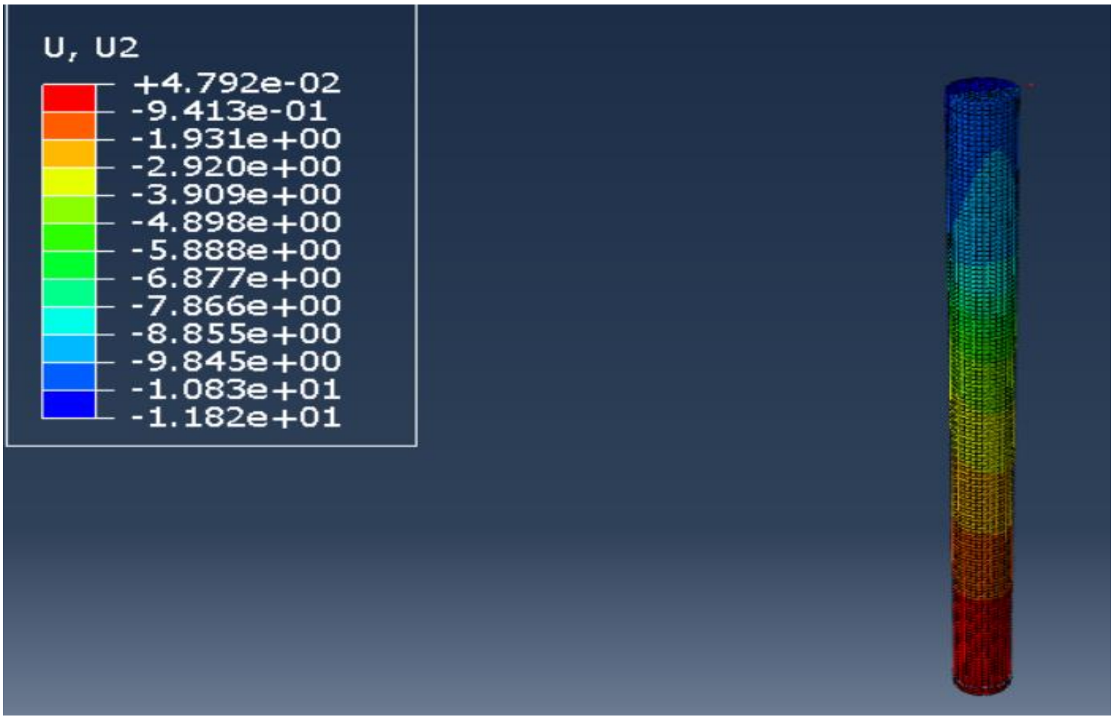


Figure22 :Without CFRP Model slender column – U2 (Vertical Displacement)

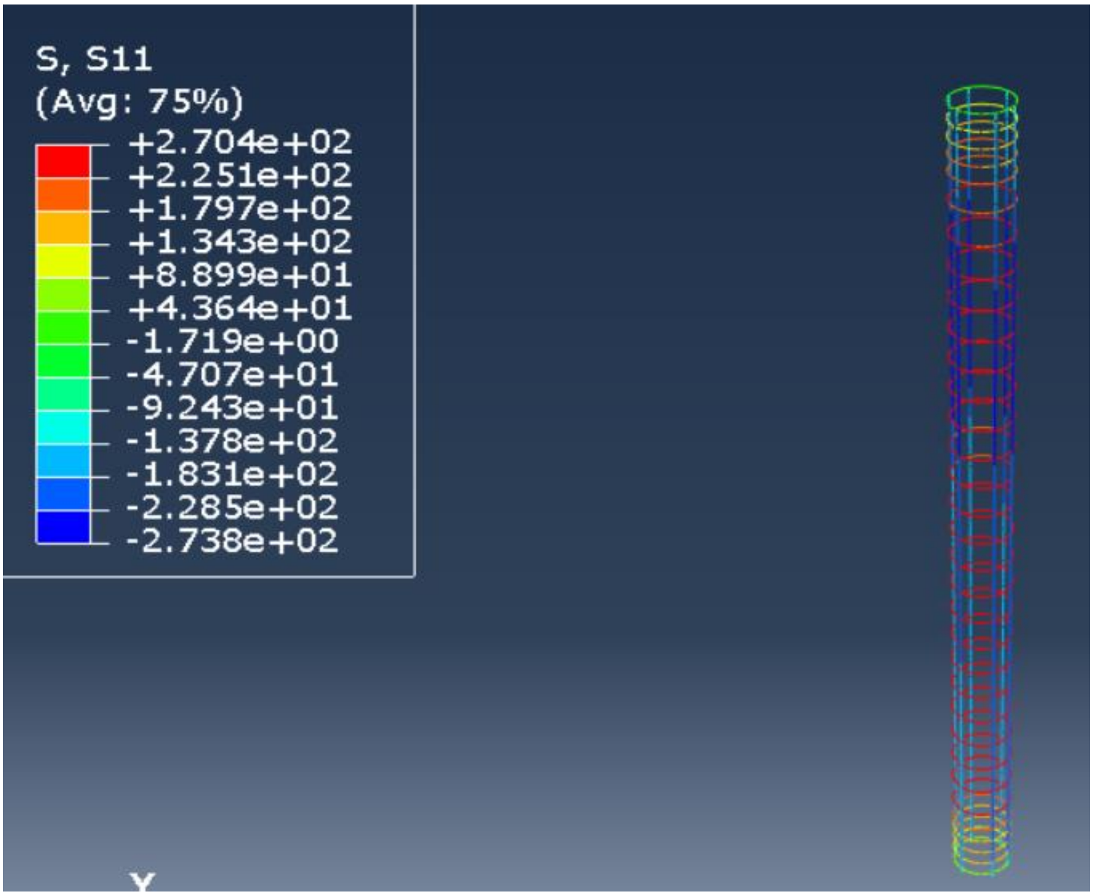


Figure 23:Without CFRP Model slender column – Steel Normal Stress

The results of test to converting from experimental to numerical is the displacement and reaction force , the paper have just the reaction force (Hu, Zhongjun et al (2021)), Abaqus model showed a very similar behavior and reaction of the experimental column. Maximum load capacities were approximately 610 kN and 550 kN in Abaqus model and experiment respectively at top displacement of 7 mm from Abaqus . The difference of the maximum load capacity obtained from Abaqus is increased about 10.9% which is acceptable percentage.

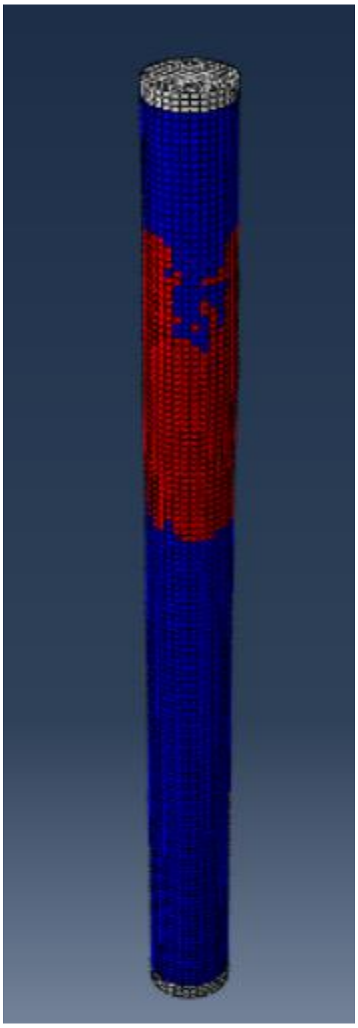


Figure 24:slender column – flair damage Abaqus

Figure25 : slender column – flair damage experimental

3-8-4 Control slender column (with CFRP)

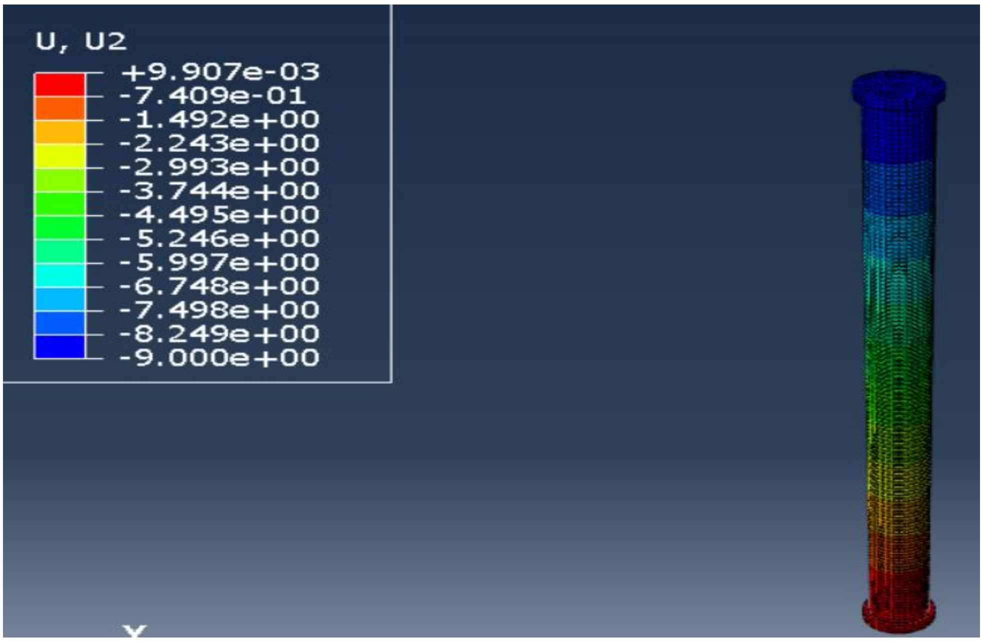


Figure:26 With CFRP Model slender column – U2 (Vertical Displacement)

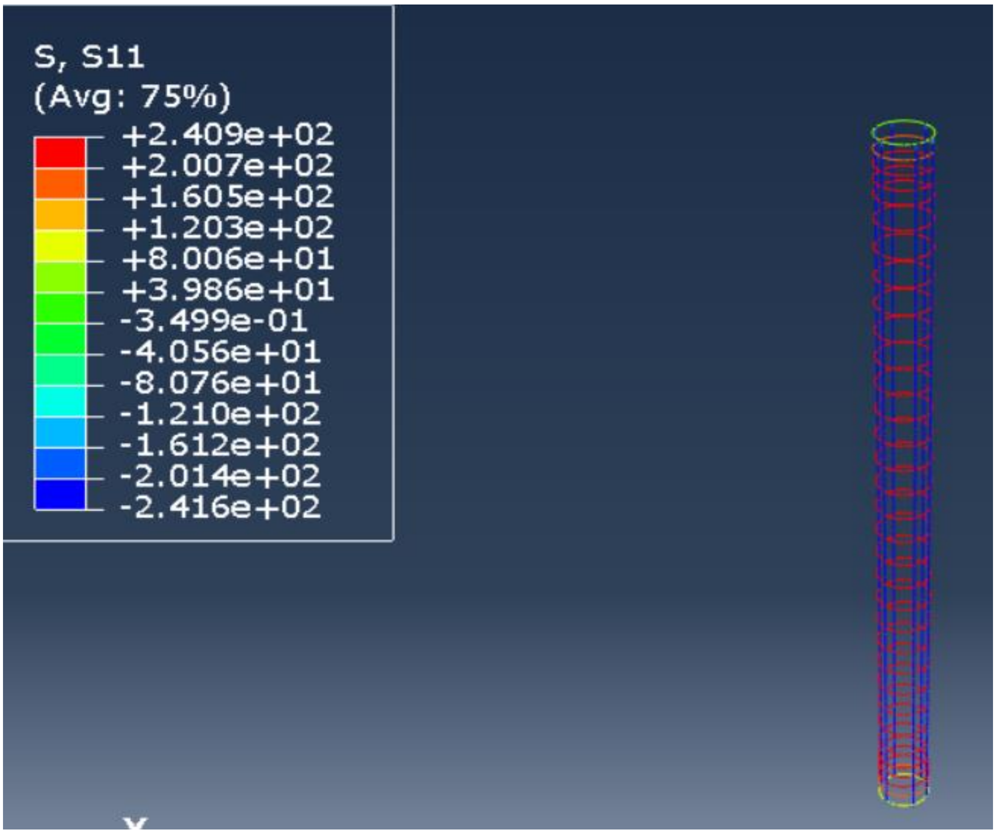


Figure27 :With CFRP Model slender column – Steel Normal Stress

The figure below shows the relation between load and displacement on the TOP of the column(the converting point of the size of the column both given by the paper (Hu, Zhongjun et al (2021))and obtained from the Abaqus software. Abaqus model showed a very similar behavior and reaction of the experimental column . Maximum load capacities were approximately 864 kN and 890 kN in Abaqus model and experiment respectively at top displacement of 8 mm. The difference of the maximum load capacity obtained from Abaqus is decrease about 3.1 % which is acceptable percentage. We can see that using CFRP can increase the axial load capacity up to 340 kN, which means a development of more than 38%.

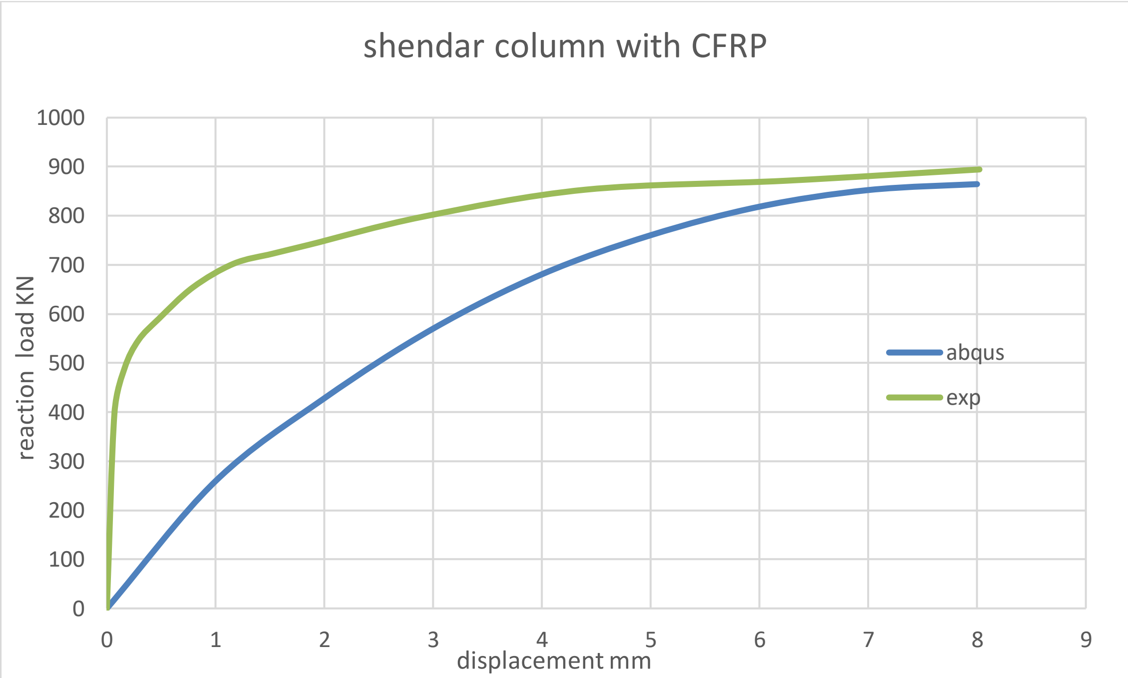


Figure 28: Load – Displacement Curve for CFRP model

3-9 Parametric study

Parametric study is conducted to investigate the behavior of fall scale R.C Colum strengthened by CFRP in different cases by made a numerical test on short and slander specimens (Hu, Zhongjun et al (2021) studied two variables (slender ratio raids to the length and existing of CFRP). We will study the behavior affected by many parameters on full scale columns short and slender . These parameters are:

3-9-1 : strength of concrete

In this parameter we will study increasing the strength of concert. There are 2 models for this variable:

3-9-1-1: 24 Mpa concret strength (300)

3-9-1-2: 28 Mpa concret strength (350)

3-9-2 : Oreintayion of CFRP

In this parameter we will study change of the Orientation of CFRP. There are 2 models for this variable:

3-9-2-1 : CFRP horizontal direction

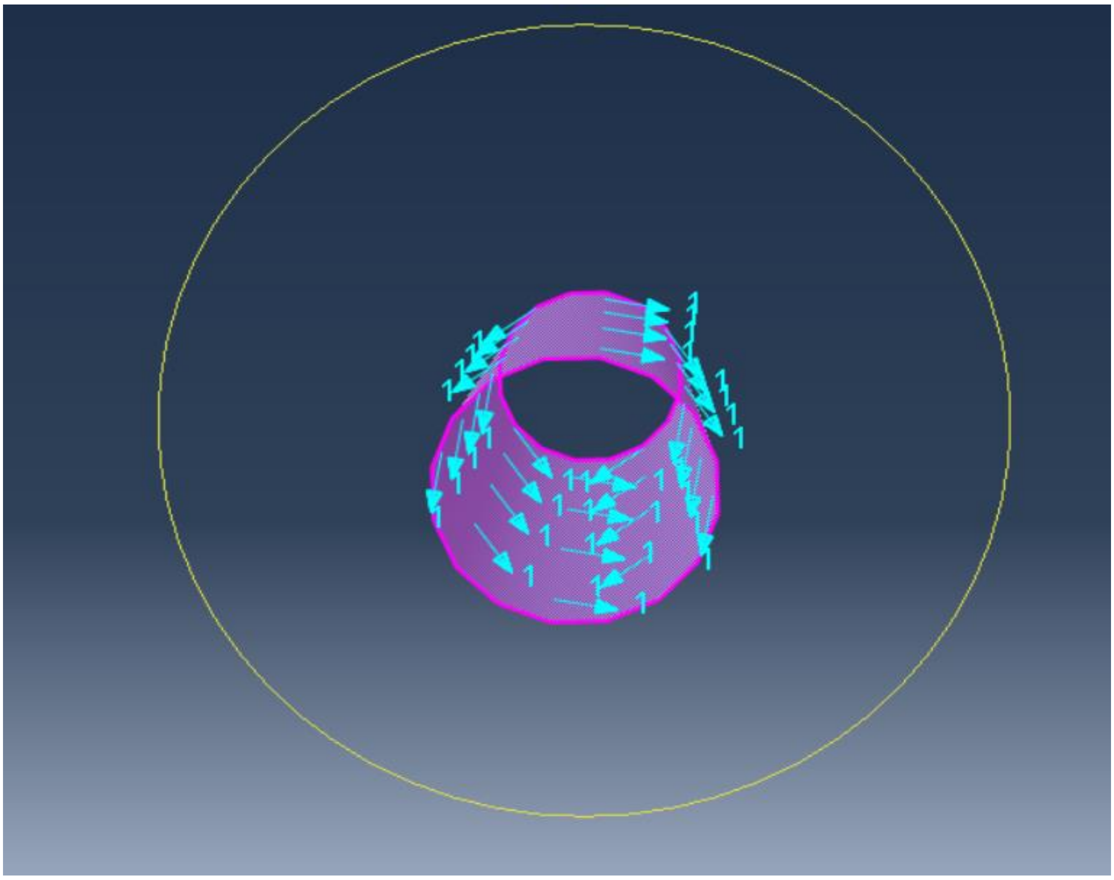


Figure 29 :CFRP horizontal direction

3-9-2-2 : CFRP vertical direction

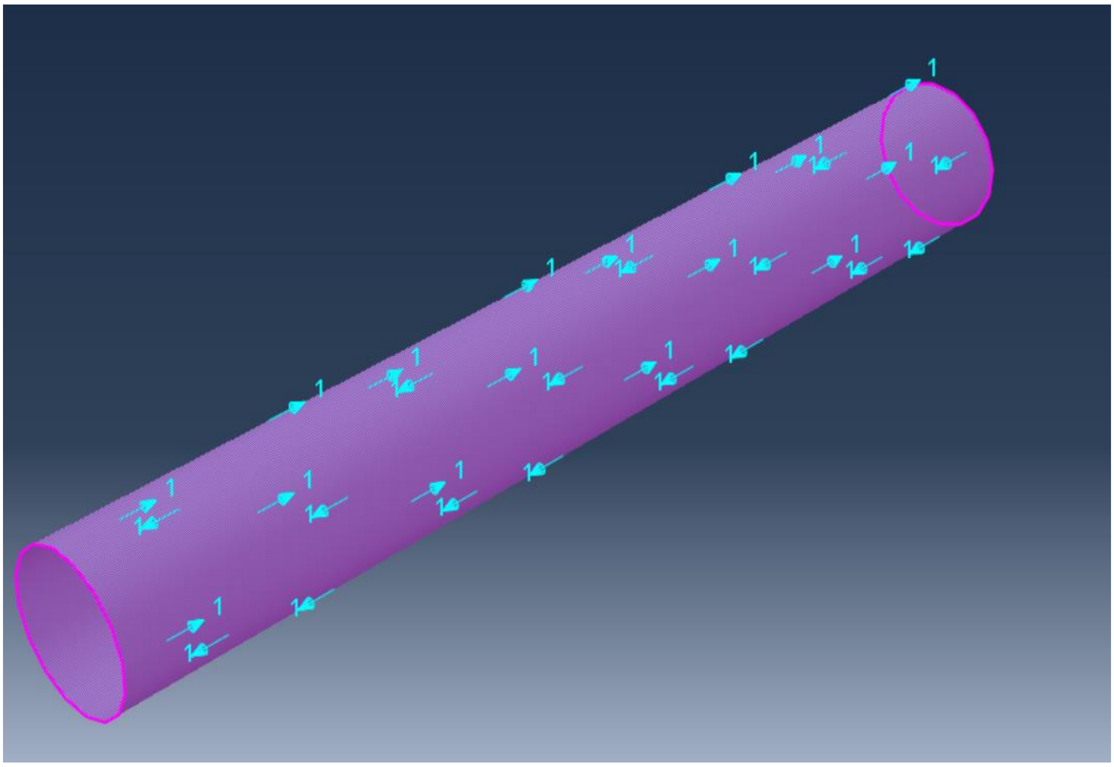


Figure30 :CFRP vertical direction

3-9-2-3 CFRP vertical and horizontal directio

Bay using tow layer of CFRP every layer with thickness 100mm combined with the to gather.

3-9-3 Geometry of columns on parametric study

We imposed two specimens of circler concrete column shortly and slender used in the Abaqus verification program, the slender Colum and short is a circler section with a, a diameter of 800 mm and length of 6000 mm and 4000 mm respectively with the same materials on (Hu, Zhongjun et al (2021) , strengthened by a one layer of 200 mm CFRP coting shape and the attached figure shows the shape and dimension of the sample

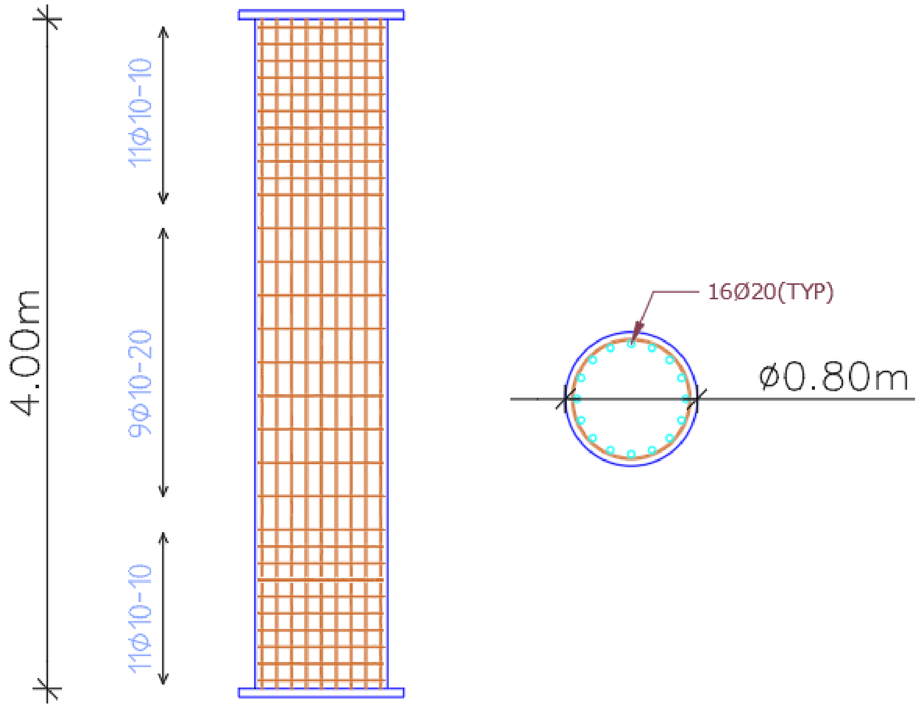


Figure 31: shape of fully scale shorter column

Chapter 4 : Results and discussion

In this chapter we will present the main results of all parameters studied that were mentioned in Chapter 3 (3.9.1 to 3.9.3). load-deflection curves will be shown for all cases and will be discussed.

