FAILURE PATTERNS IN A CONCRETE CYLINDER

Spring Semester 2021

CE42006 : Behaviour of RC Structures

Assignment 1

Abaqus Modelling

Deepak Choudhary

17CE31001

Department of Civil Engineering Indian Institute of Technology Kharagpur 721302

Content

Part	Title	Page
1	Introduction to model	3
2	Model with Stiff plattens	6
	a) Height 300mm	7
	b) Height 600mm	10
	c) Height 1000mm	13
3	Model with flexible plattens	16
	a) Height 300mm	17
	b) Height 600mm	20
	c) Height 1000mm	22
4	Mesh dependence in the solution	24
5	Reference	27

Part 1
Introduction to model

Software used is **Abaqus 6.14**.

This project involves studying the failure patterns in a concrete cylinder of diameter 150 mm and variable height (300 mm, 600 mm, 1000 mm) loaded in unconfined compression by stiff as well as flexible plattens.

An axisymmetric finite element model is created for cylinder in abaqus. Concrete material is modelled using Concrete Damaged Plasticity model.

Properties given for concrete are –

- Compression strength = 27 MPa
- Ultimate strain = 0.003.
- Density = 2400 Kg/m3
- Young's modulus = 29 GPa
- Poisson's ratio = 0.2

Plastic properties for concrete are –

- Dilatation angle = 36 degree.
- Flow field eccentricity, ε = .1
- ratio of biaxial compressive yield stress to uniaxial compressive yield stress = 1.16
- Kc, ratio of stress invariants on tensile and compressive meridian = .67

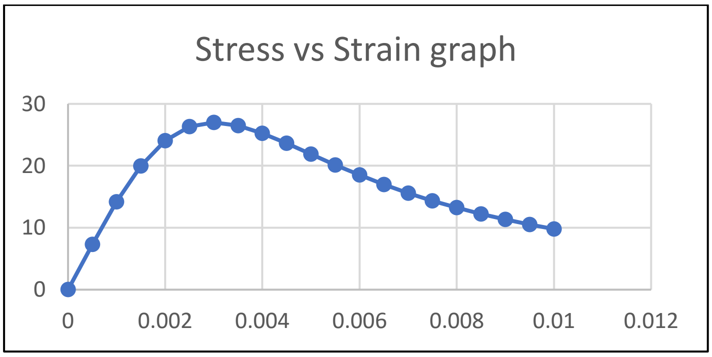
Concrete Compression Damage data –

To define the stress-strain curve in uniaxial compression, we used the empirical equations given in Popovics (1973), specifically Eqns. (2) and (3) in that paper.

$$f = f_0 \frac{\varepsilon}{\varepsilon_0} \frac{n}{n - 1 + (\varepsilon/\varepsilon_0)^n}$$

$$n_{concrete} = 0.4 \times 10^{-3} f_0 + 1.0$$

Elastic Strain	Stress	Inelastic strain	Damage Factor
0	0	0	0
0.0005	7.325725	0	0
0.001	14.20482	0.000510179	0
0.0015	19.96649	0.0008115	0
0.002	24.0644	0.001170193	0
0.0025	26.33453	0.001591913	0
0.003	27	0.002068966	0
0.0035	26.49073	0.002586527	0.018861803
0.004	25.25161	0.003129255	0.064755198
0.0045	23.63716	0.003684925	0.124549514
0.005	21.88837	0.004245229	0.189319685
0.0055	20.15088	0.004805142	0.253671194
0.006	18.50345	0.00536195	0.314687148
0.0065	16.98258	0.005914394	0.371015441
0.007	15.60005	0.006462067	0.422220514
0.0075	14.35407	0.007005032	0.468367677
0.008	13.23614	0.007543582	0.509772739
0.0085	12.23483	0.008078109	0.546858065
0.009	11.33802	0.008609034	0.580073401
0.0095	10.53392	0.009136761	0.60985471
0.01	9.811673	0.009661666	0.636604695