BEAM #.	Specimen Designation	First comparison crack, (*kN*)	**Def (mm)**	**maximum** load, (*kN*)	**Def (mm)**	**Failure load (kN)**	**Def (mm)**
1	CS24	6295	300	16803	1300	14500	1500
2	CS28	9243	400	18707	1300	16200	1400
3	CL24	2684	200	11720	1800	11650	1800
4	CL28	2889	200	12258	1700		
5	CS24 FH	6383	300	19705	1600		
6	CS24 FV	6473	300	19013	1500		
7	CS24 FX	6429	300	19404	1500		
8	CL24 FH	5041	300	19505	2200		
9	CL24 FV	5130	300	18811	2100		
10	CL24 FX	5086	300	19200	2100		

BEAM #.	Specimen Designation	First comparison crack, (*kN*)	**Def (mm)**	**maximum** load, (*kN*)	**Def (mm)**	**Failure load (kN)**	**Def (mm)**
1	CS28FH	9359	400	21507	1600		
2	CS28 FV	9464	400	20902	1500		
3	CS28 FX	9414	400	21260	1500		
4	CL28 FH	7132	400	21200	2200		
5	CL28 FV	7247	400	20688	2100		
6	CL28 FX	7190	400	21059	2100		

- C: COLUMN
- S: SORTLY
- L: LONG
- F: FIBER
- H: HORESINTAIL ORIENTATION
- V:VERTICAL ORIENTATION
- X : HORESINTAIL AND VERTICAL ORIENTATION
- 24 &28 : CONCRETE STRENGTHENED MPA

4- 1: Strength of concrete

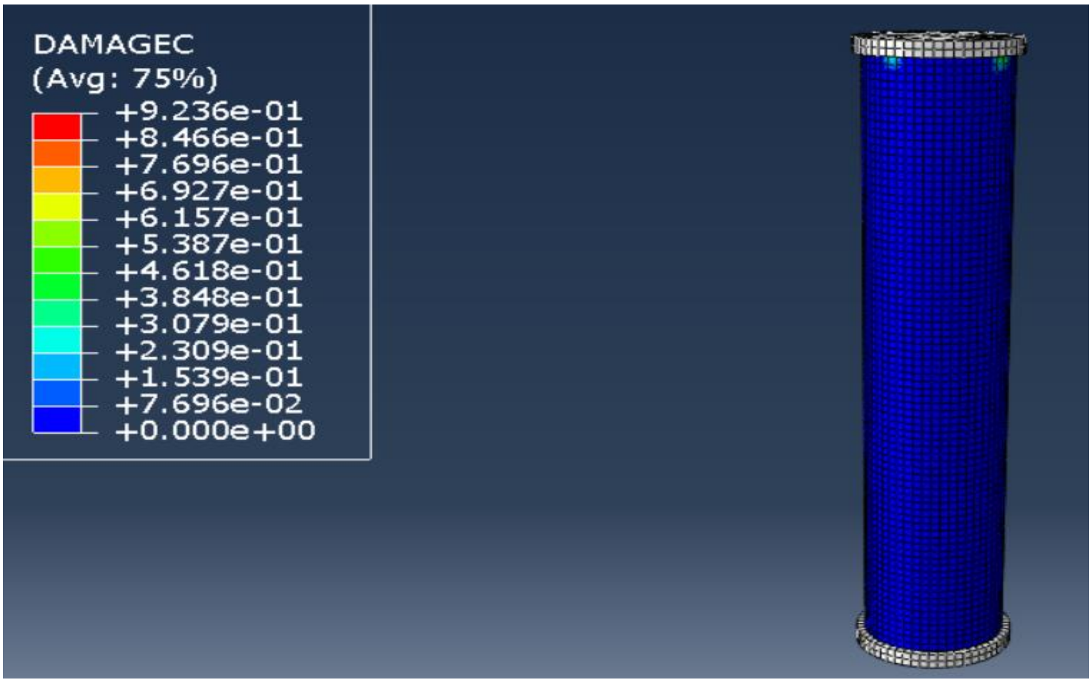


Figure 32: CS24- damage comparison -First crack

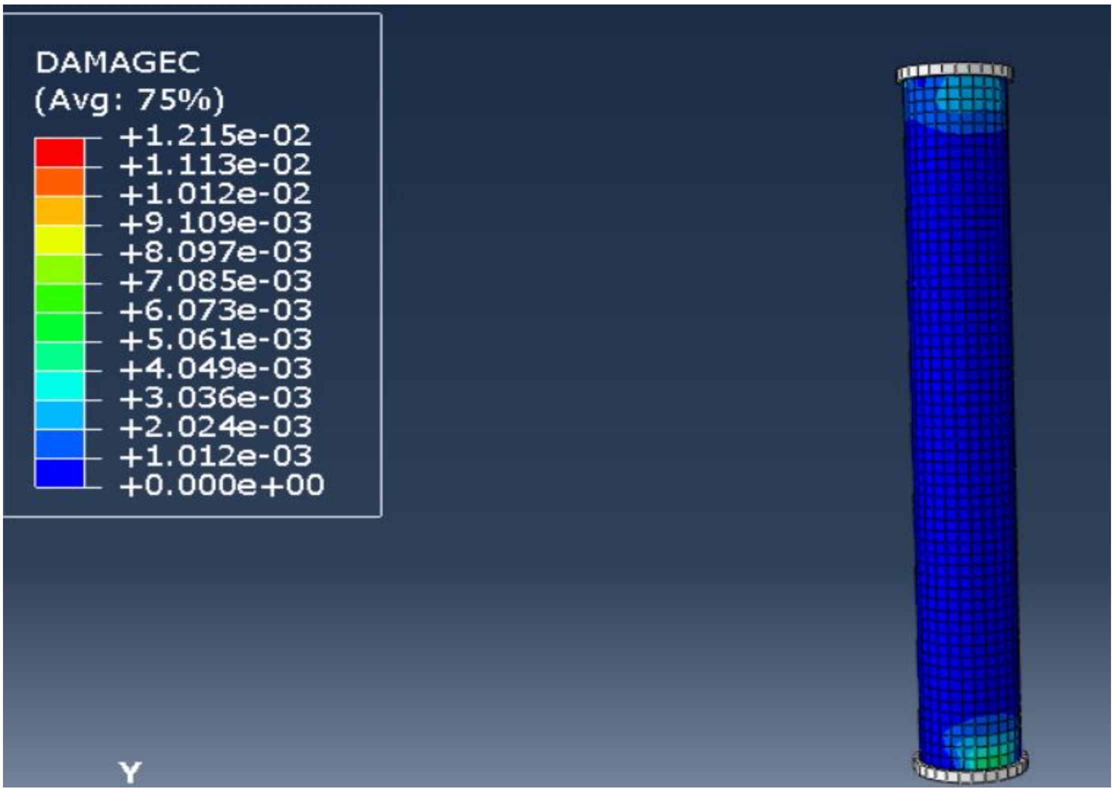


Figure33 :CL24- damage comparison -First crack

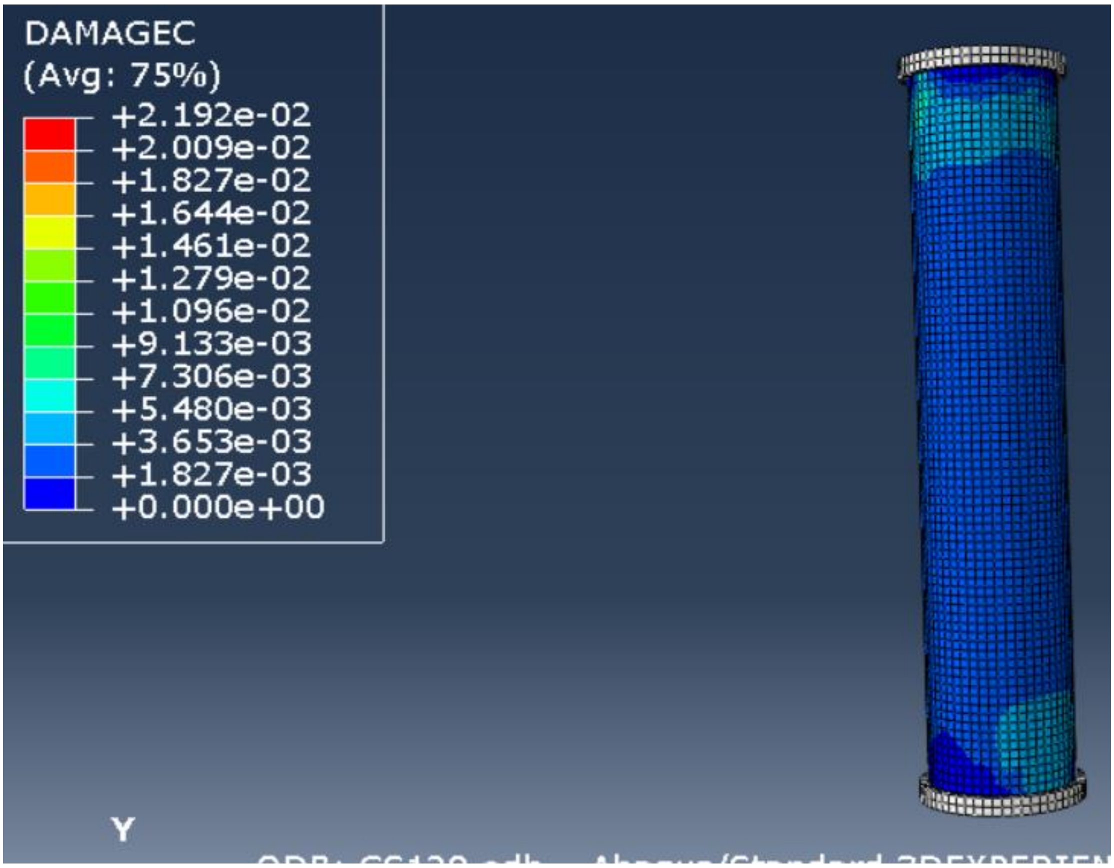


Figure 34:CS28- damage comparison -First crack

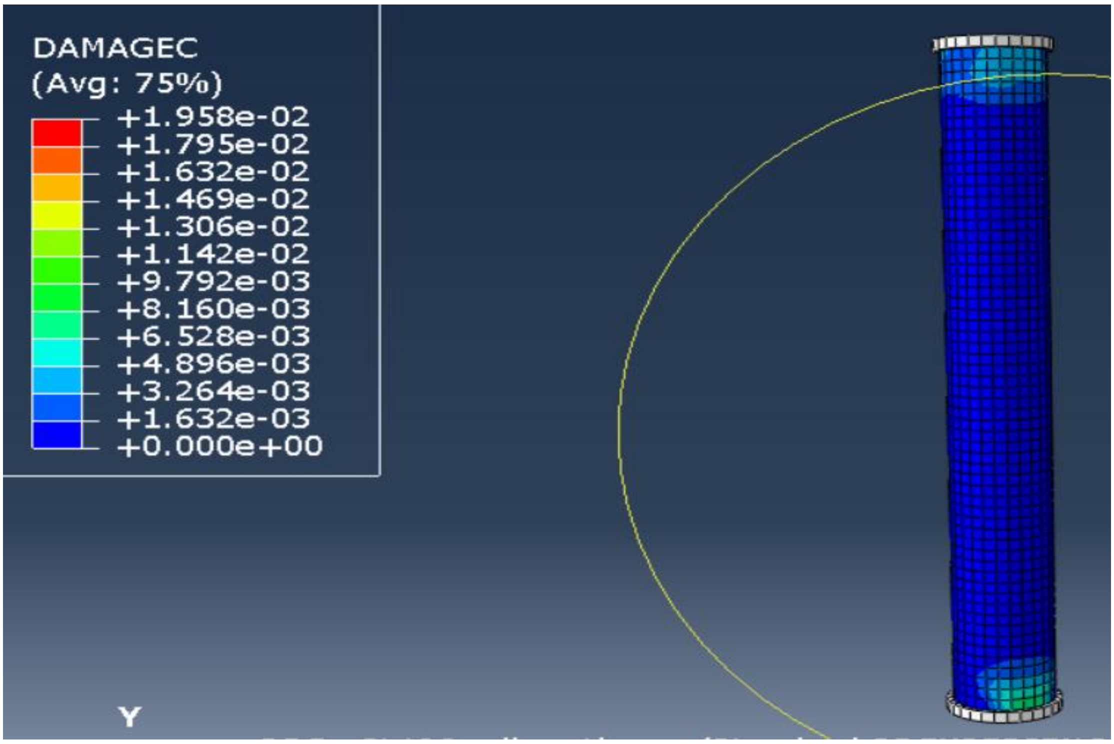


Figure35 :CL28- damage comparison -First crack

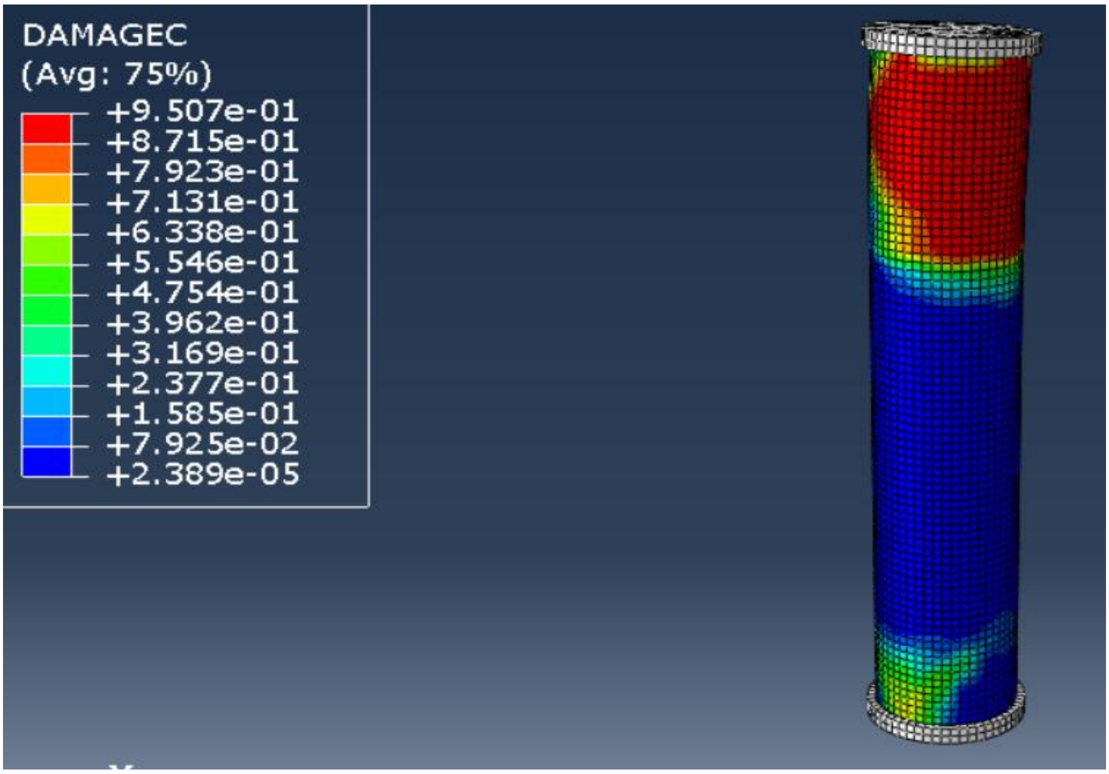


Figure 34: CS24- damage comparison - at ultimate crack

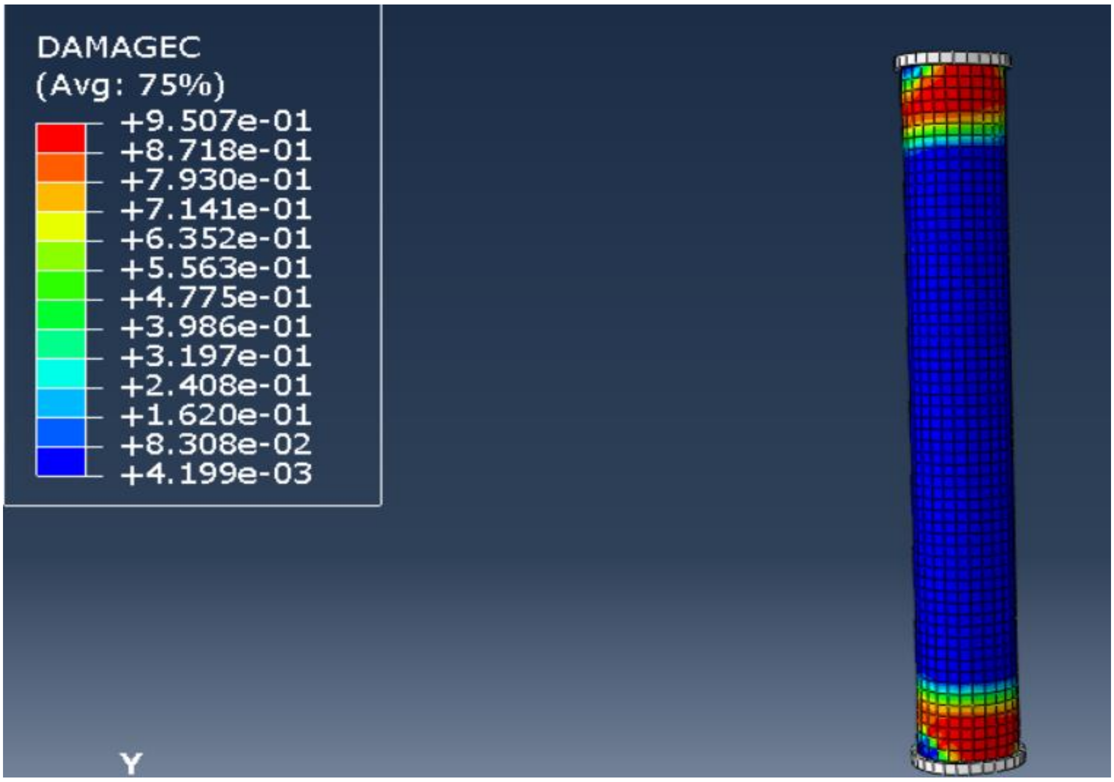


Figure 35: CL24- damage comparison - at ultimate crack

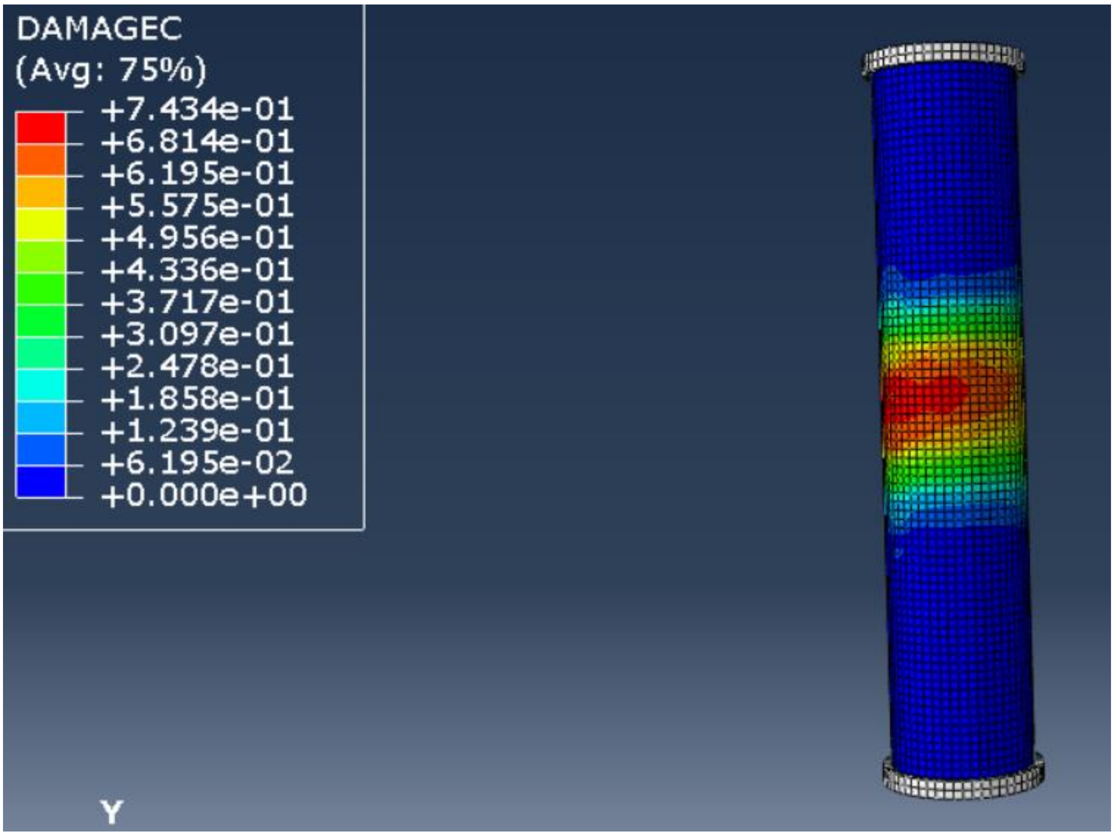


Figure38 :CS28- damage comparison - at ultimate crack

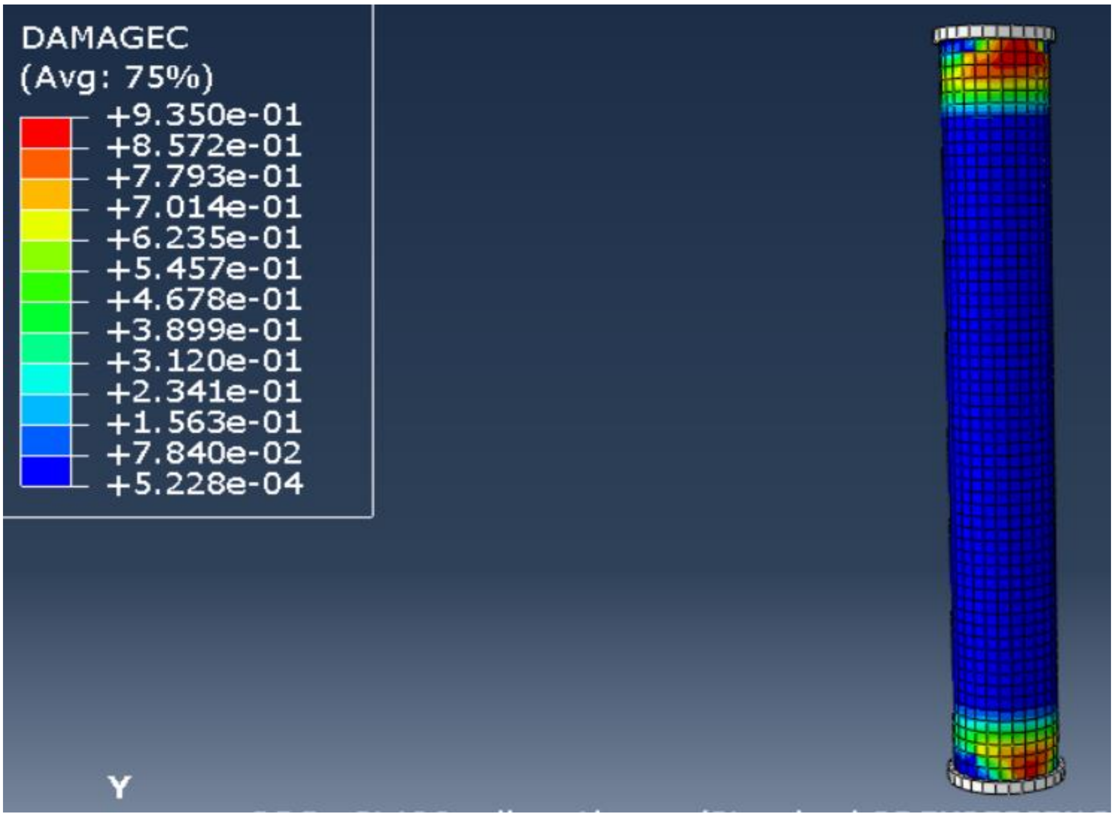


Figure36 :CL28- damage comparison - at ultimate crack

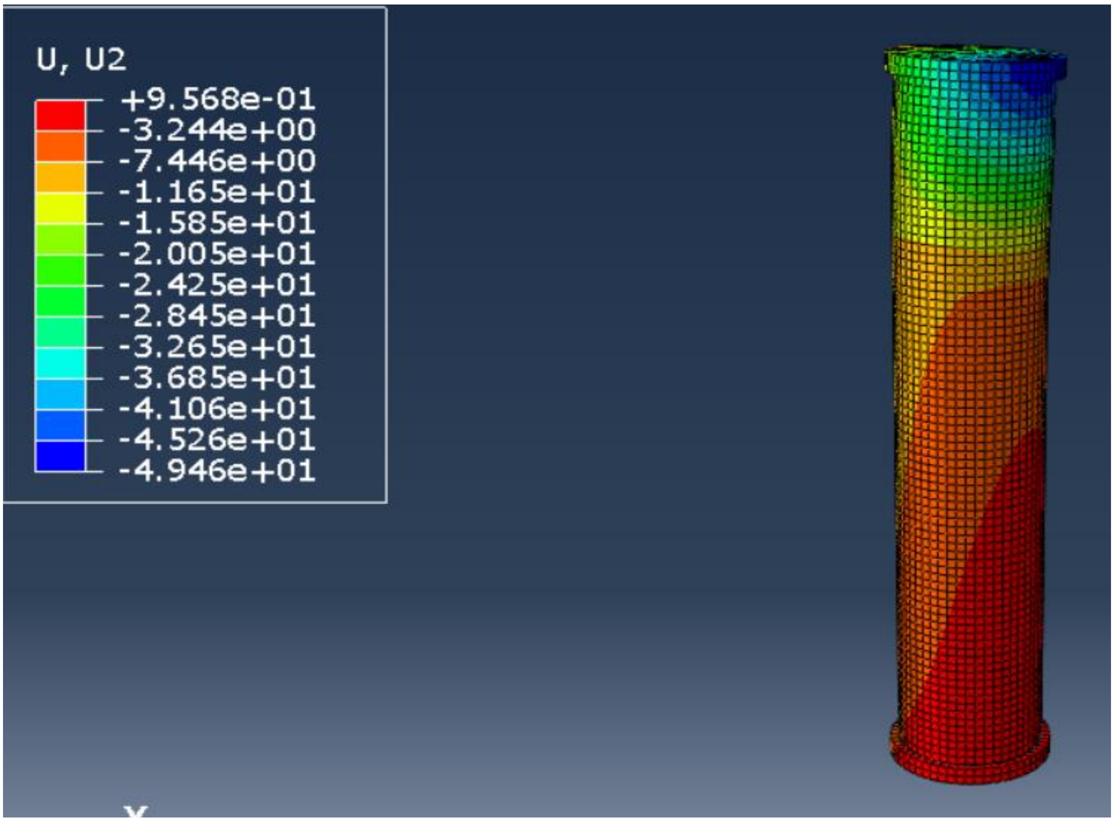


Figure:37 :CS24 U2 (vertical displacement) at ultimate

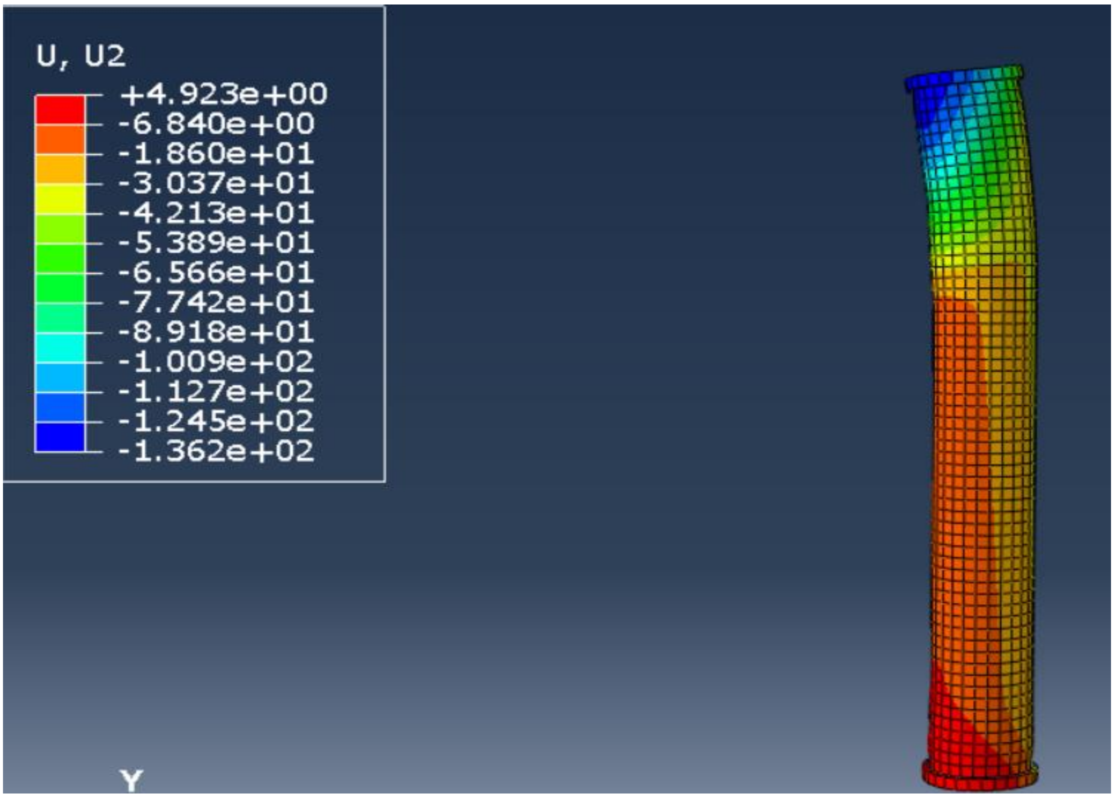


Figure38 :CL24 U2 (vertical displacement) at ultimate

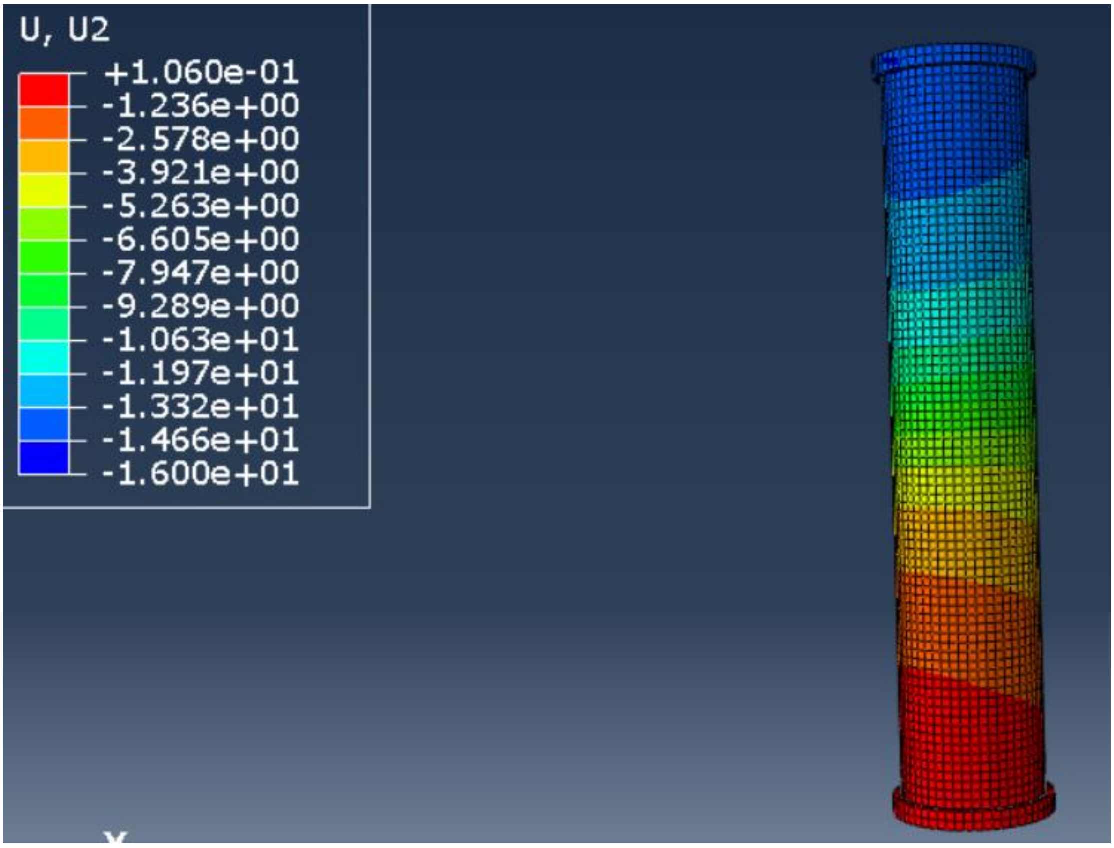


Figure39 :CS28 U2 (vertical displacement) at ultimate

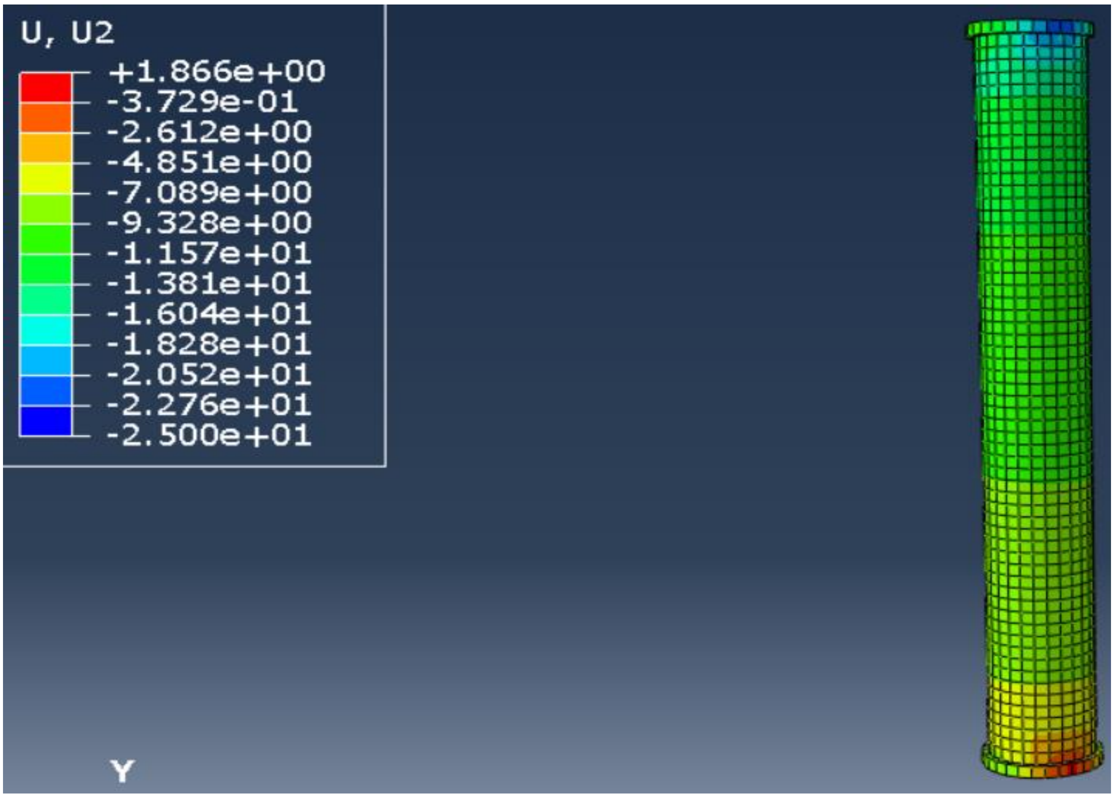


Figure40 :CL28 U2 (vertical displacement) at ultimate

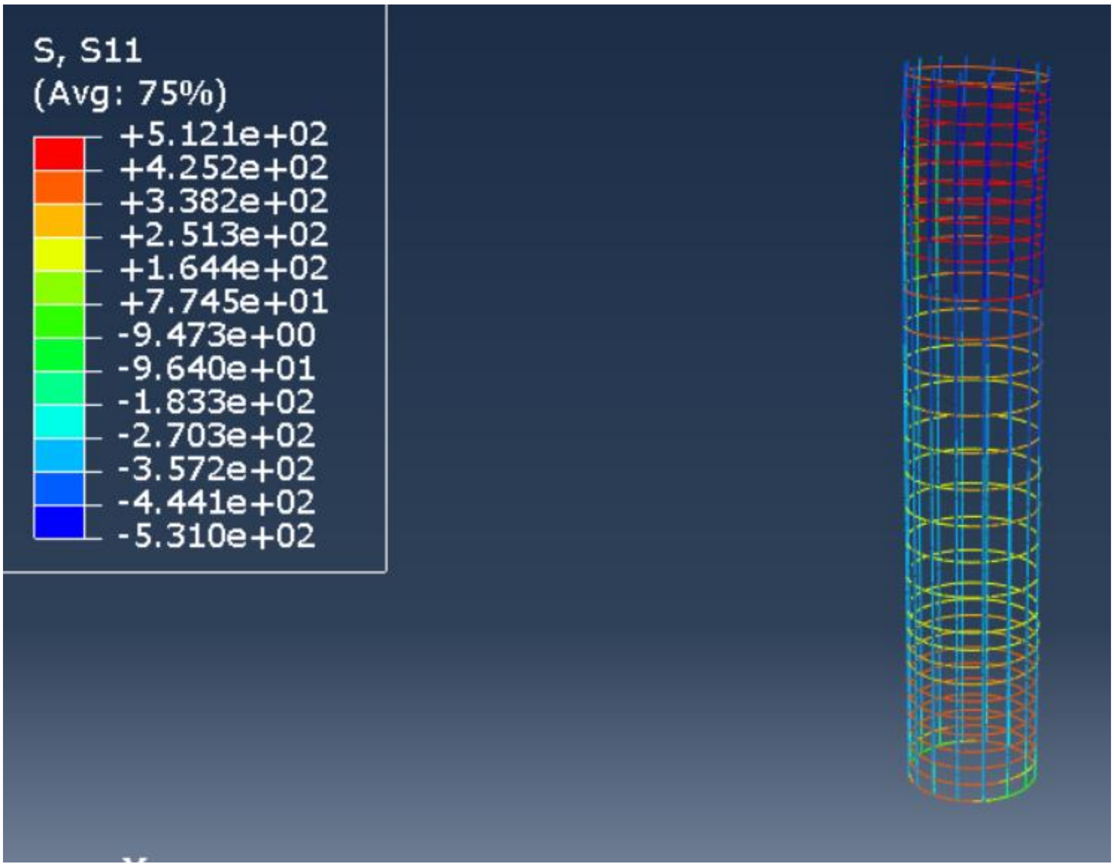


Figure 41:CS24 Steel normal strain at ultimate crack

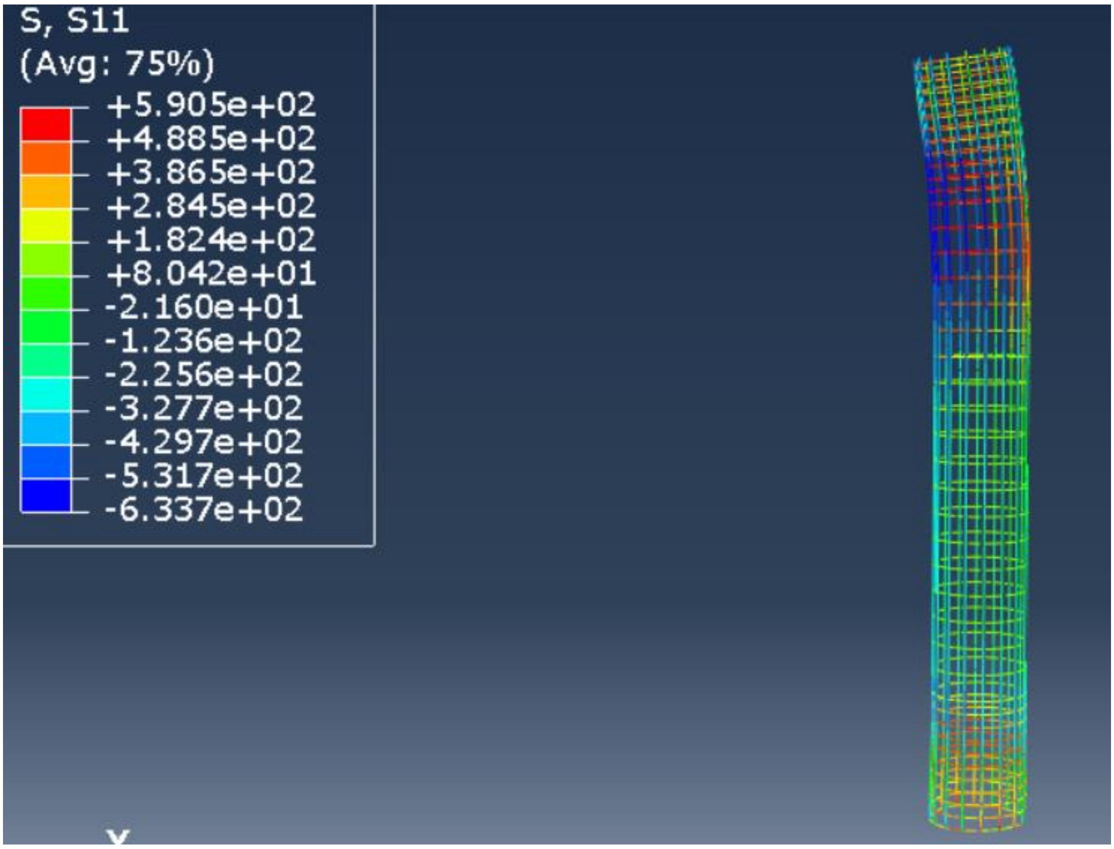


Figure 42:CL24 Steel normal strain at ultimate crack

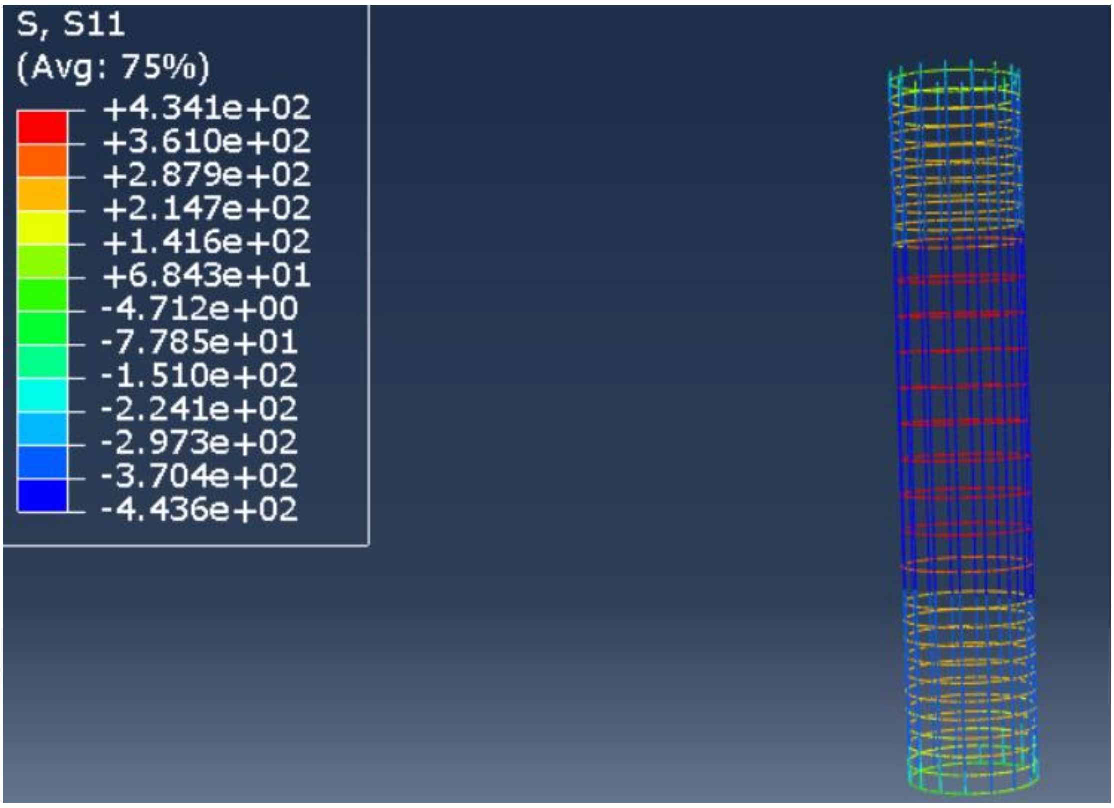


Figure 43:CS28 Steel normal strain at ultimate crack

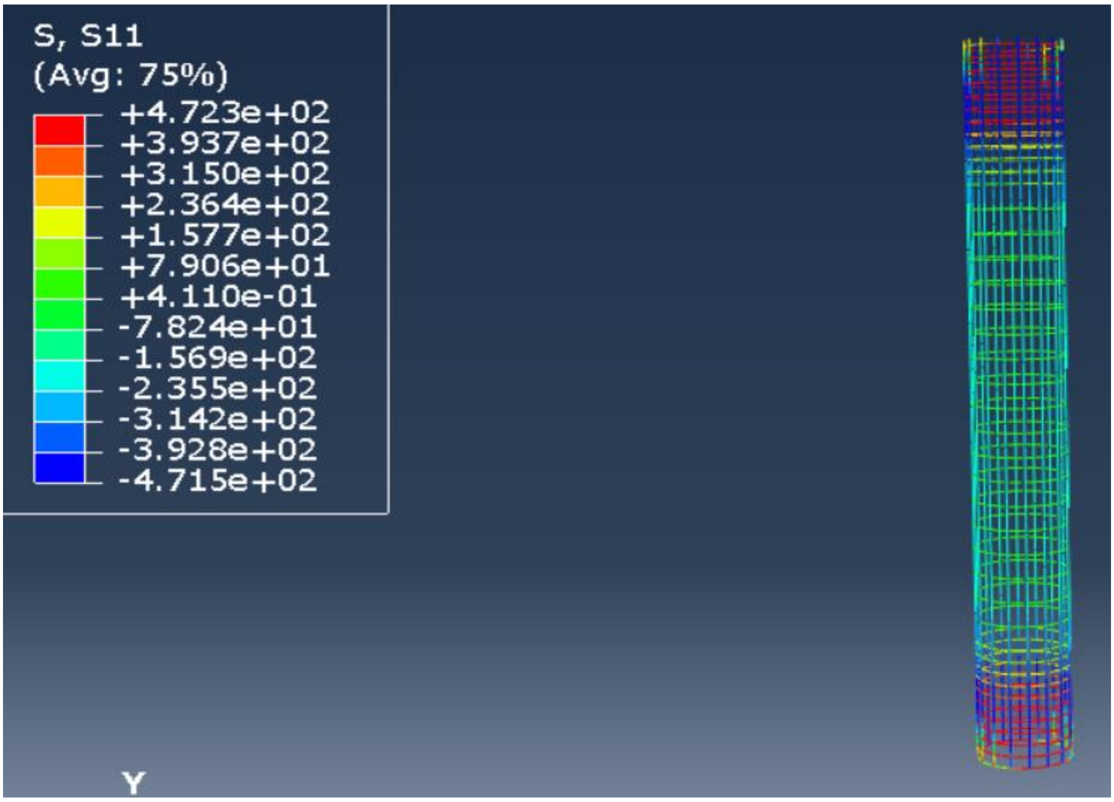


Figure 44:CL28 Steel normal strain at ultimate crack

Based on the results shown in chapter 4 after using finite element method and after comparing the load-displacement curves of models with the strength of concert and as we observe in the figure below that the change in strength of concert significantly affect the increase in loads and displacements, We note that short column (24 Mpa) sample from gave results is more then the short column (24Mpa) with increasing on load by 13% and displacement by 7.7% on other hand long column carves show the increasing strength of concert from 24 to 28 (Map) increased the amount of load by 2% and derezzed displacement by 5.8%.

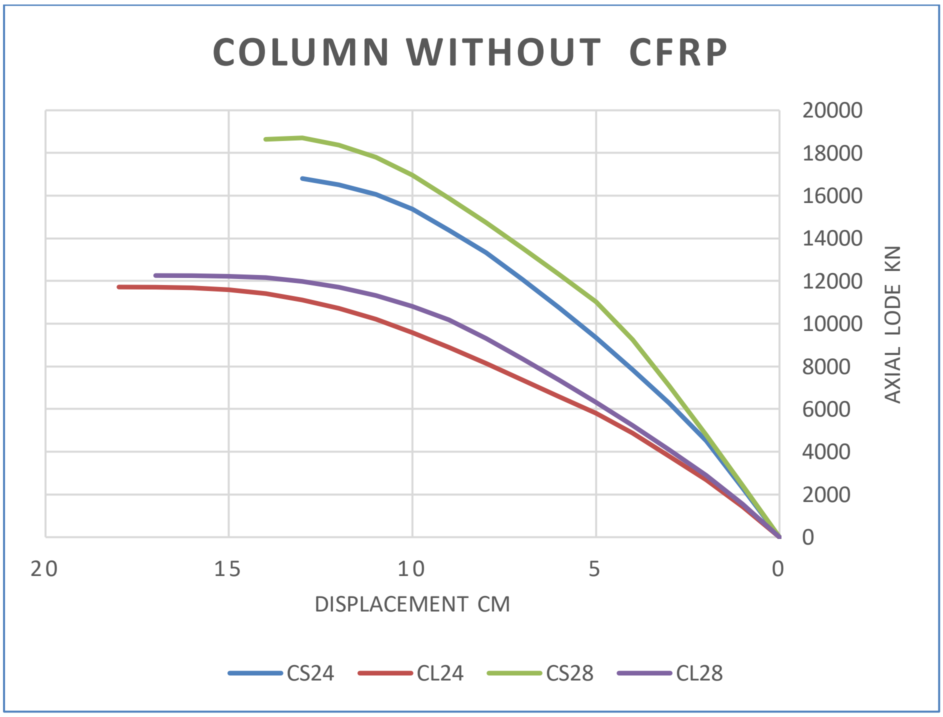


Figure 45: load-displacement curve- for change strength of concrete

4- 2: withte and without CFRP

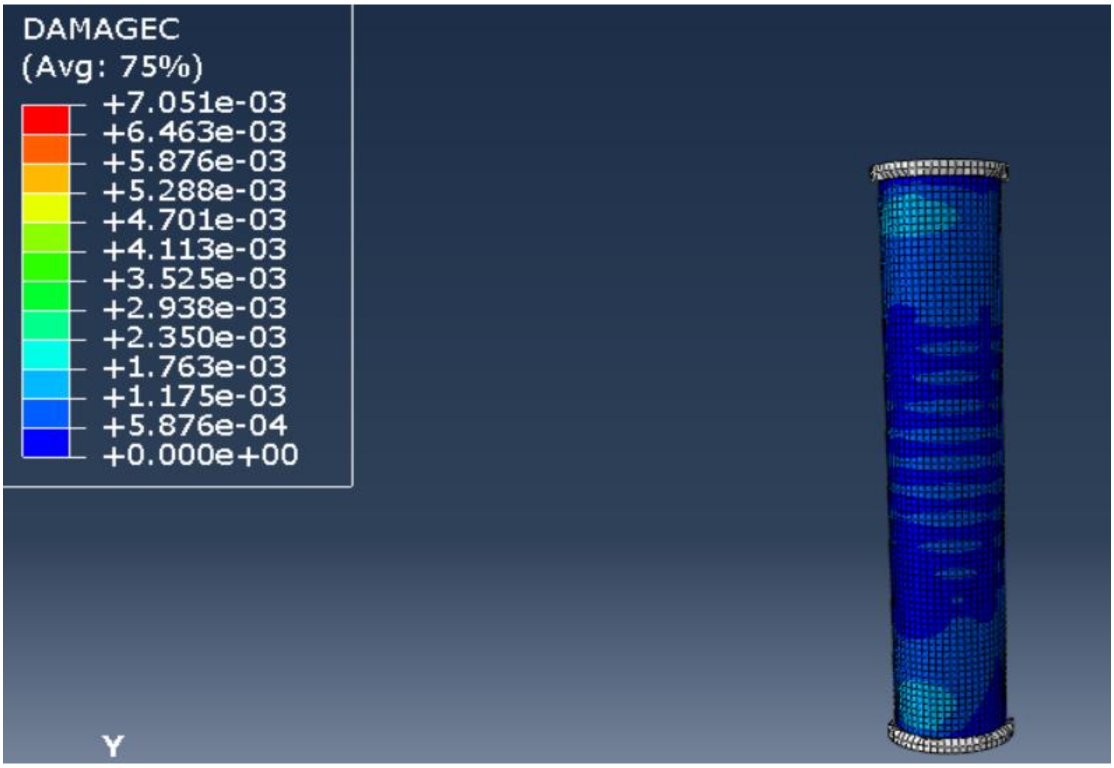


Figure 46:CS24 FH- damage comparison -First crack

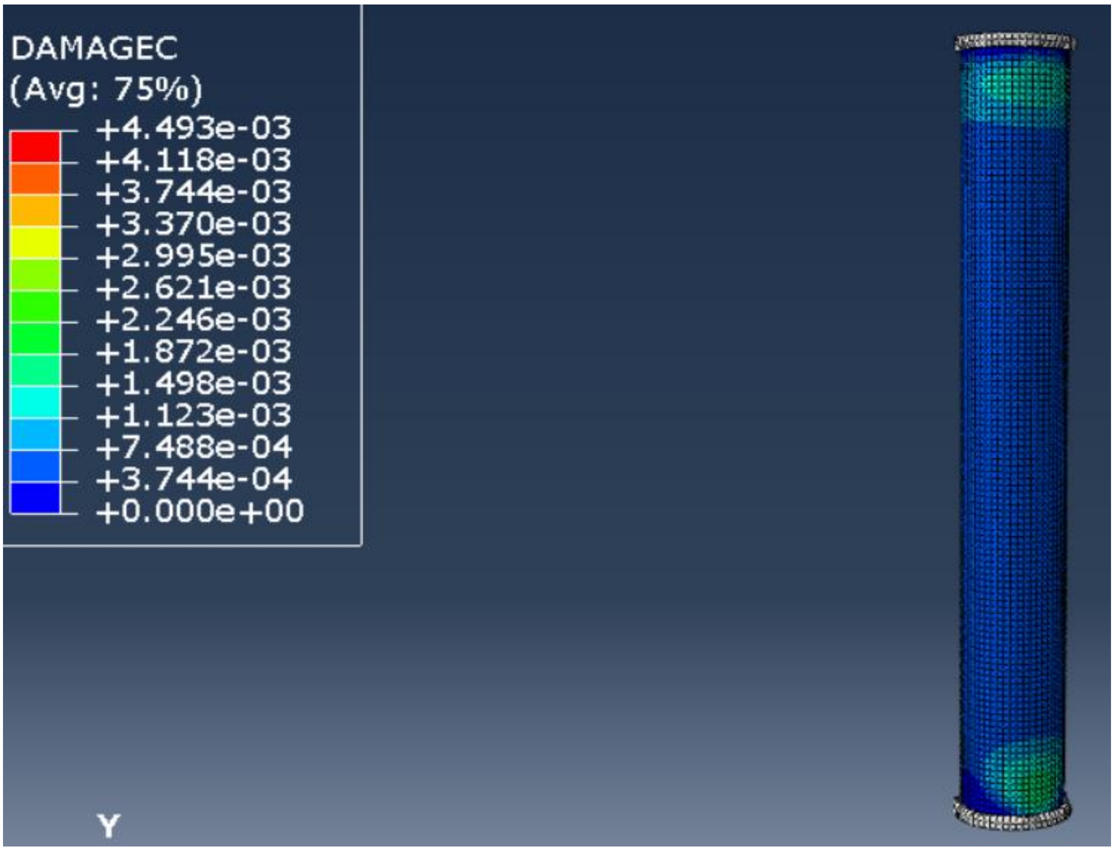


Figure 47:CL24 FH- damage comparison -First crack

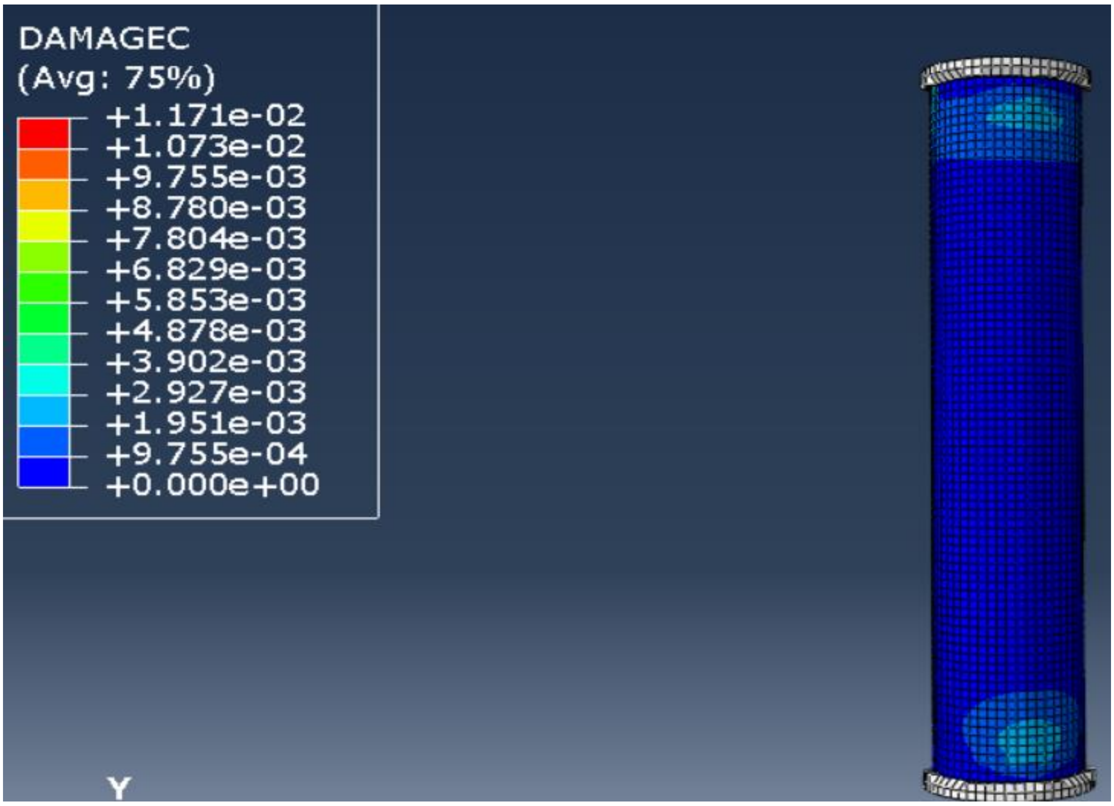


Figure48 :CS28 FH- damage comparison -First crack

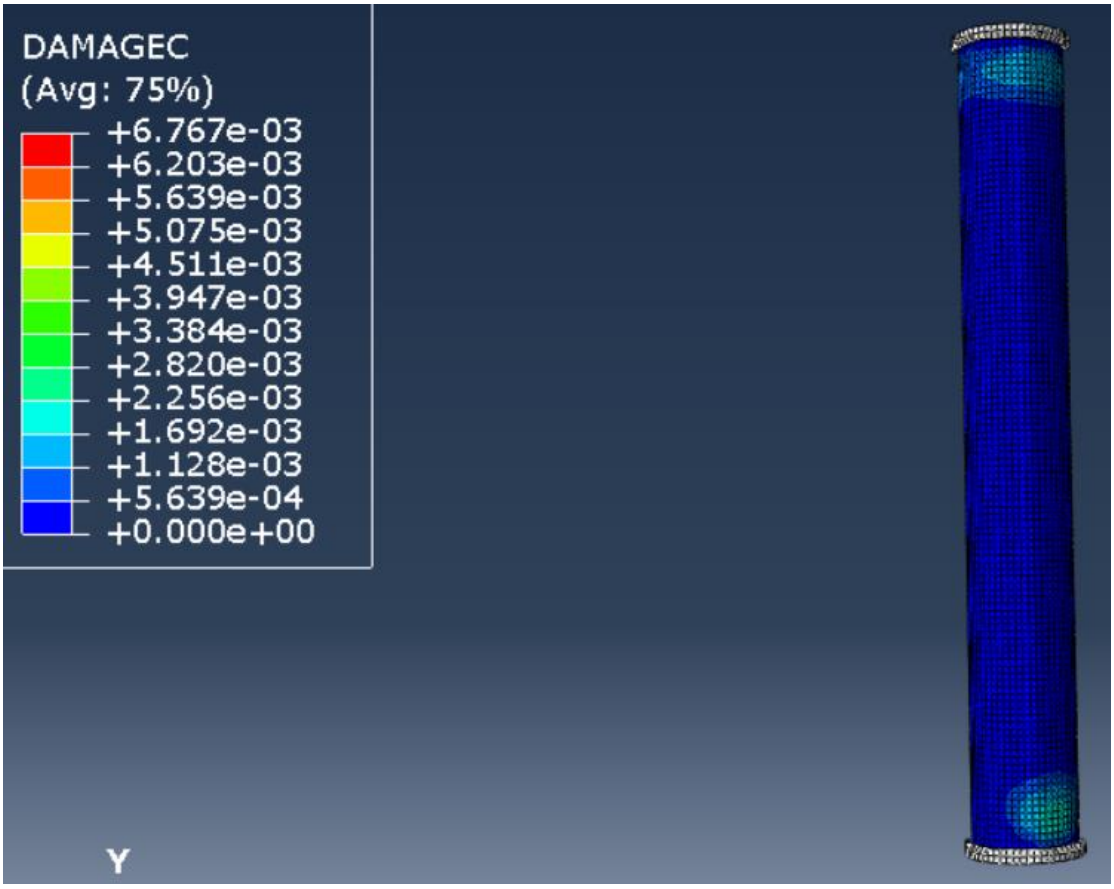


Figure 49:CL28 FH- damage comparison -First crack

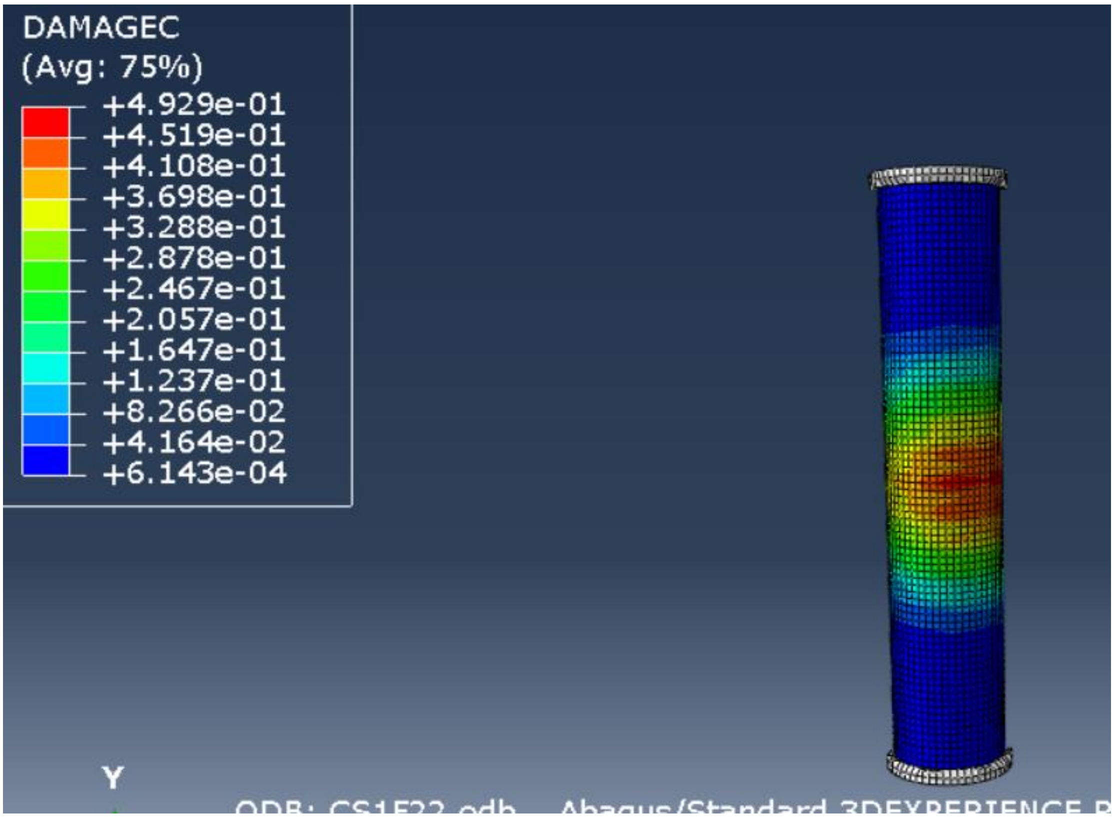


Figure 50:CS24 FH- damage comparison - at ultimate crack

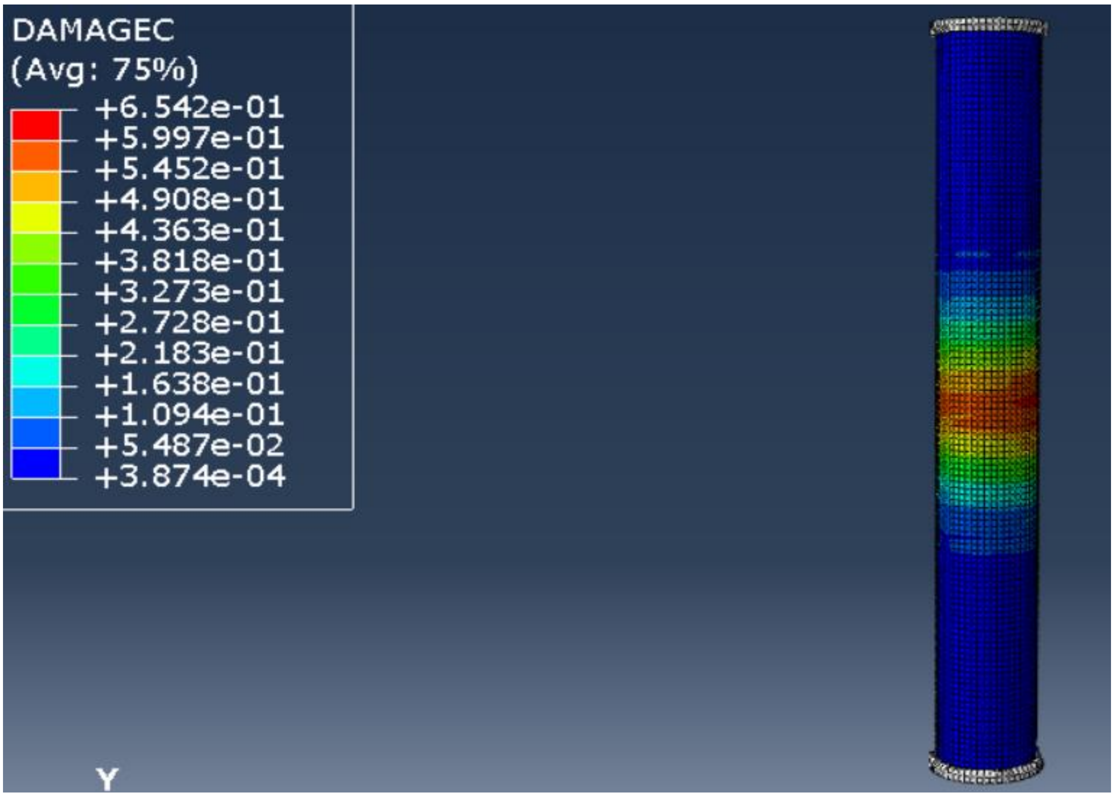


Figure51 ::CL24 FH- damage comparison - at ultimate crack

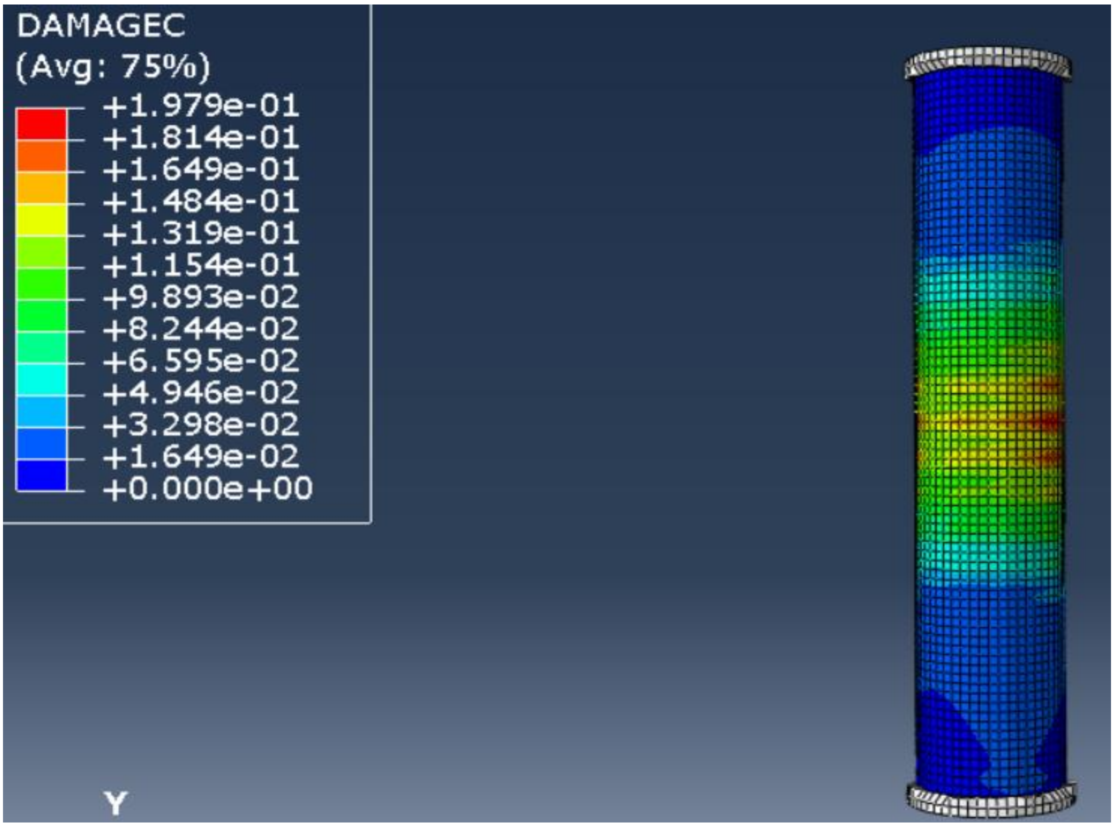


Figure::52 : CS 28 FH- damage comparison - at ultimate crack

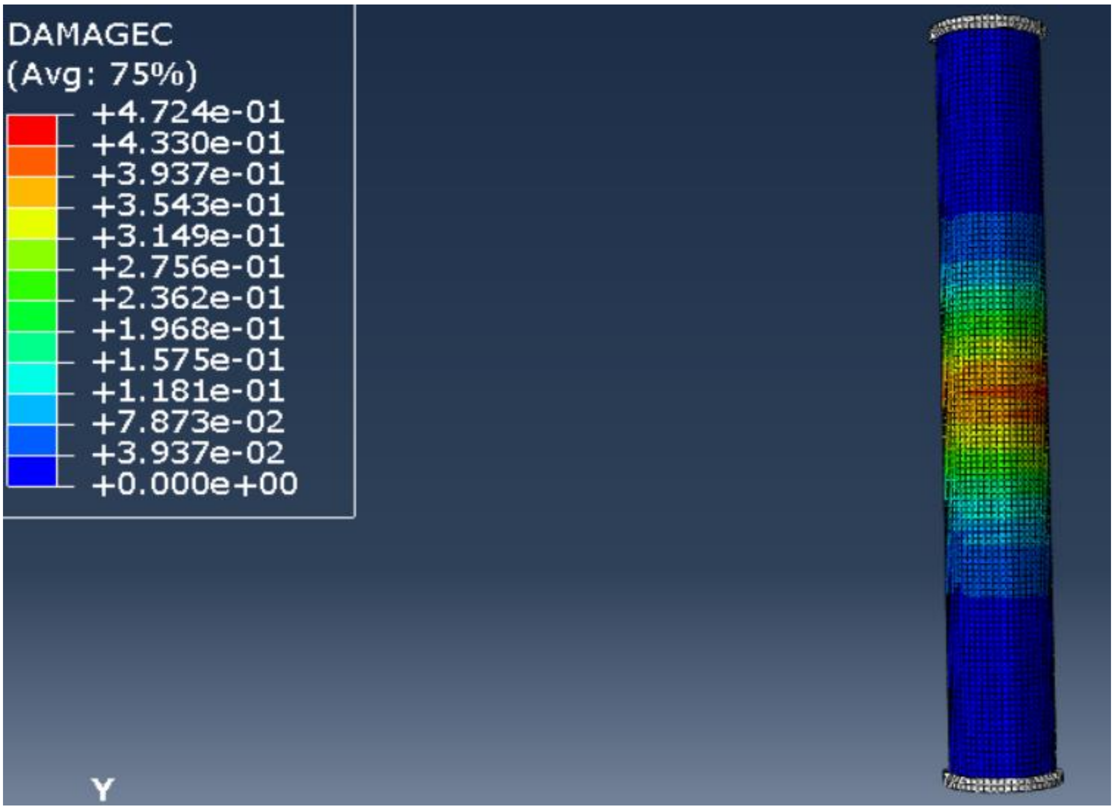


Figure53 :CL28 FH- damage comparison - at ultimate crack

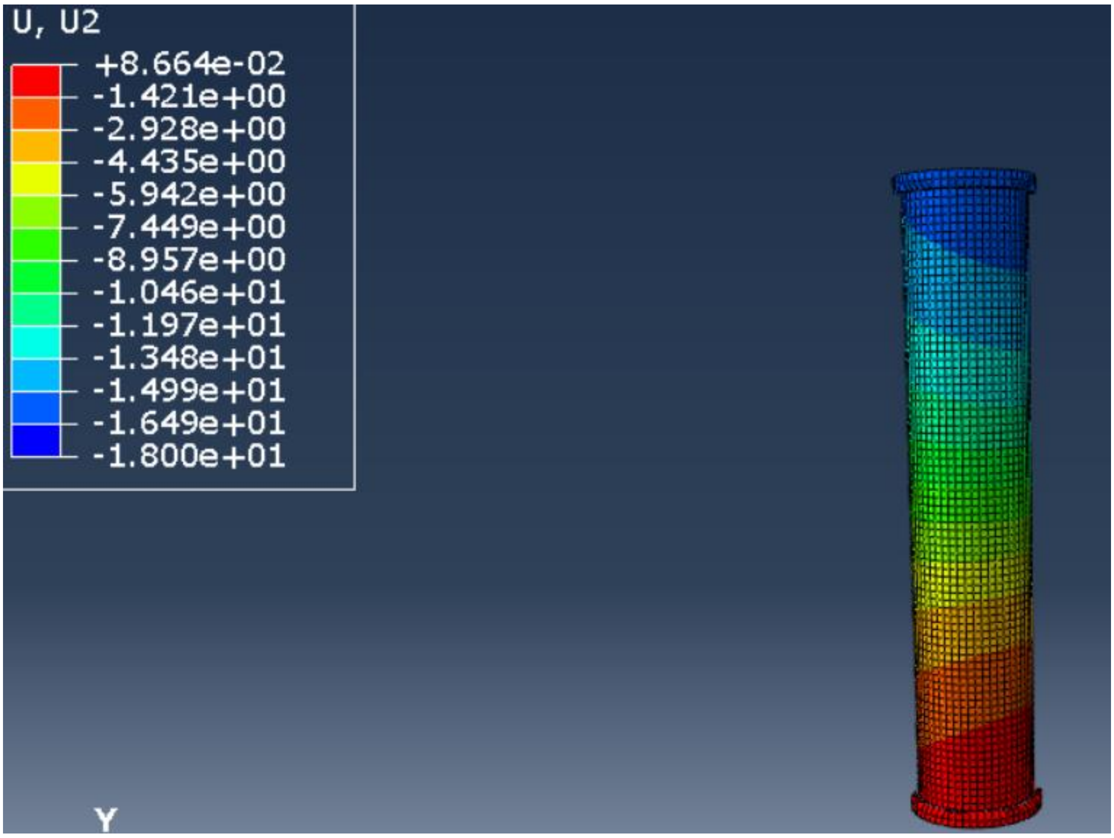


Figure 54:CS24 FH- U2 (vertical displacement) at ultimate

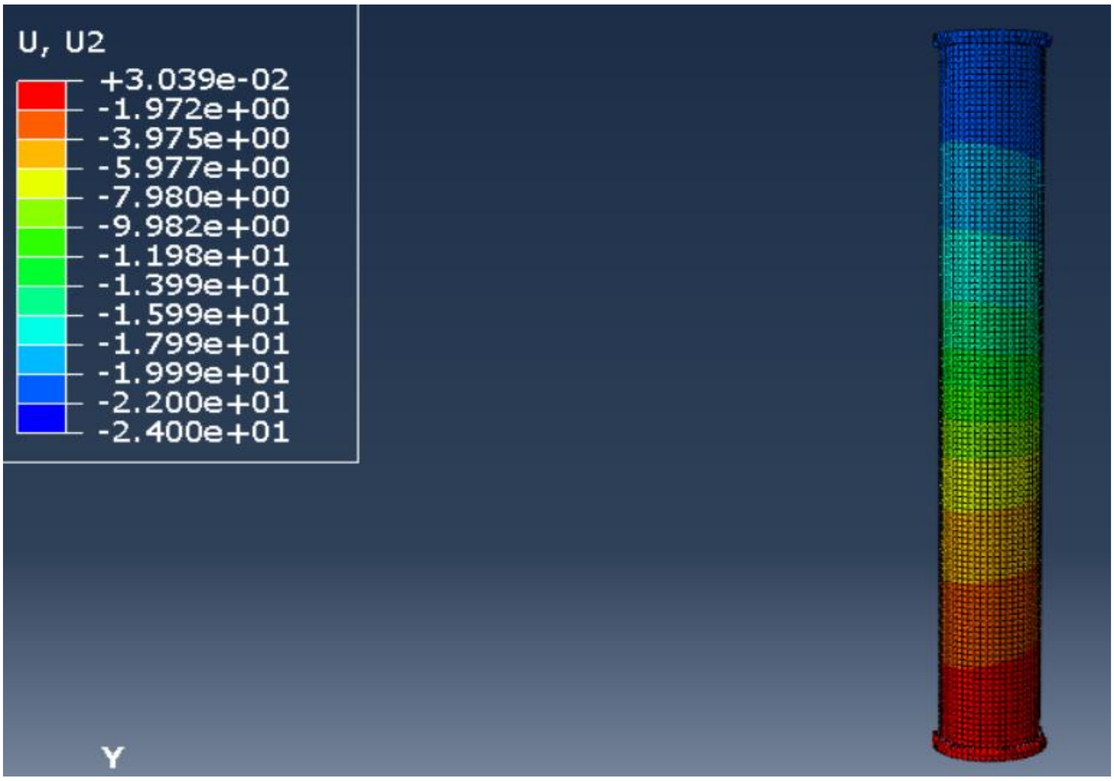


Figure55 :CL24 FH- U2 (vertical displacement) at ultimate

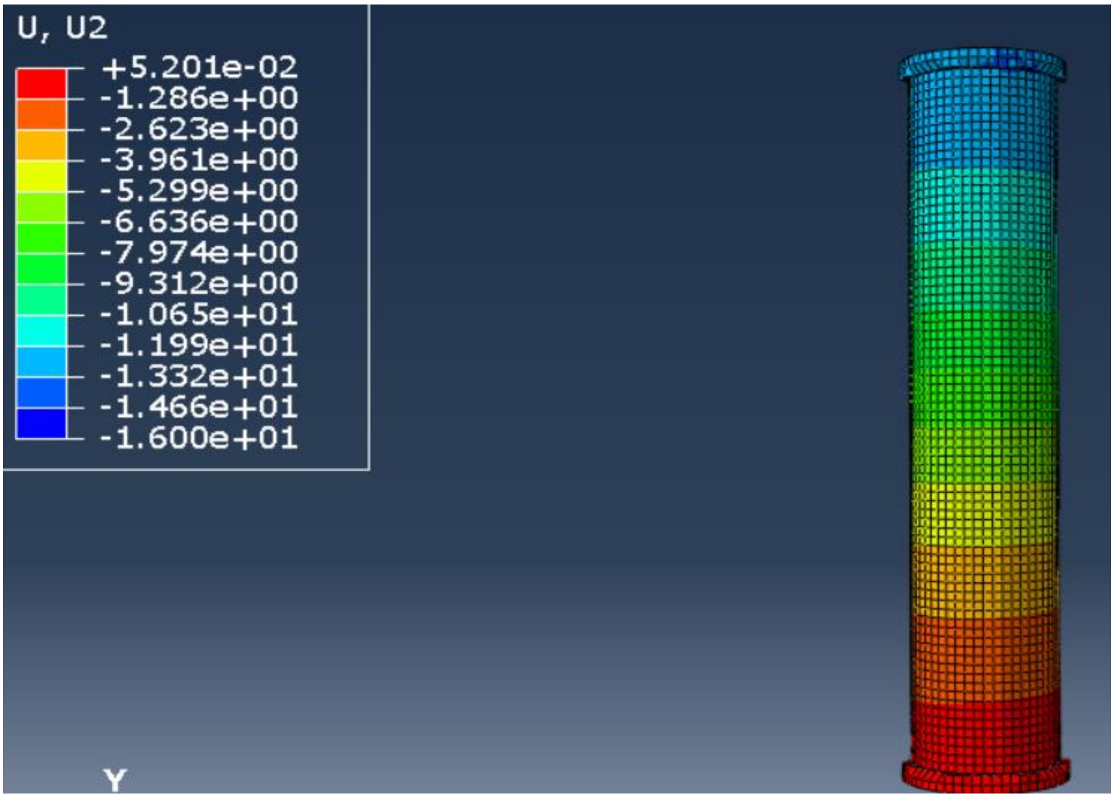


Figure56 :CS28 FH- U2 (vertical displacement) at ultimate

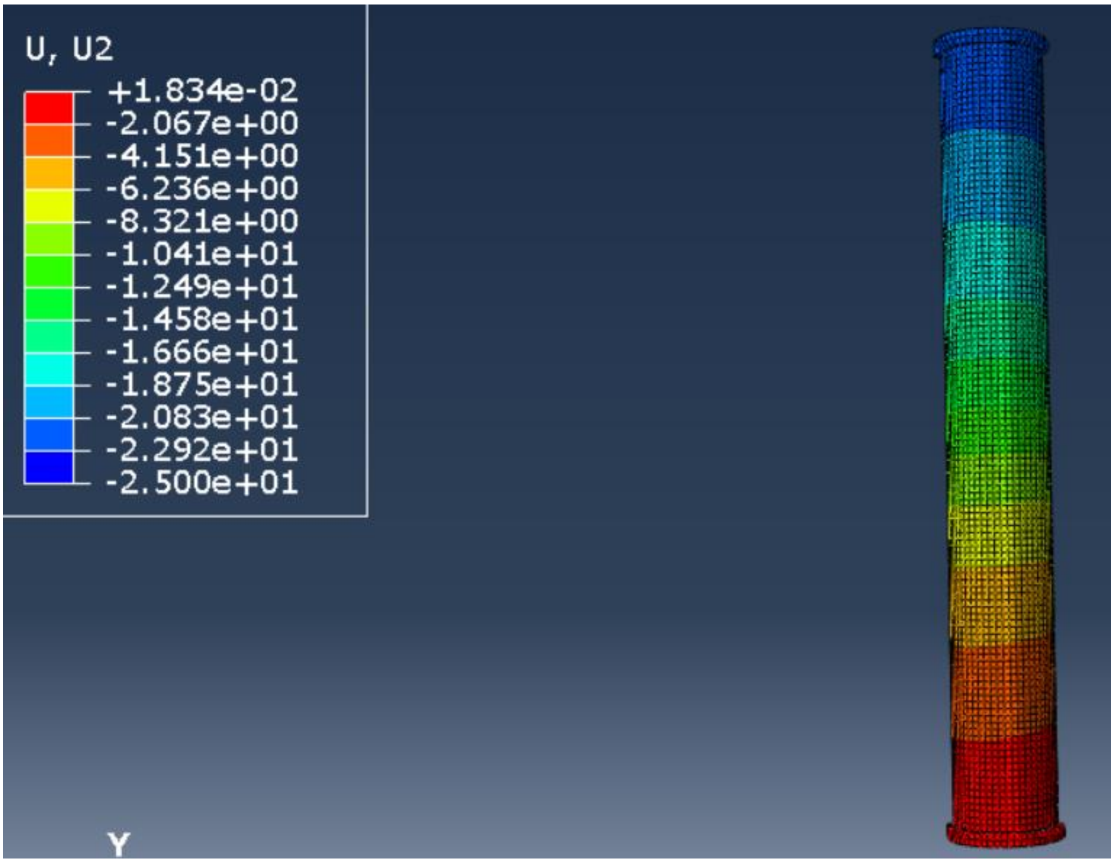


Figure57 :CL28 FH- U2 (vertical displacement) at ultimate

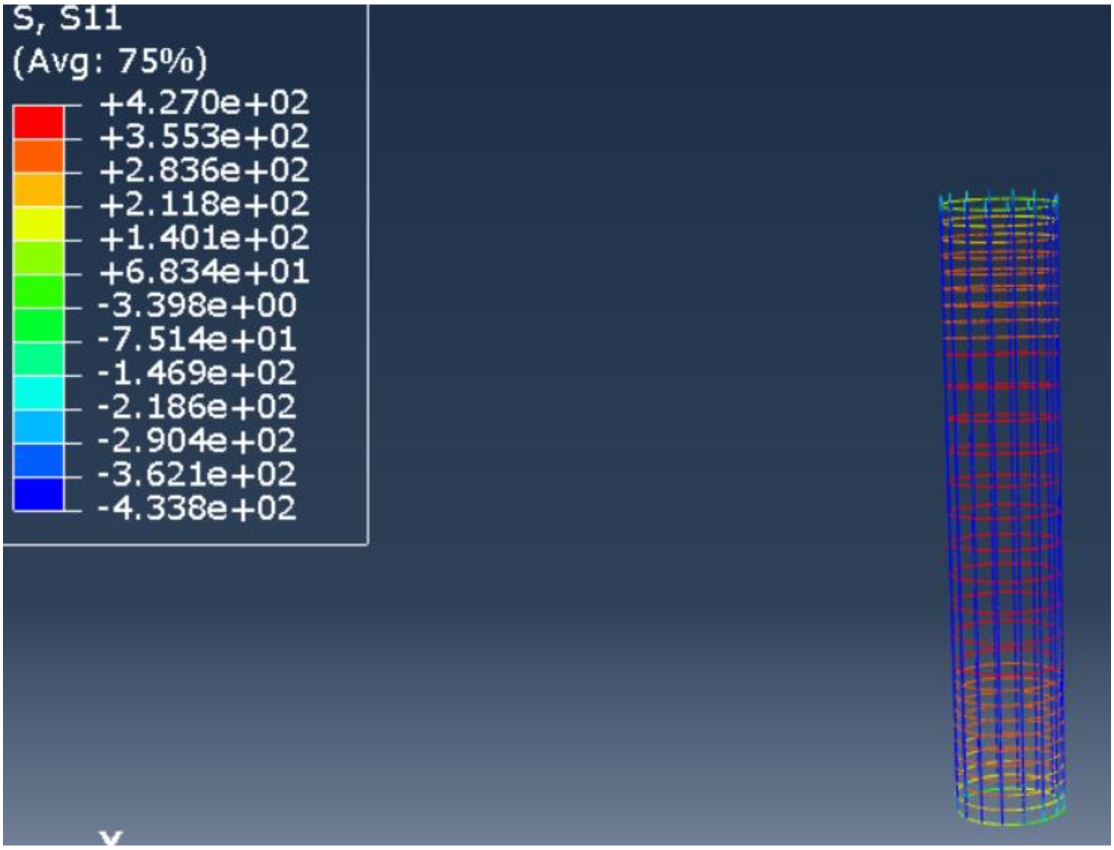


Figure 58:CS24 FH- Steel normal strain at ultimate crack

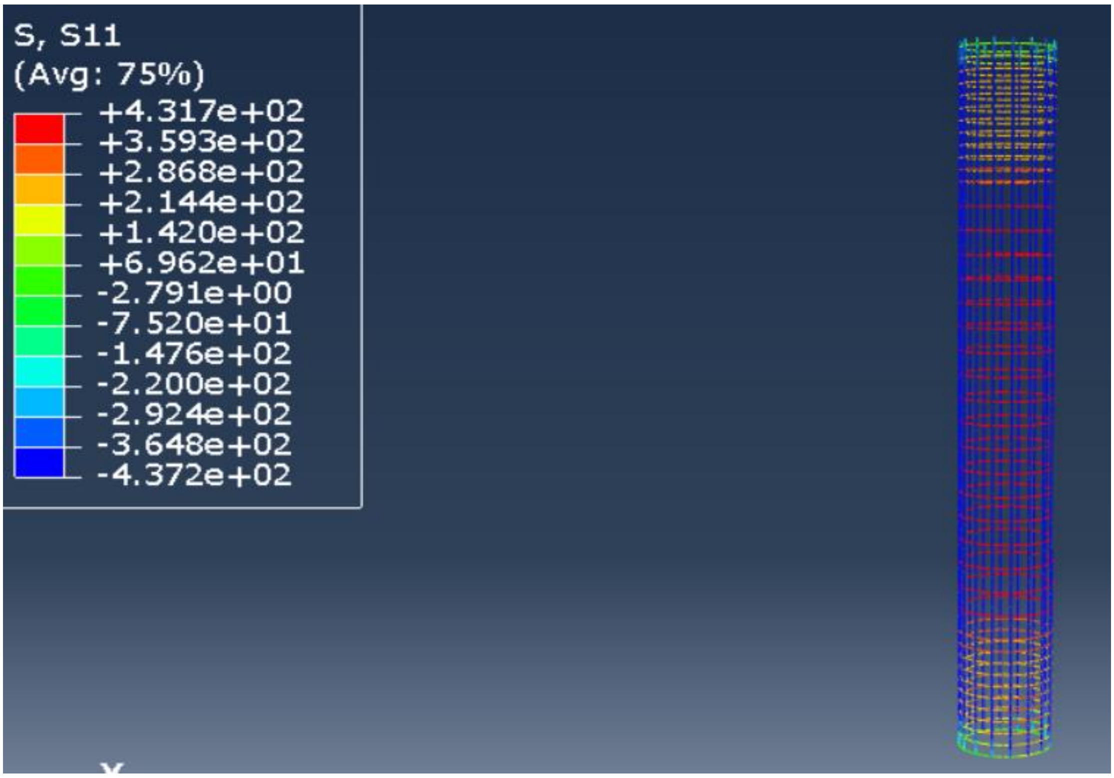


Figure 59:CL24 FH- Steel normal strain at ultimate crack

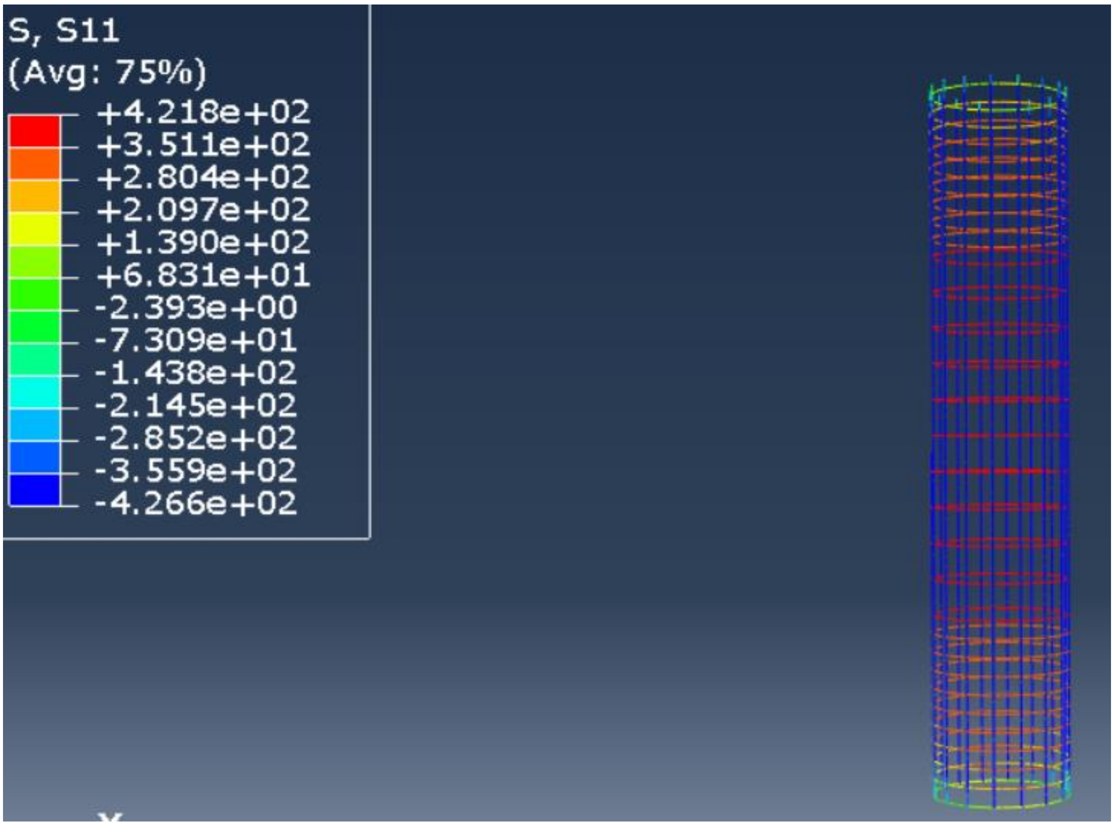


Figure 60:CS28 FH- Steel normal strain at ultimate crack

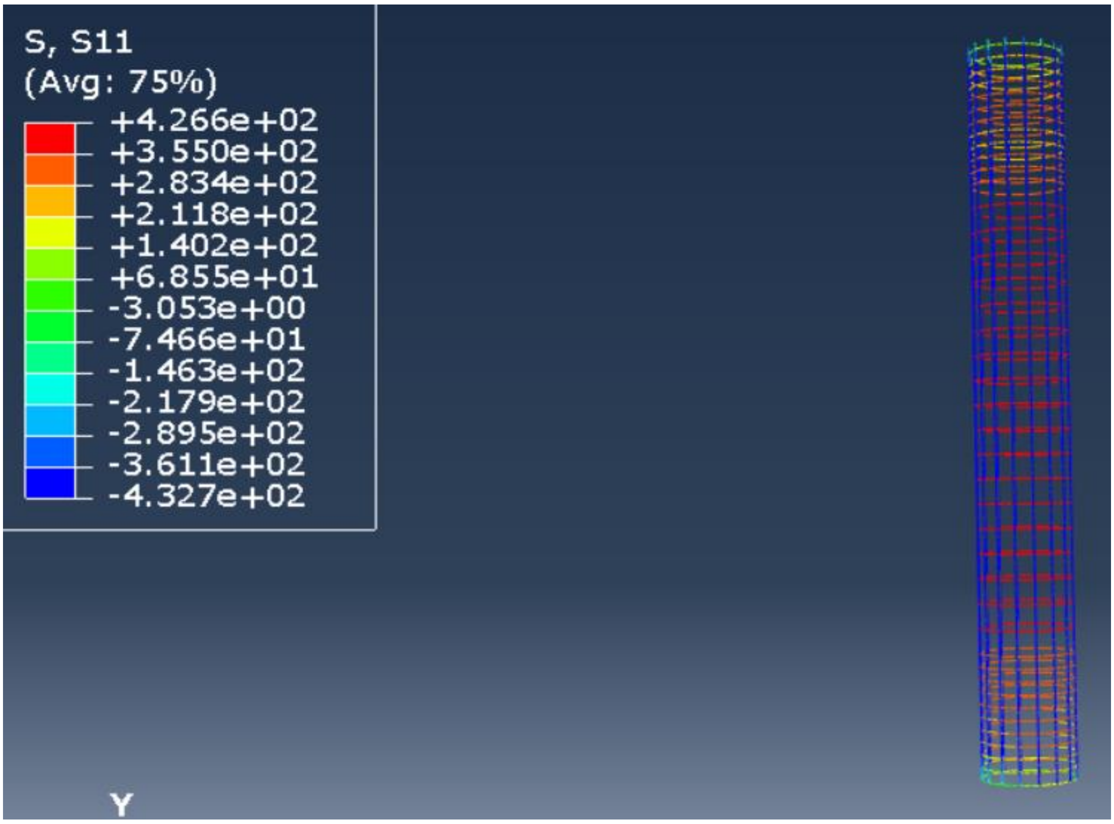


Figure 61:CL28 FH- Steel normal strain at ultimate crack

Based on the results shown in chapter 4 after using finite element method and after comparing the load-displacement curves of models with the strength of concert and CFRP and as we observe in the figure below that the CFRP significantly affect the increase in loads and displacements, We note that short column (24 Mpa) with CFRP sample from gave results increasing on load by 17.2% and displacement by 23% and the same column (28Mpa) from gave results increasing on load by 15.5% and displacement by 14% on other hand long column carves(24 Mpa) show the using CFRP increased the amount of load by 66.6% and displacement by 30% and the same column (28 Mpa) increasing on load by 77.2% and displacement by 29%.

..

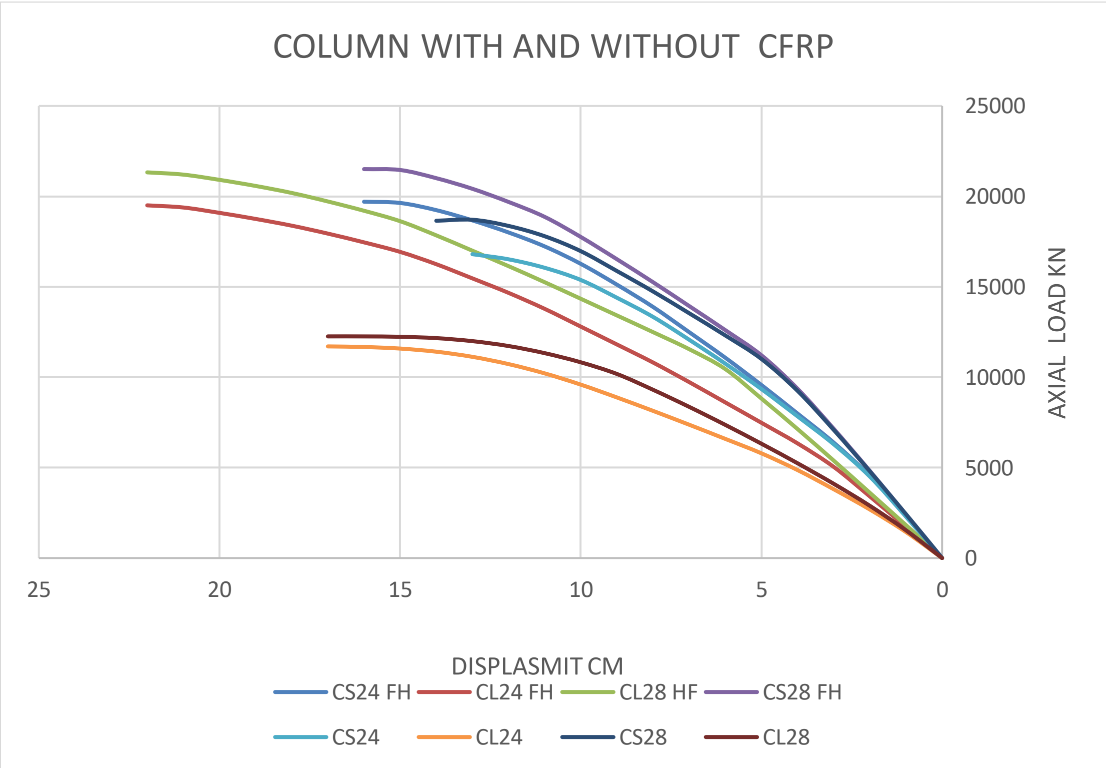


Figure 62: load-displacement curve- for change strength of concrete and with and without CFRP

4- 3: Orientation of CFRP

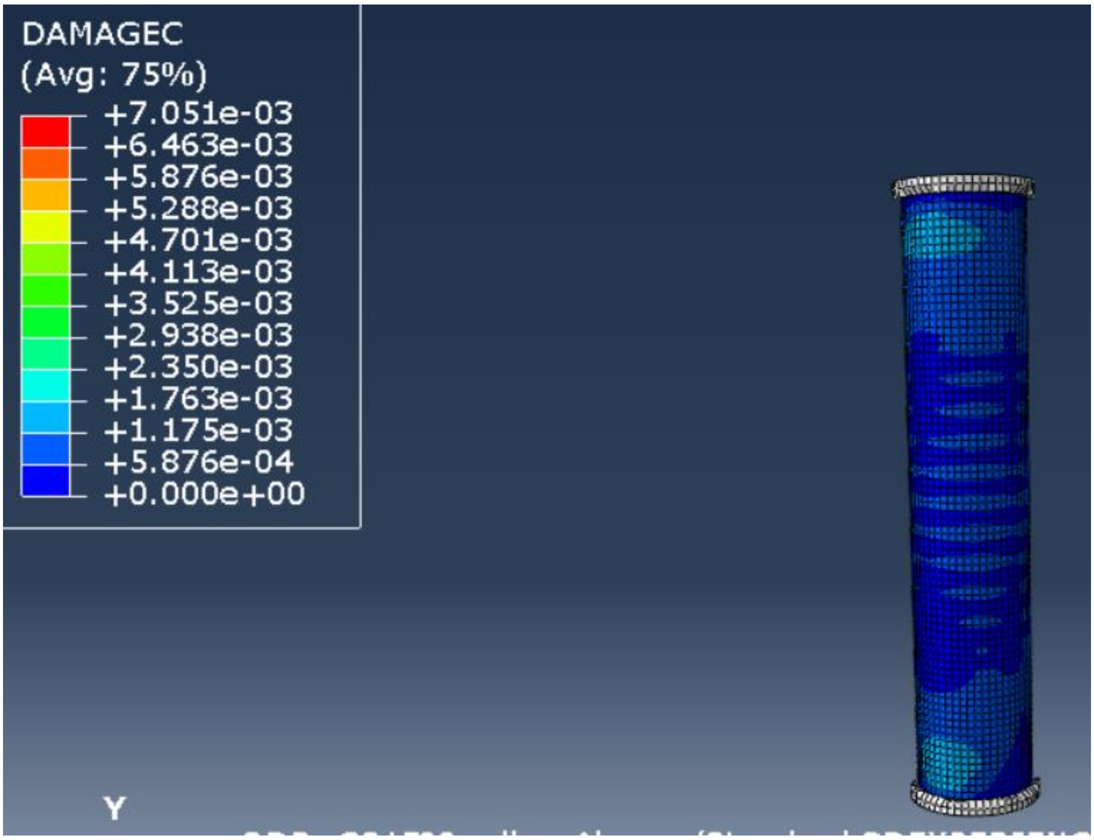


Figure 63::CS24 FV- damage comparison -First crack

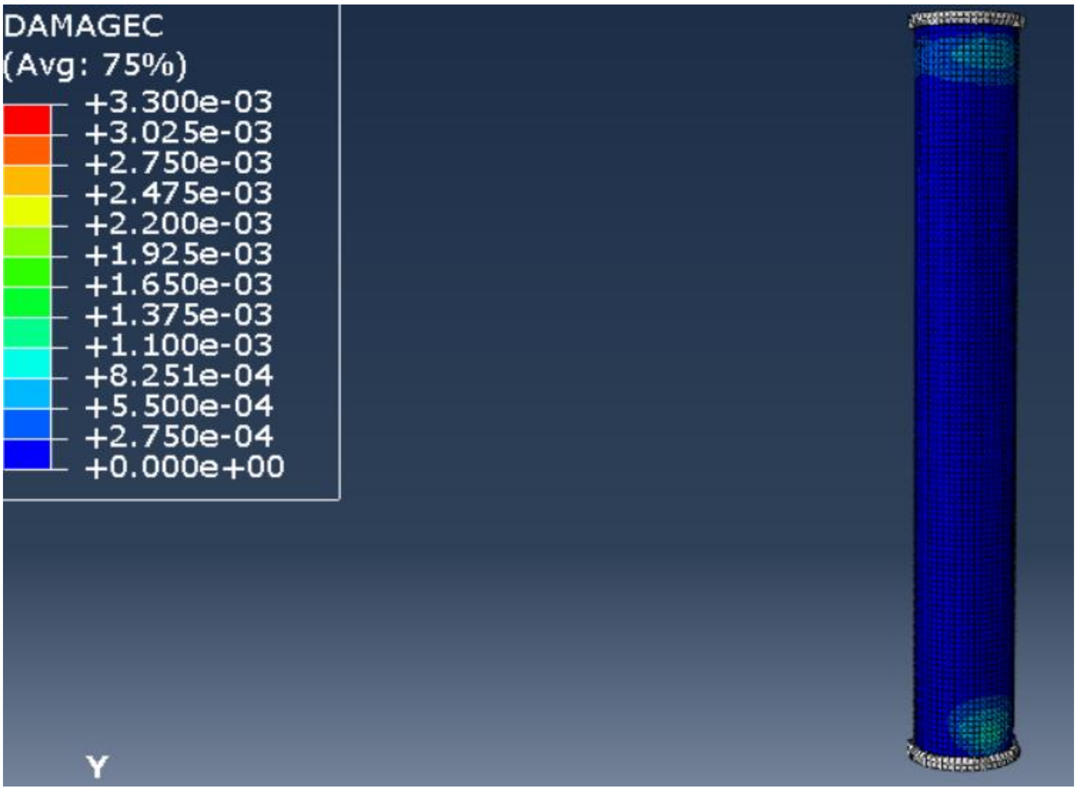


Figure64 :CL24 FV- damage comparison -First crack

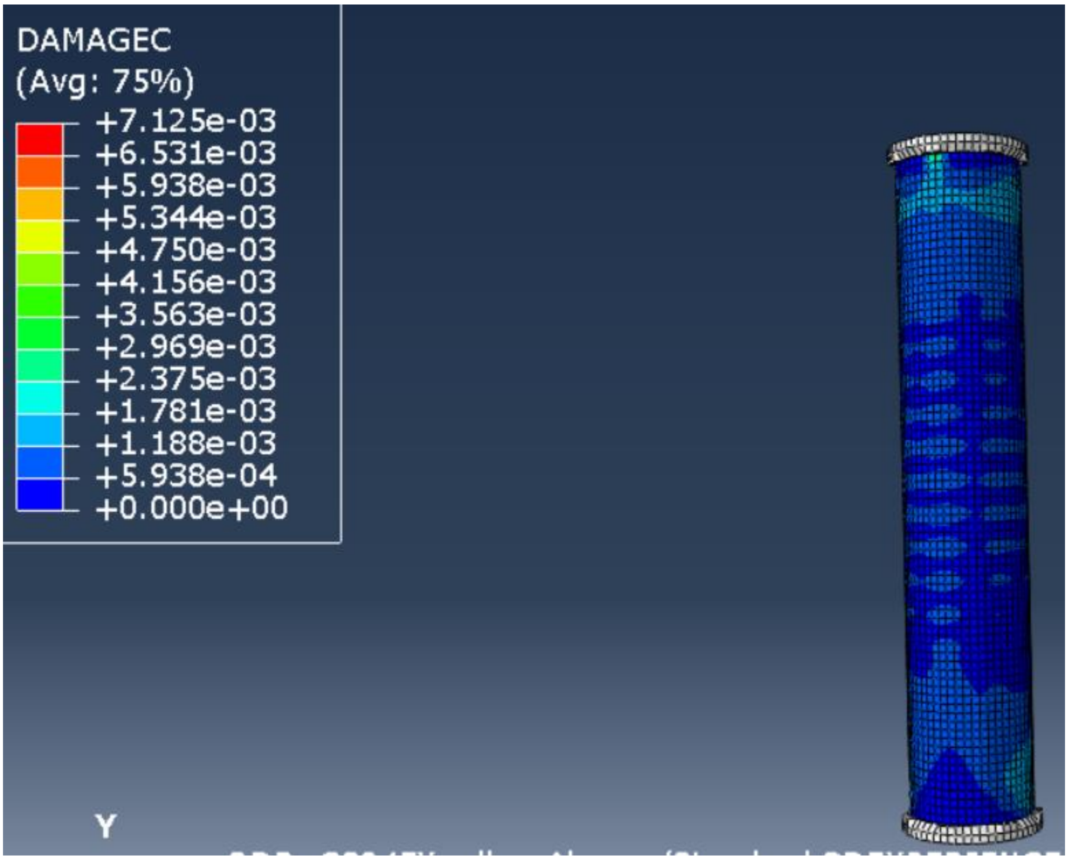


Figure:65 :CS28 FV- damage comparison -First crack

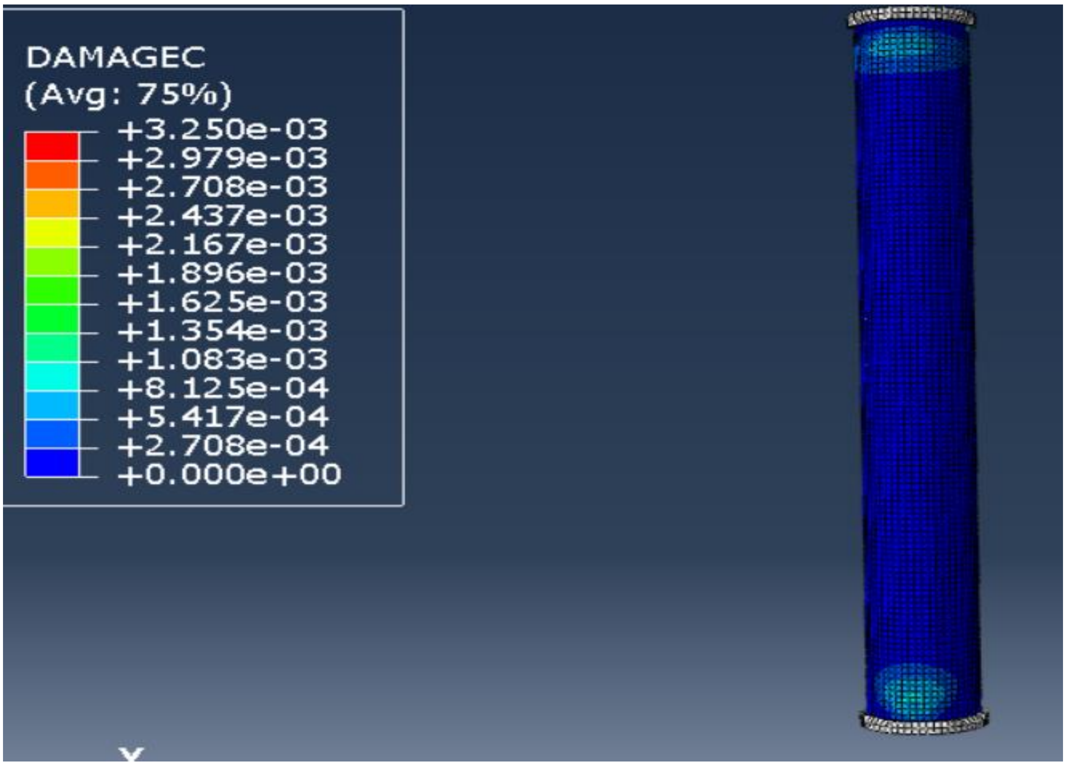


Figure66 :CL28 FV- damage comparison -First crack

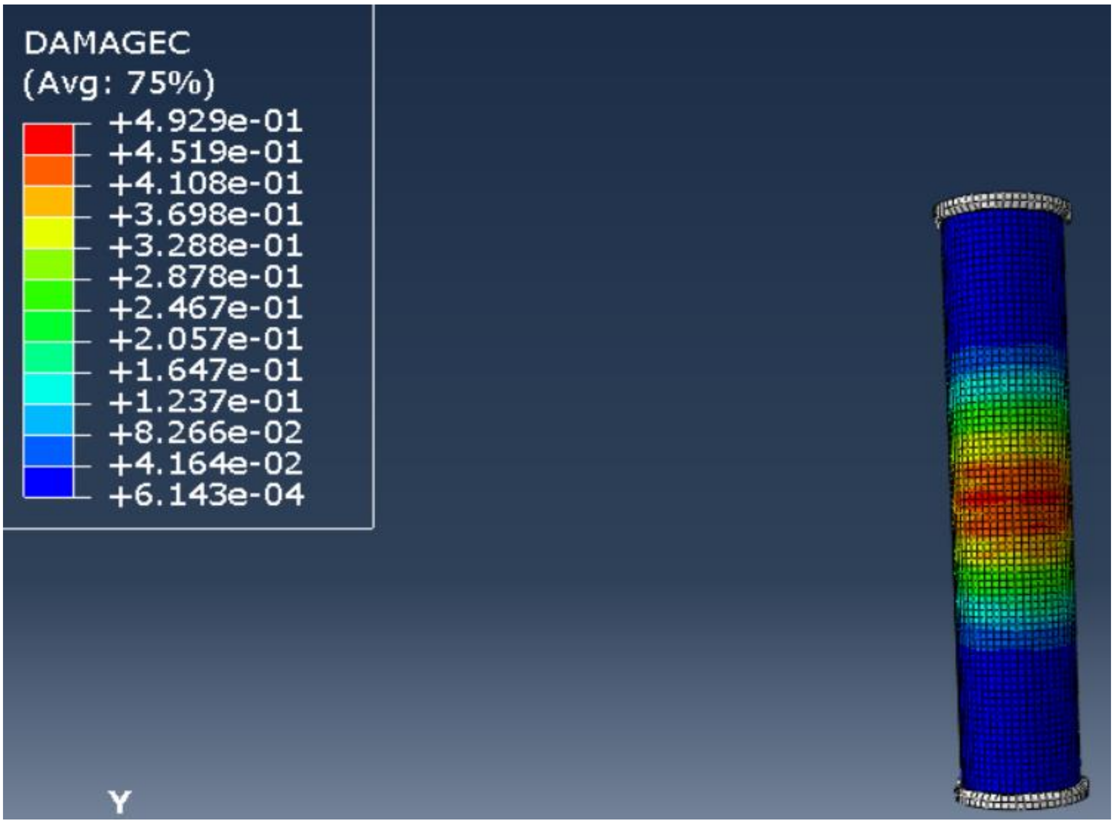


Figure67 ::CS24 FV- damage comparison - at ultimate crack

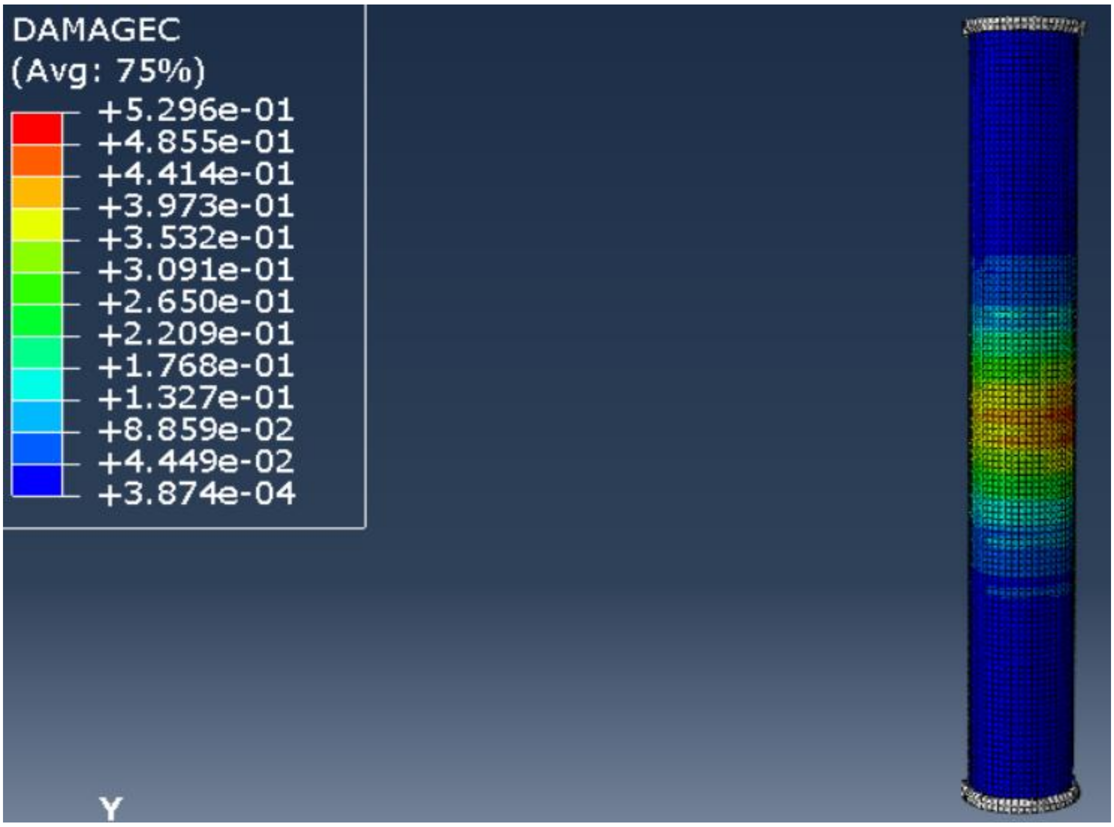


Figure68 ::CL24 FV- damage comparison - at ultimate crack

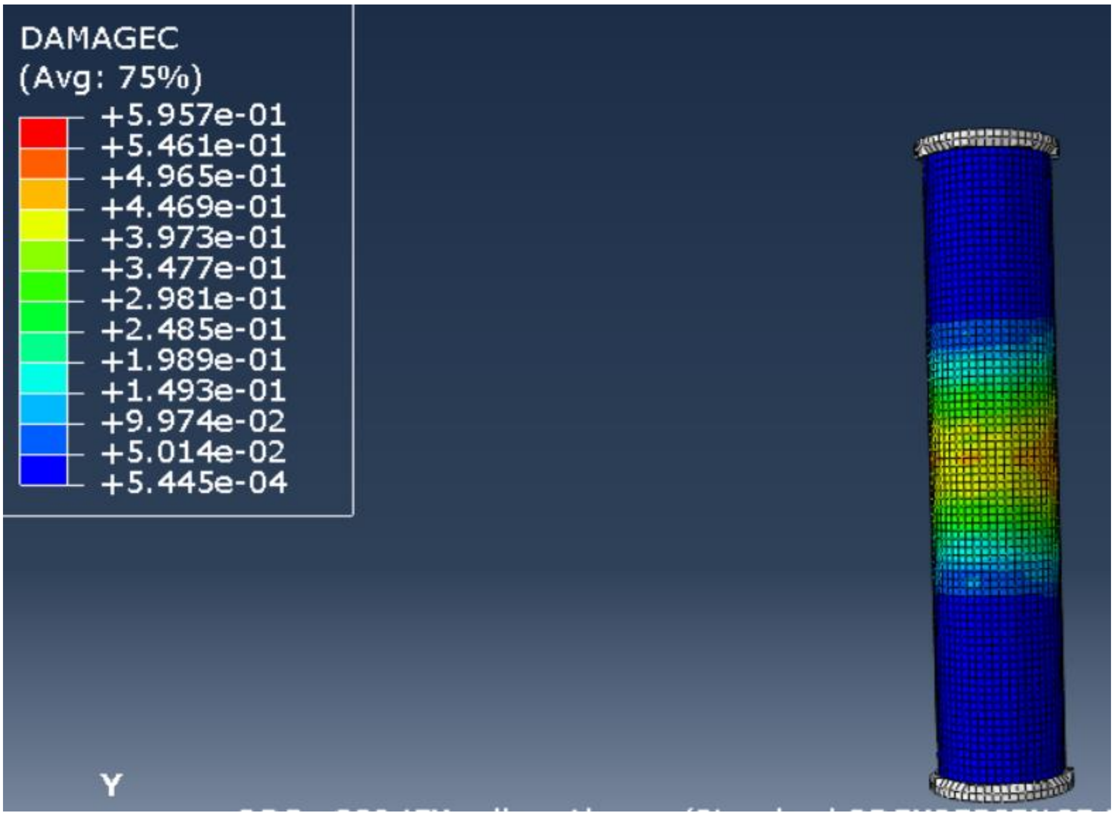


Figure69 :CS28 FV- damage comparison - at ultimate crack

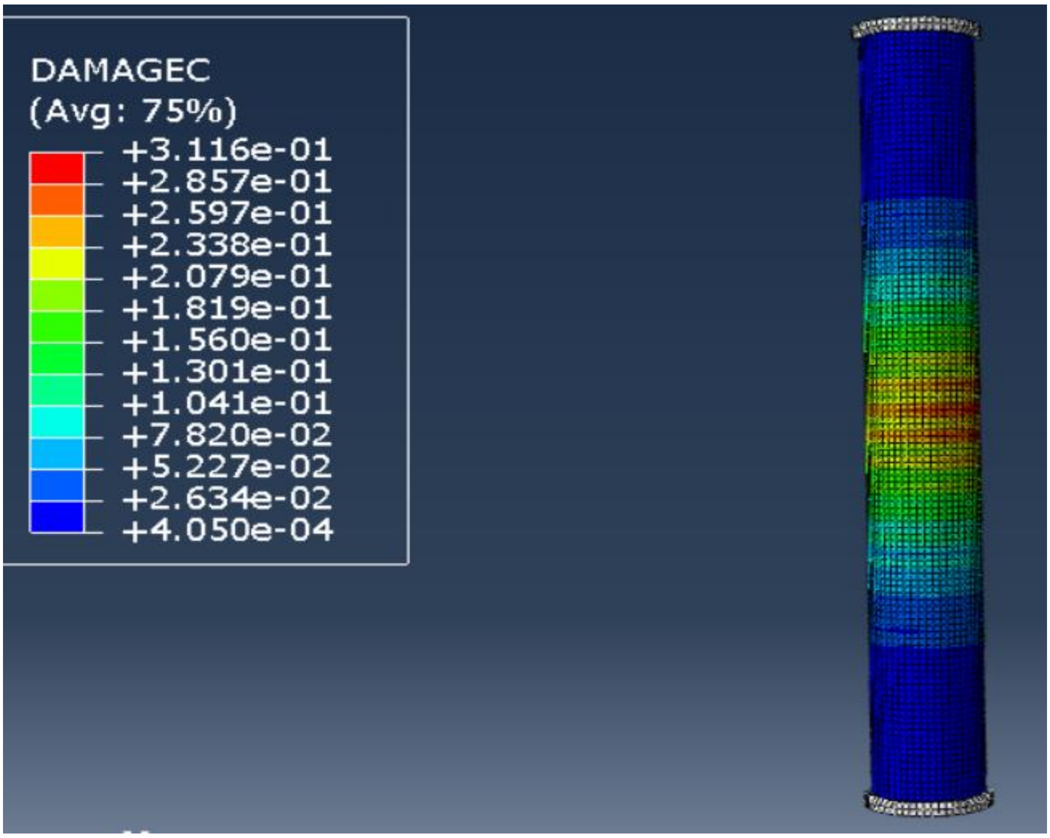


Figure 70 ::CL28 FV- damage comparison - at ultimate crack

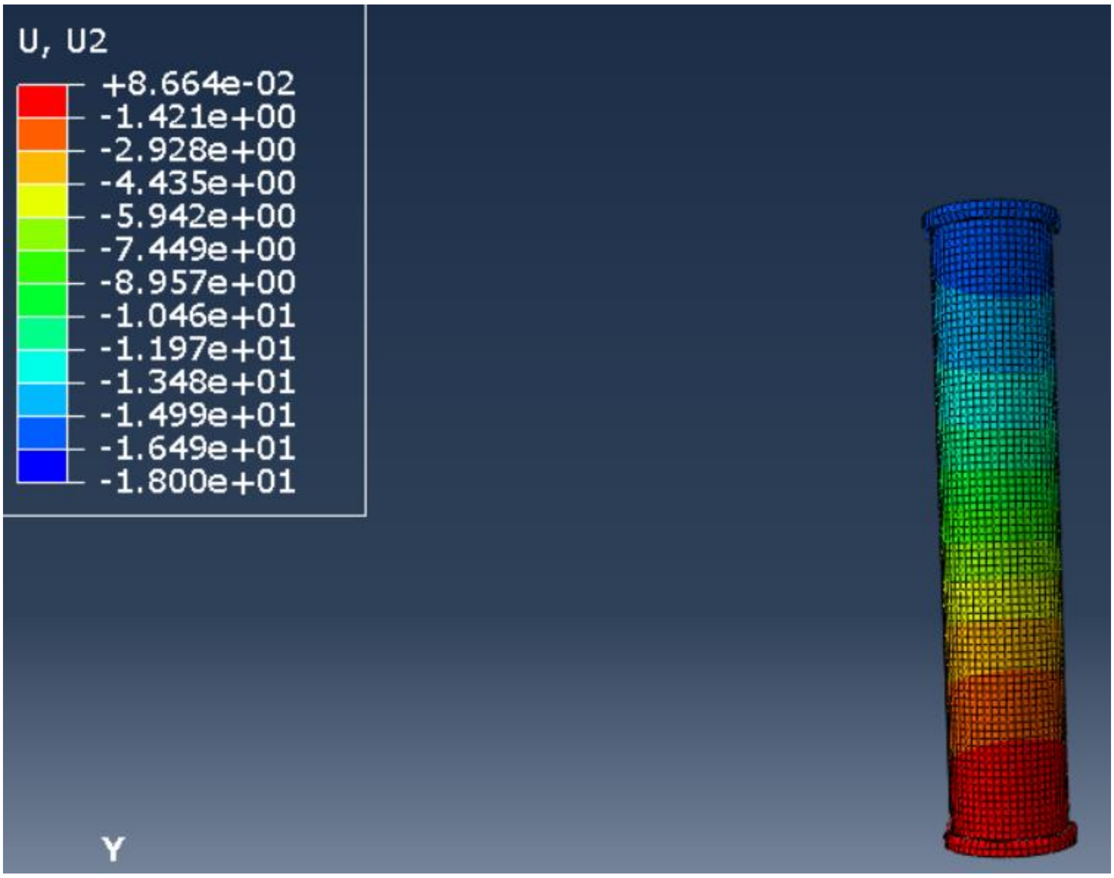


Figure71 :CS24 FV- U2 (vertical displacement) at ultimate

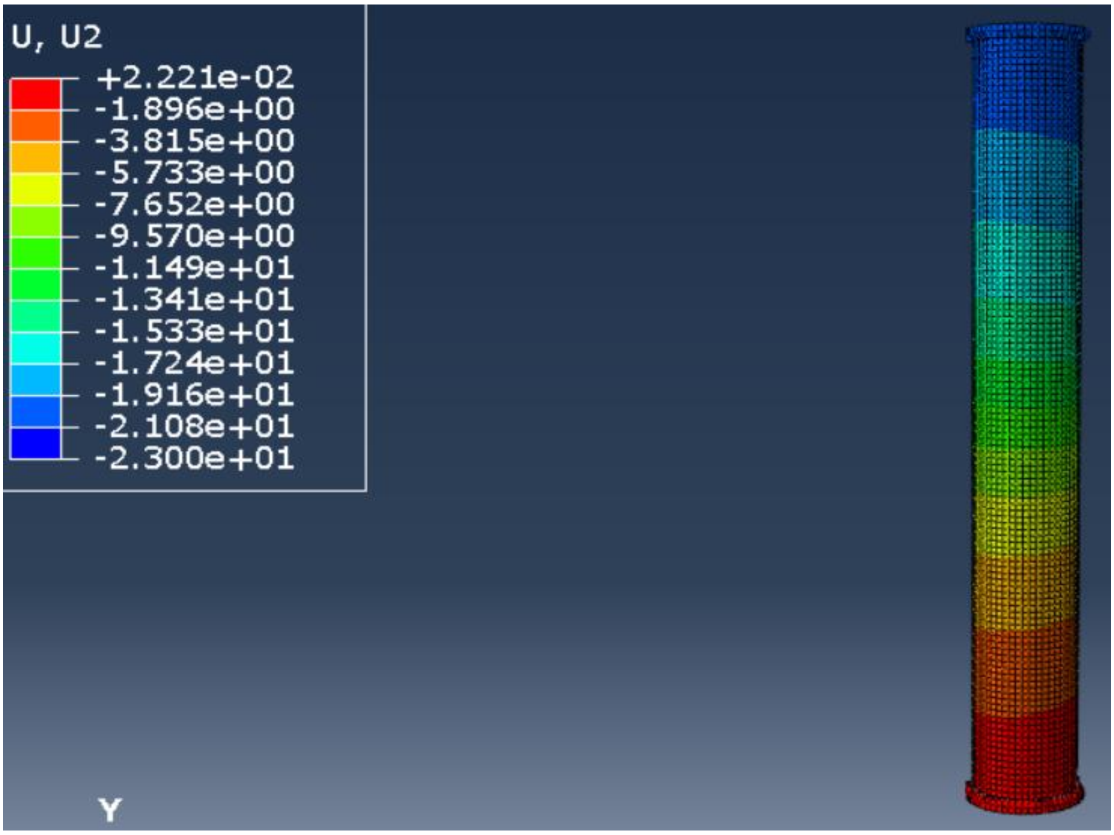


Figure72 :CL24 FV- U2 (vertical displacement) at ultimate

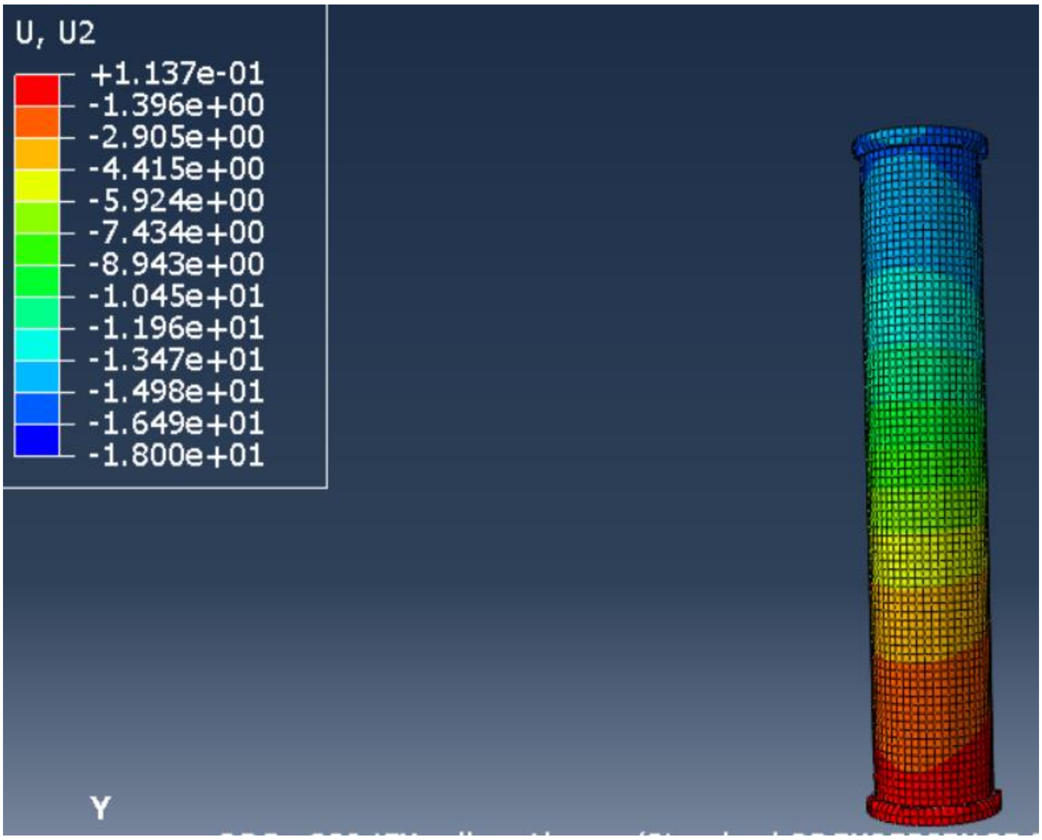


Figure73 :CS28 FV- U2 (vertical displacement) at ultimate

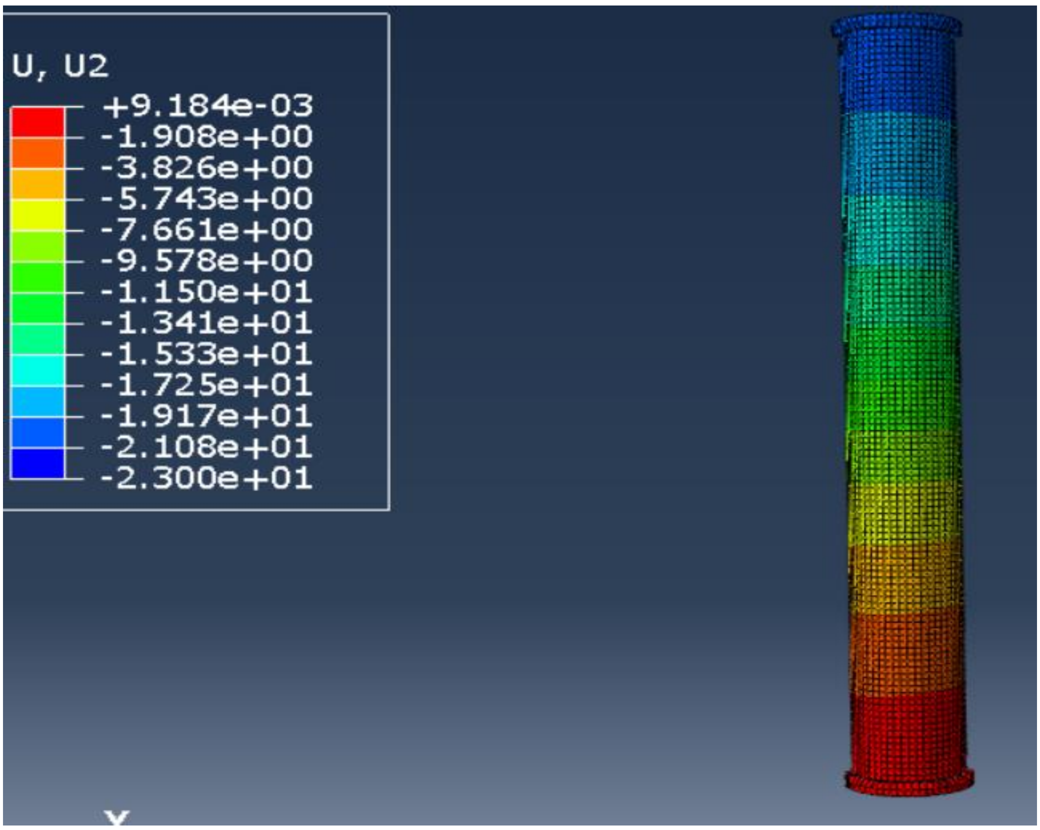


Figure 74 :CL28 FV- U2 (vertical displacement) at ultimate

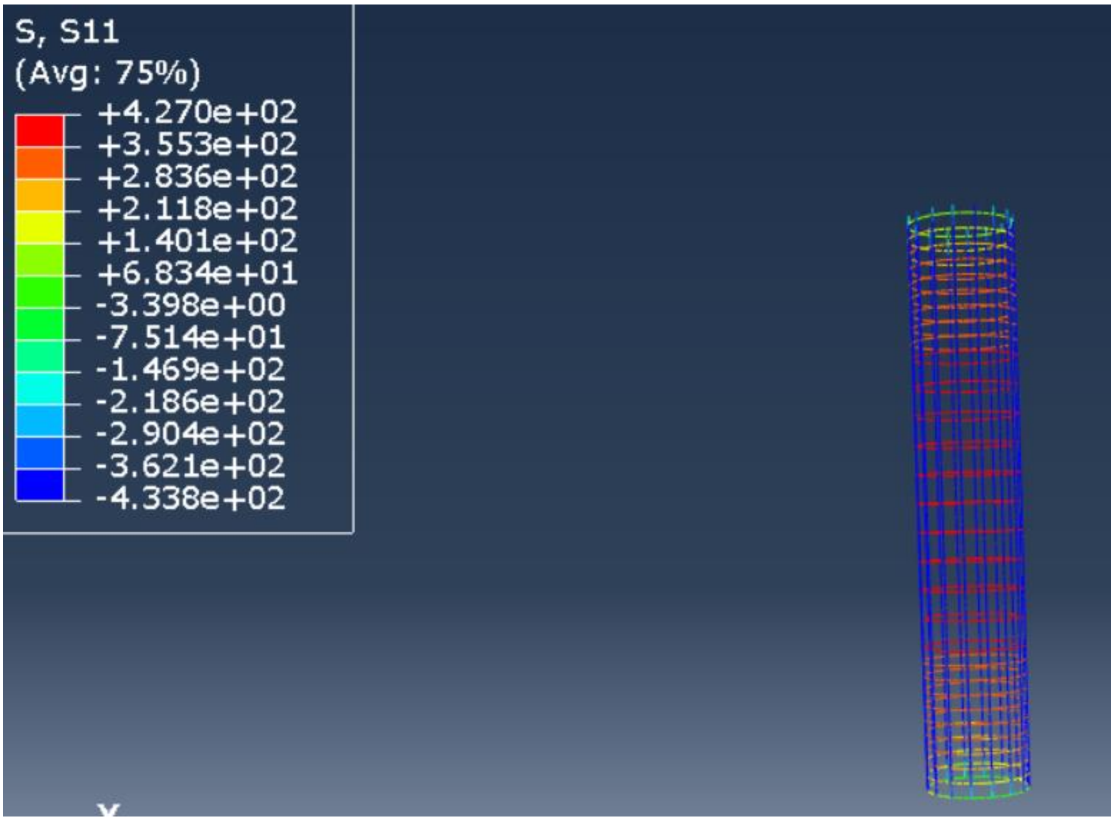


Figure 75:CS24 FV- Steel normal strain at ultimate crack

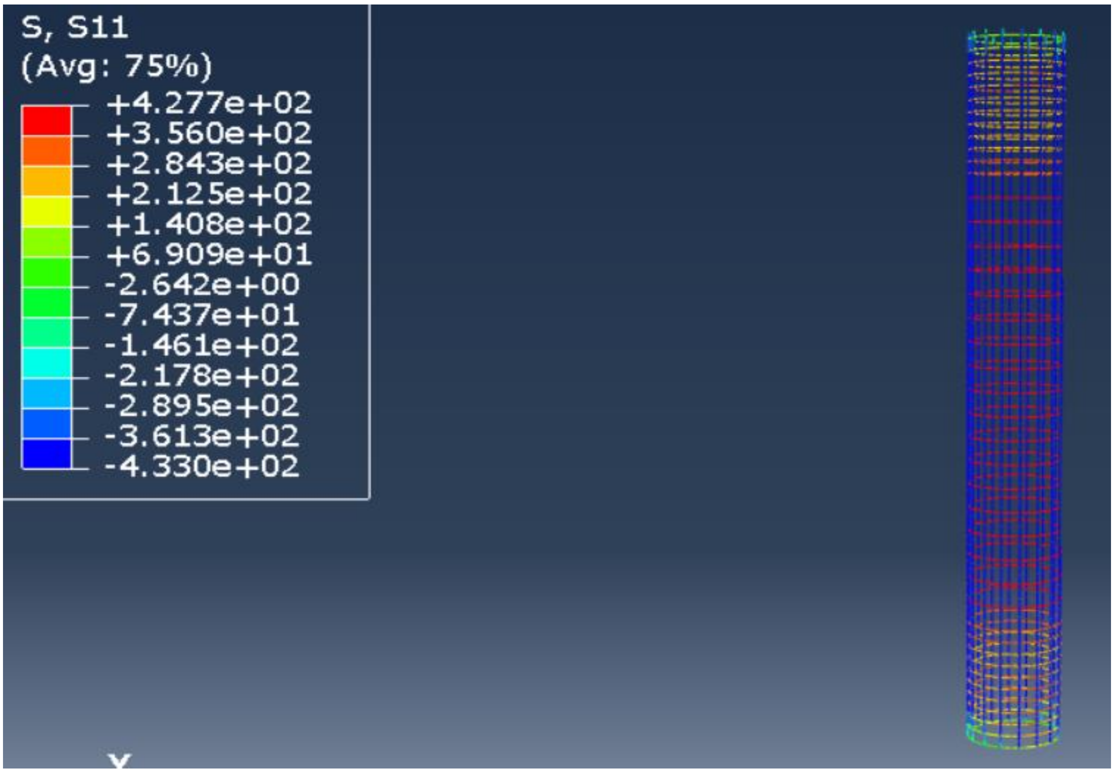


Figure 76:CL24 FV- Steel normal strain at ultimate crack

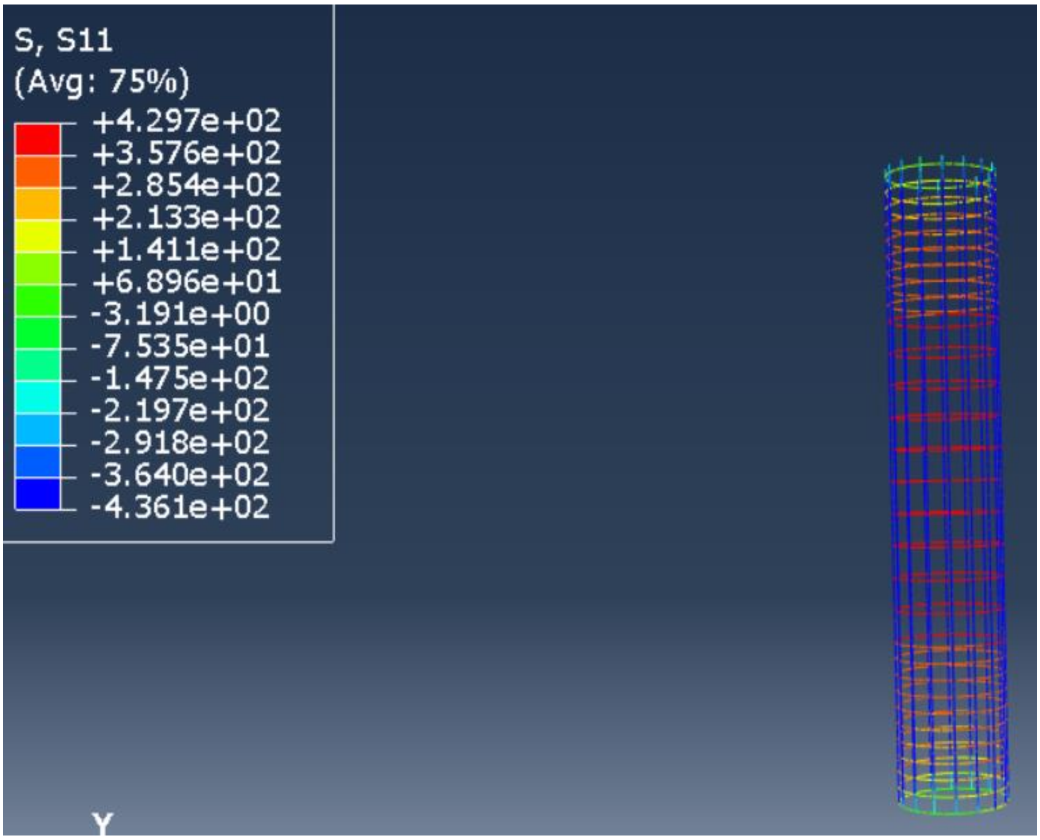


Figure 77:CS28 FV- Steel normal strain at ultimate crack

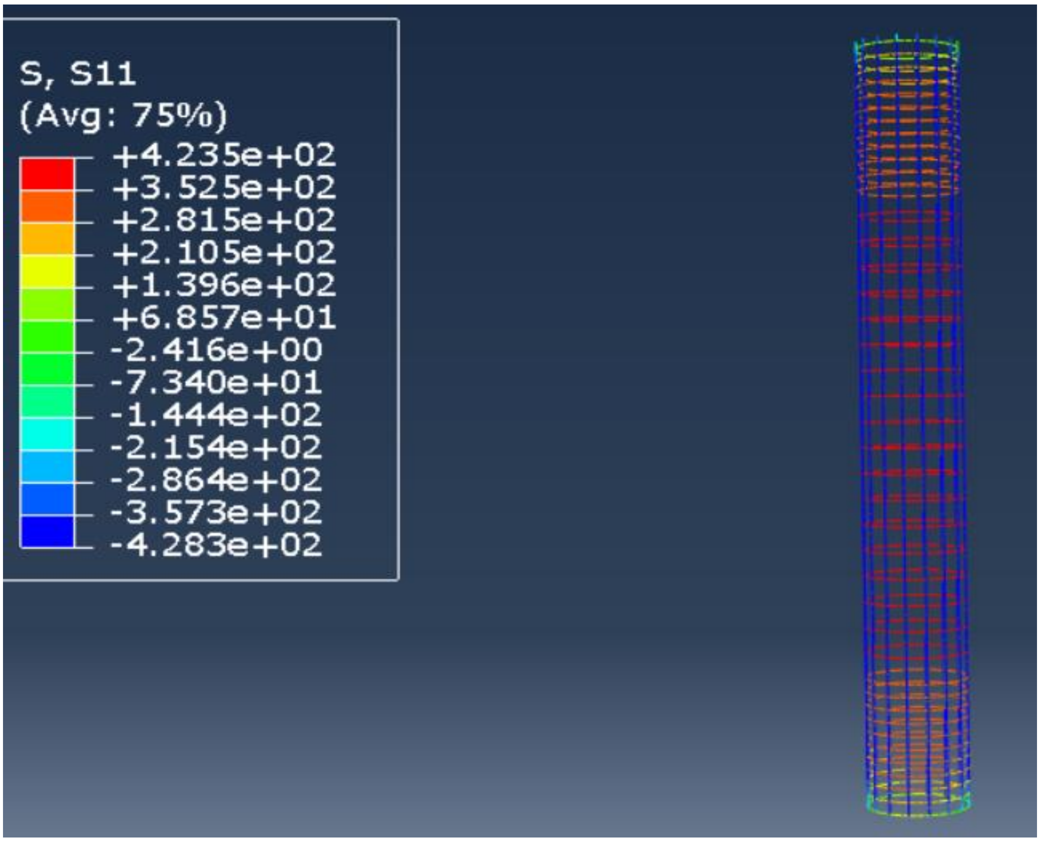


Figure 78:CL28 FV- Steel normal strain at ultimate crack

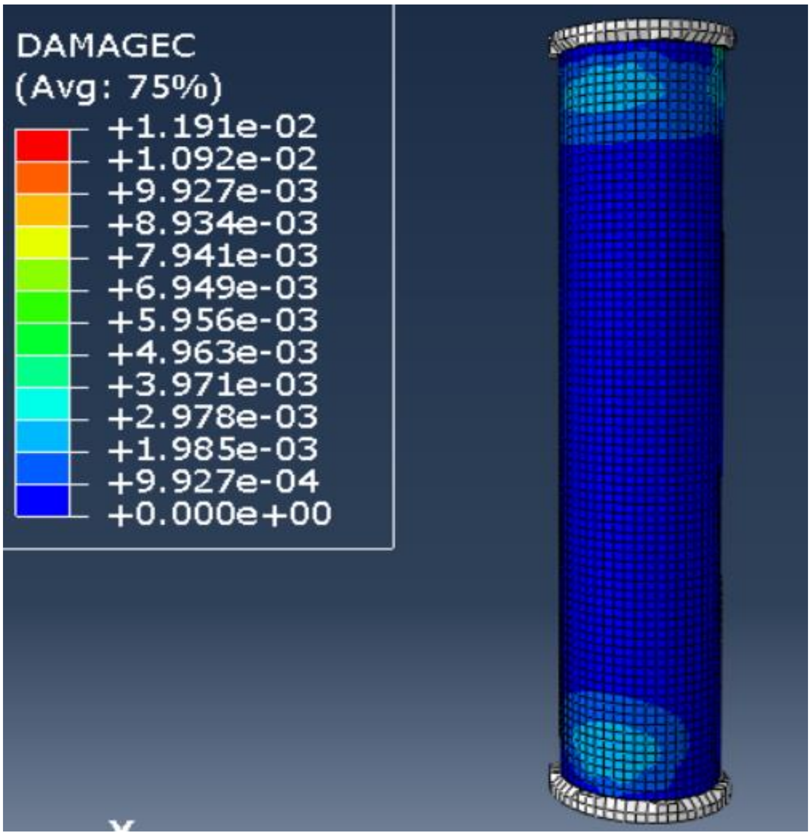


Figure 79 :CS24 FX- damage comparison -First crack

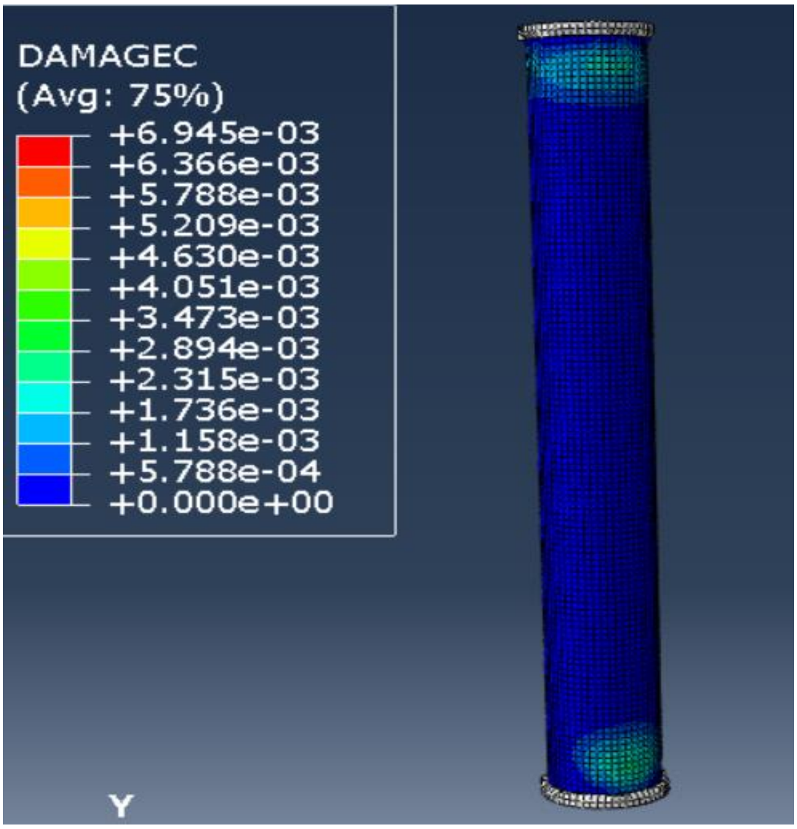


Figure 80 :CL24 FX- damage comparison -First crack

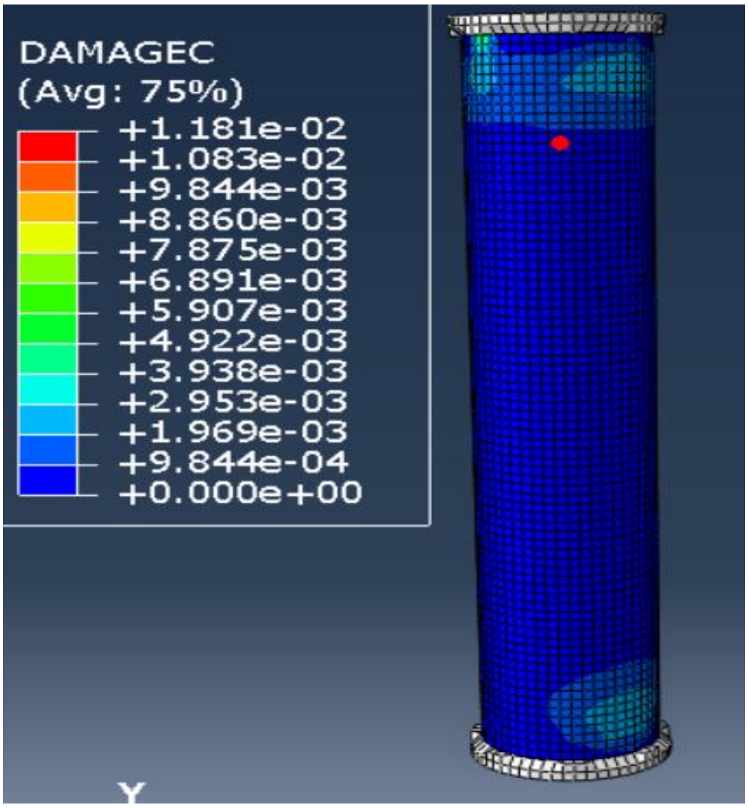


Figure81 :CS28 FX- damage comparison -First crack

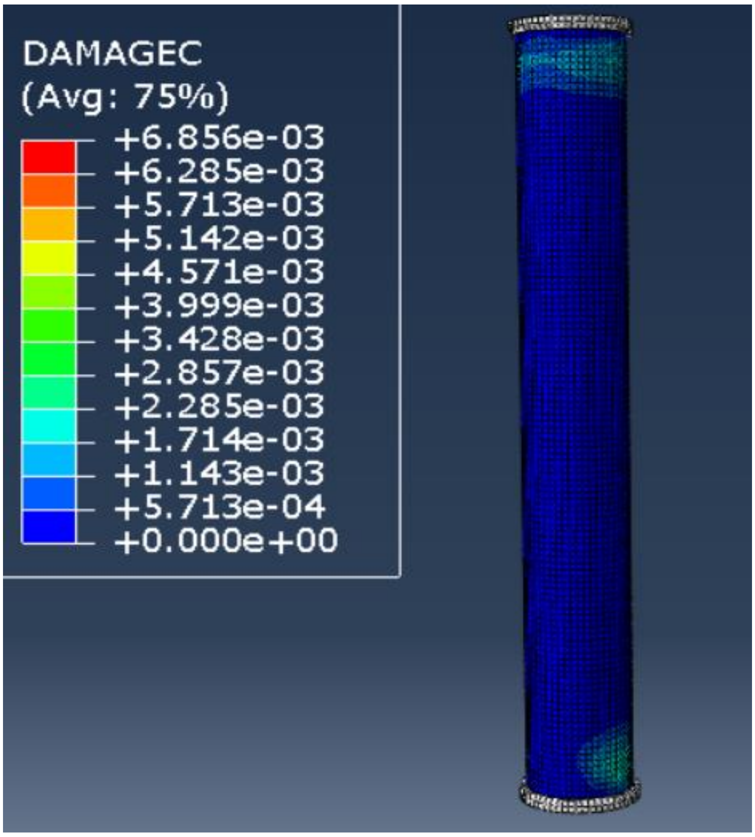


Figure:82 CL28FX- damage comparison -First crack

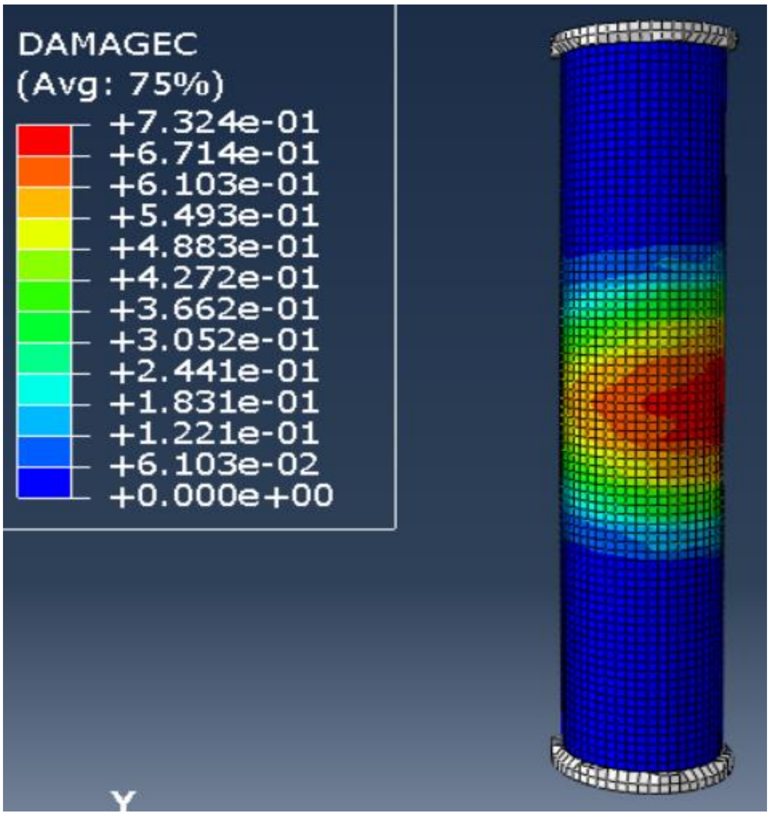


Figure83 :CS24 FX- damage comparison - at ultimate crack

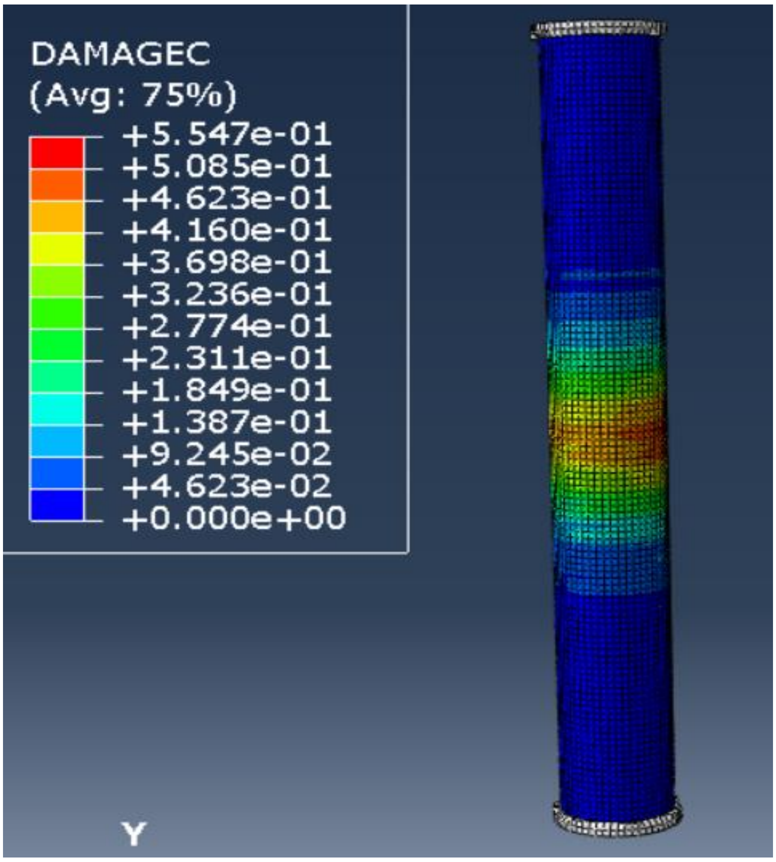


Figure84 ::CL24 FX- damage comparison - at ultimate crack

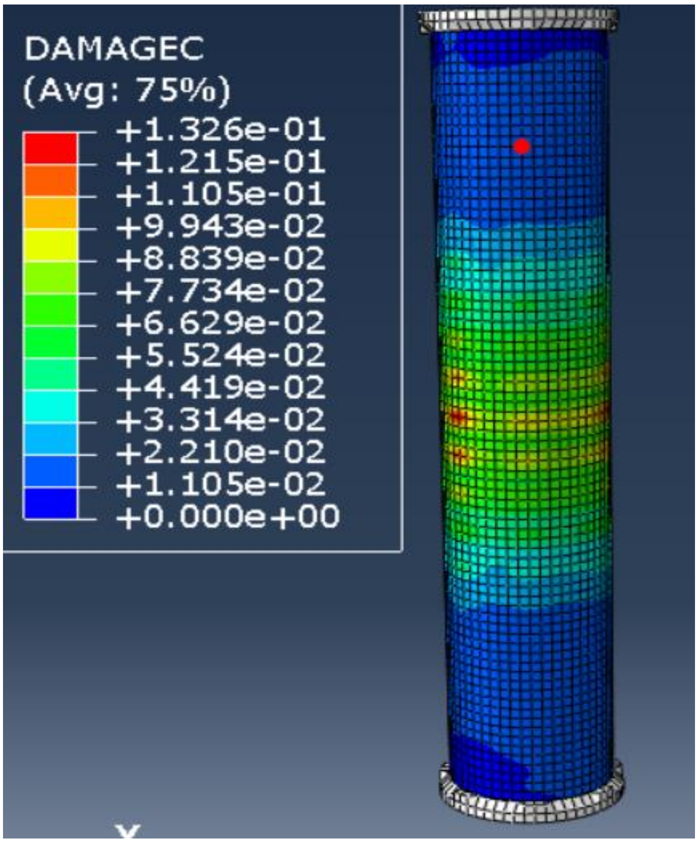


Figure85 ::CS28 FX- damage comparison - at ultimate crack

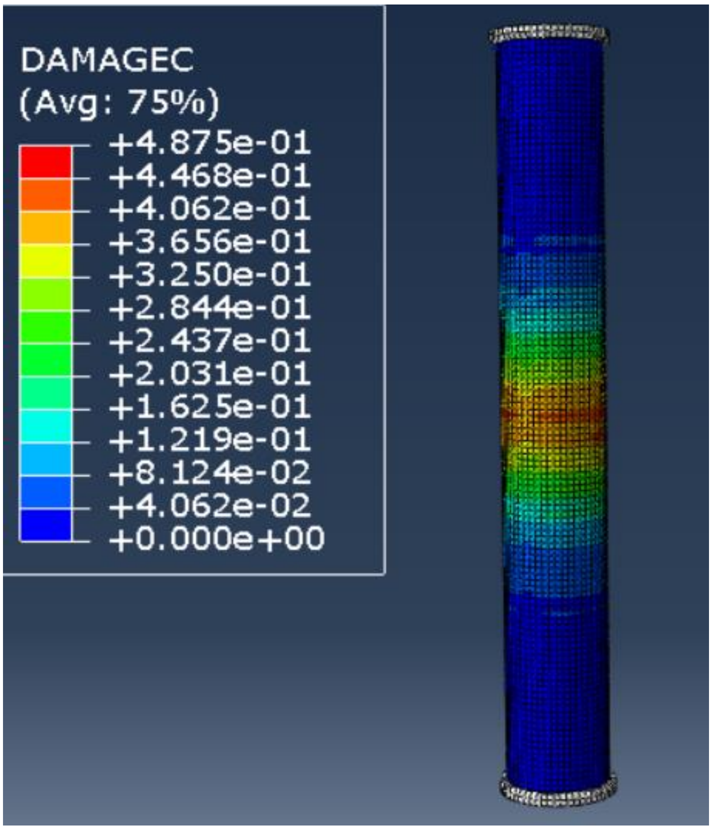


Figure86 ::CS28 FX- damage comparison - at ultimate crack

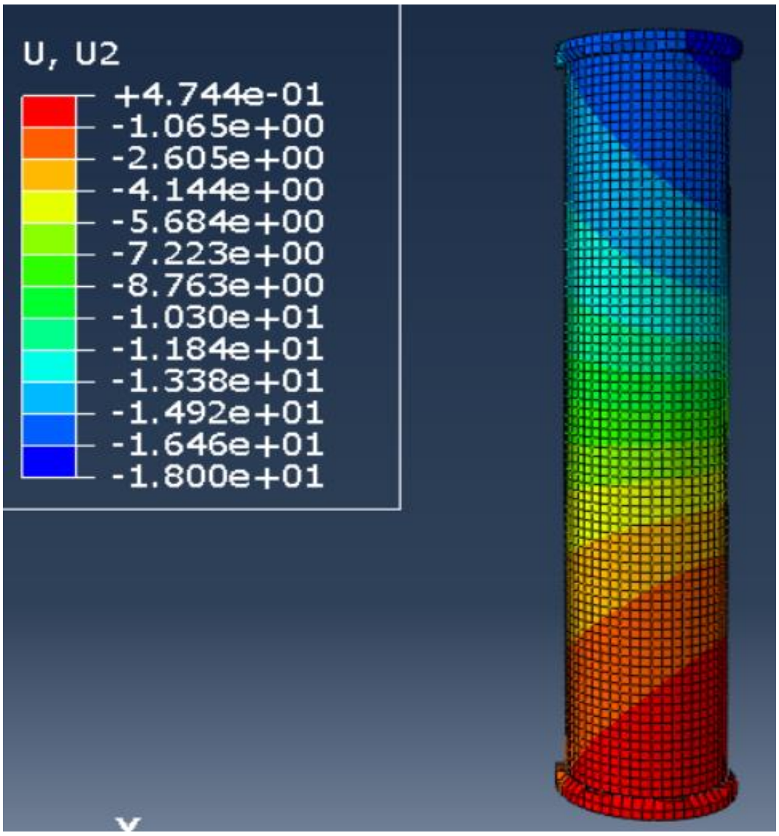


Figure:87 CS24 FX- U2 (vertical displacement) at ultimate

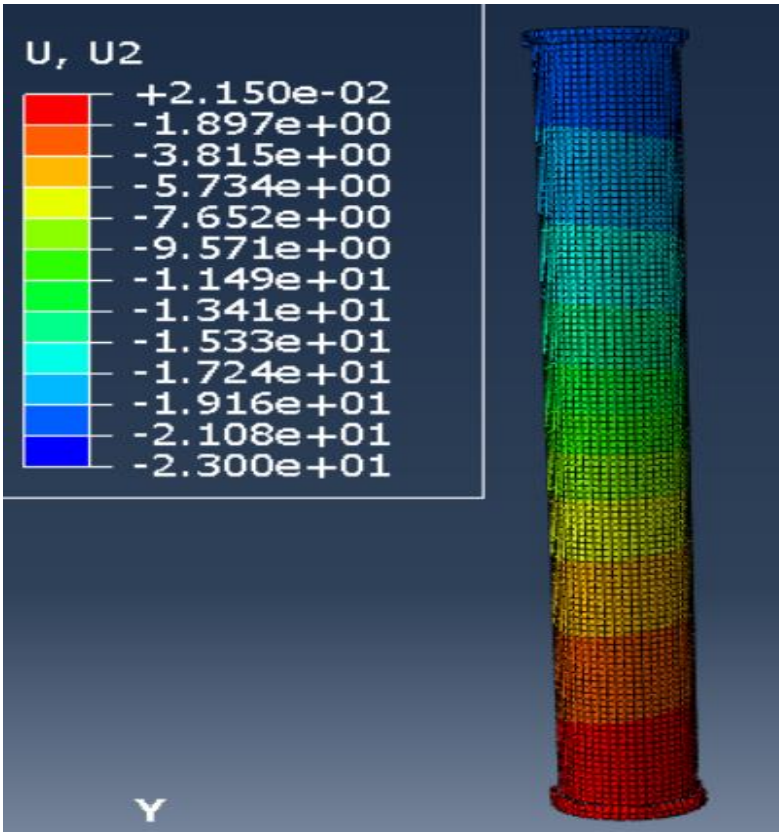


Figure88 :CL24 FX- U2 (vertical displacement) at ultimate

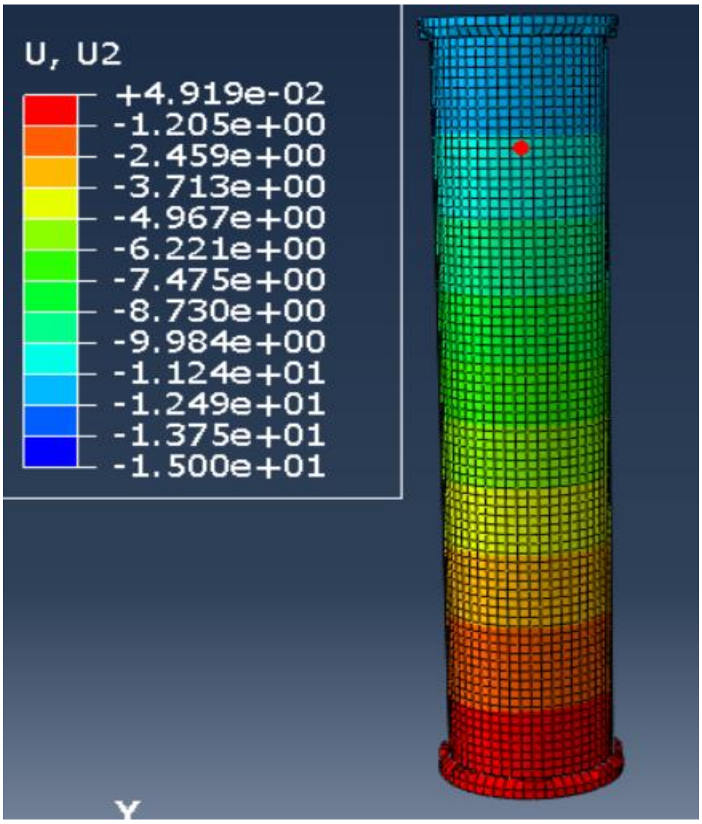


Figure:89 CS28 FX- U2 (vertical displacement) at ultimate

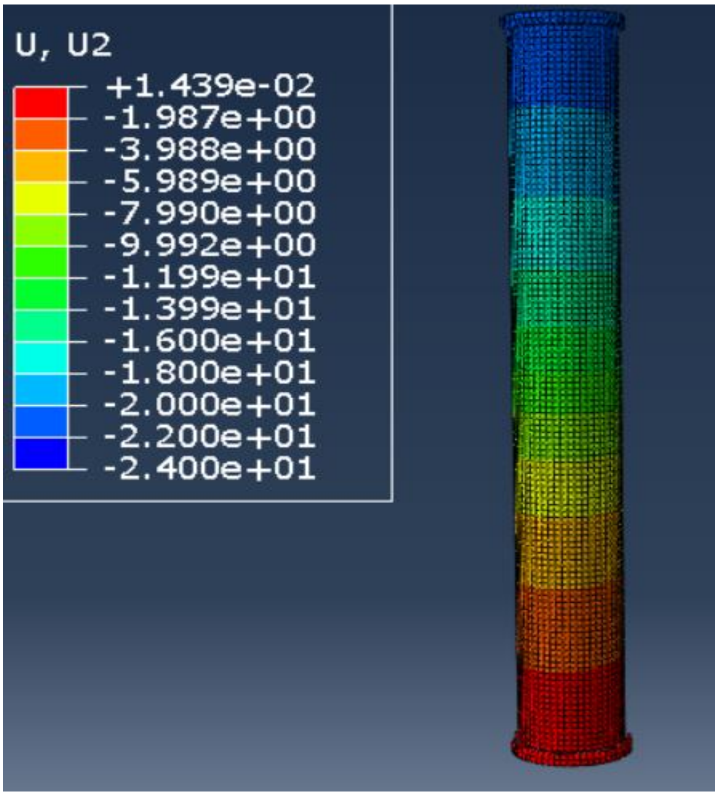


Figure::90 CL28 FX- U2 (vertical displacement) at ultimat

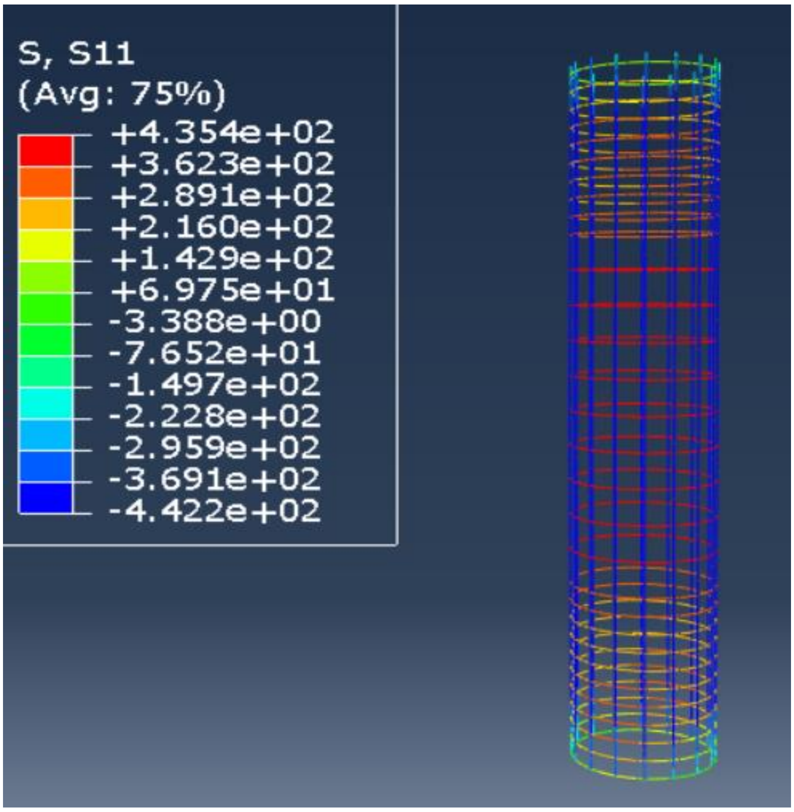


Figure 91:CS24 FX- Steel normal strain at ultimate crack

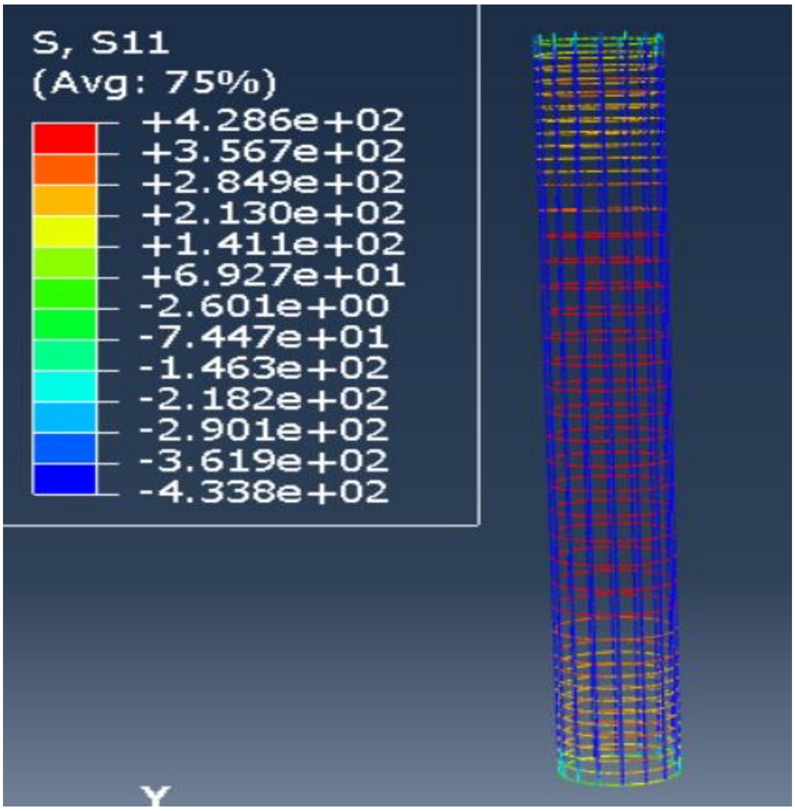


Figure 92:CL24 FX- Steel normal strain at ultimate crack

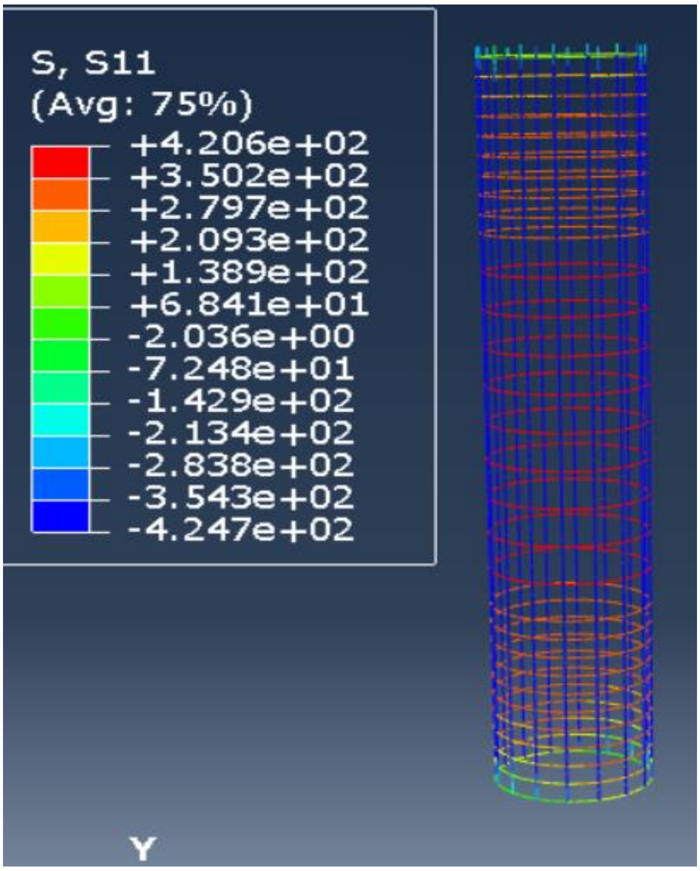


Figure 93:CS28 FX- Steel normal strain at ultimate crack

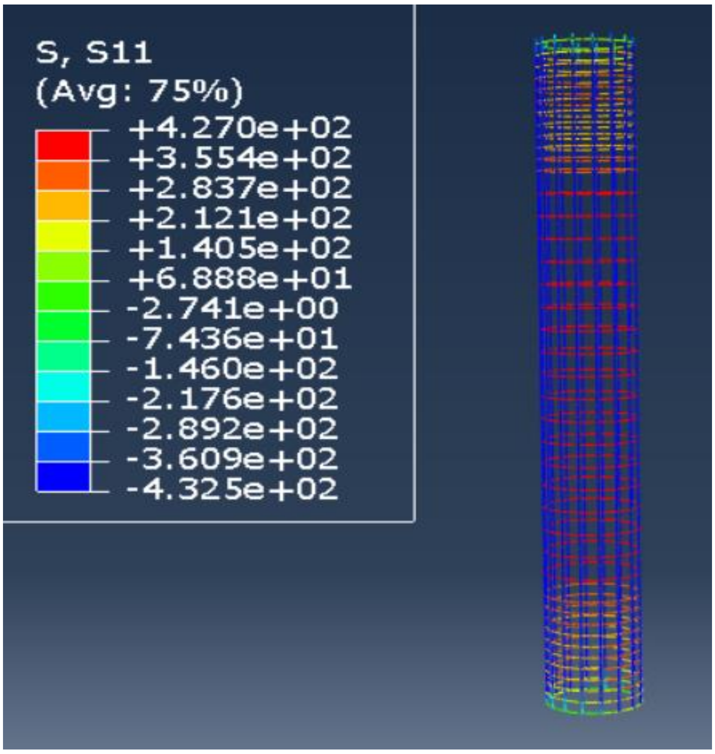


Figure 94:CL28 FX- Steel normal strain at ultimate crack

Based on the results shown in chapter 4 after using finite element method and after comparing the load-displacement curves of models with changed the orientation of CFRP and as we observe in the figure below that the CFRP horizontal direction significantly affect the increase in loads and displacements, We note that short column (24 and 28 Mpa) with H direction sample from gave results increasing on load by3.5 % more than v direction and 1.5% more than x direction and displacement by 4.5% more than both. on other hand long column carves(24 and28 Mpa) show the using CFRP increased the amount of load by 3.5% on V direction and 1.6% on X direction and displacement by 4.5% on both.

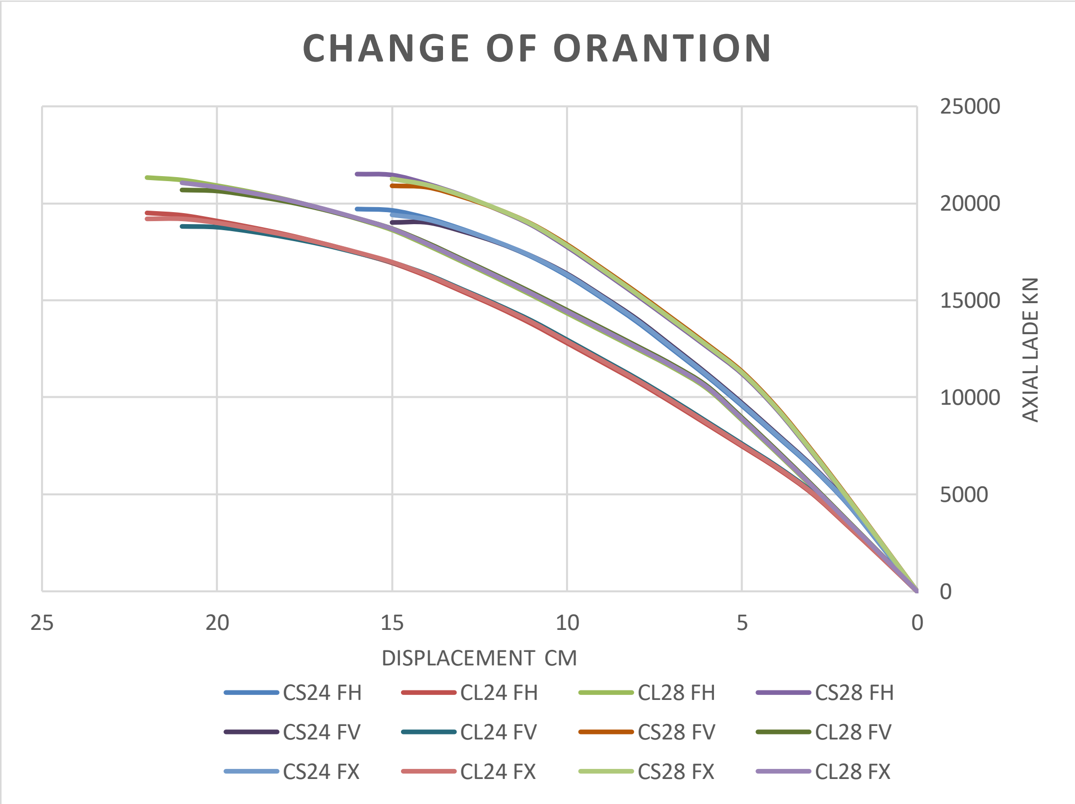


Figure:95 : load-displacement curve- for change of orientation CFRP

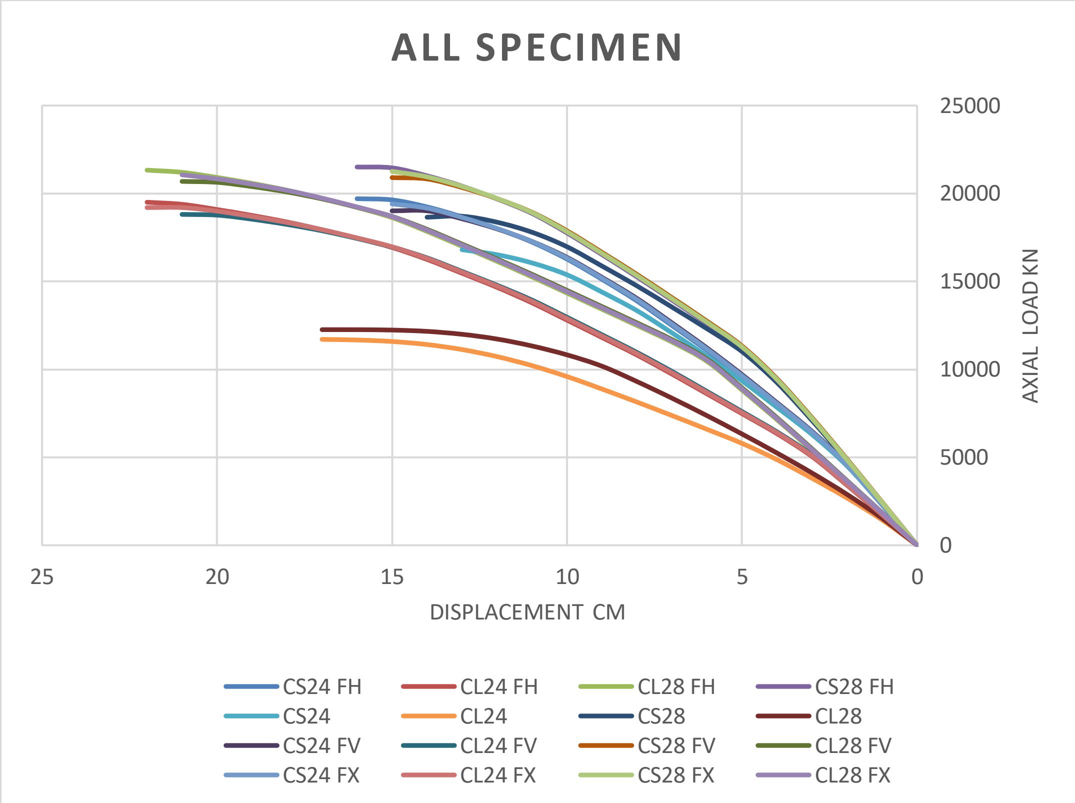


Figure96 :all spaceman

The previous figure shows load-displacement curve for all considered columns and parametric studies .we can see that the most advantageous and best way to strengthen the concrete shortly column is to strengthen the concrete strength to 28 Map and wrap CFRP horizontal orientation , as we approved to long column strengthen the concert 28 Mpa and wraped CFRP horizontal orientation .

Chapter 5 : Conclusion

- The change in strengthen of concrete does not significantly affect the increase in loads and displacements on long columns .
- The short Column have small effect by changing in concrete strength .
- After warped CFRP layer slender interaction very well to increased of loads and displacement moor then shortly column .
- The beast orientation of CFRP sheet what ever short or slender lees or more concrete strength is horizontal orientation (H)
- The beneficial effects of strengthening the RC column using CFRP , as evident from enhancement of the axial capacity .

Chapter 6 : References

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