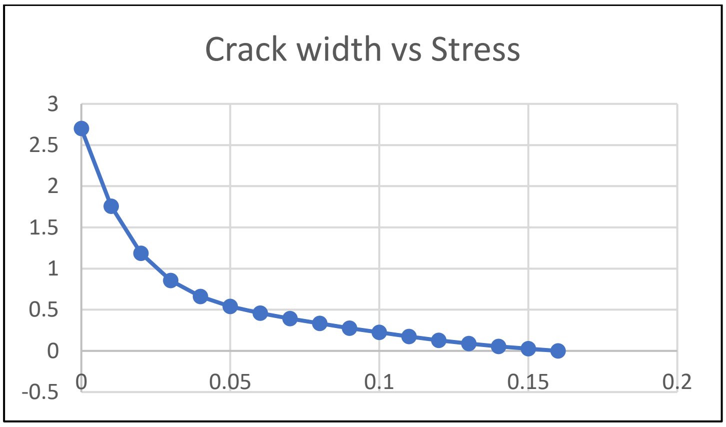
Concrete Tensile Damage data –

To define the stress-strain/crack opening behaviour in tension as well as the fracture energy we use Equation 6.1 and 6.2 in Hordijk (1991)

$$\frac{\sigma}{f_t} = \{1 + (c_1 \frac{w}{w_c})^3\} \exp(-c_2 \frac{w}{w_c}) - \frac{w}{w_c}(1 + c_1^3) \exp(-c_2)$$

$$G_F = f_t w_c [\frac{1}{c_2}\{1 + 6(\frac{c_1}{c_2})^3\} - \{\frac{1}{c_2} + c_1^3(\frac{1}{c_2} + \frac{3}{c_2^2} + \frac{6}{c_2^3} + \frac{6}{c_2^4}) + \frac{1}{2}(1 + c_1^3)\}\exp(-c_2)] \quad (6.2)$$

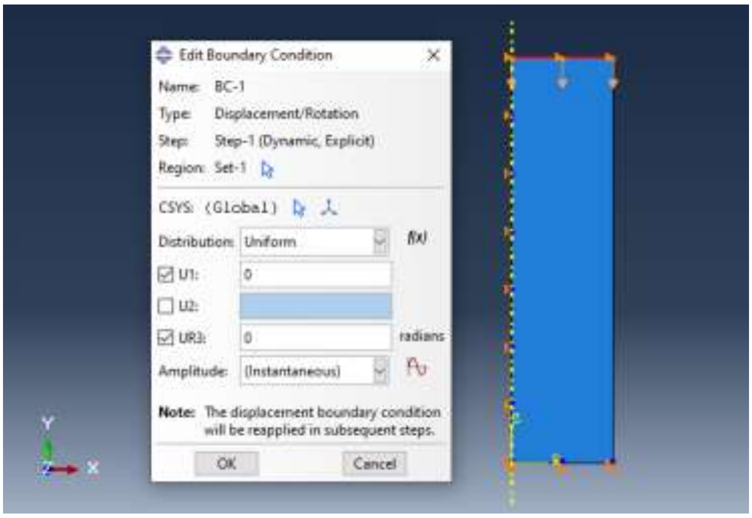
Crack width (w in mm)	Stress	Damage factor
0	2.7	0
0.01	1.757814939	0.34895743
0.02	1.186052536	0.560721283
0.03	0.853477568	0.683897197
0.04	0.660422324	0.755399139
0.05	0.541654256	0.799387313
0.06	0.458952891	0.830017448
0.07	0.392258654	0.854719017
0.08	0.332443944	0.876872613
0.09	0.276290529	0.897670175
0.1	0.223358721	0.917274548
0.11	0.174219008	0.935474442
0.12	0.129564254	0.952013239
0.13	0.089841765	0.966725272
0.14	0.055163659	0.979569015
0.15	0.025347042	0.990612207
0.16	-9.36751E-18	1



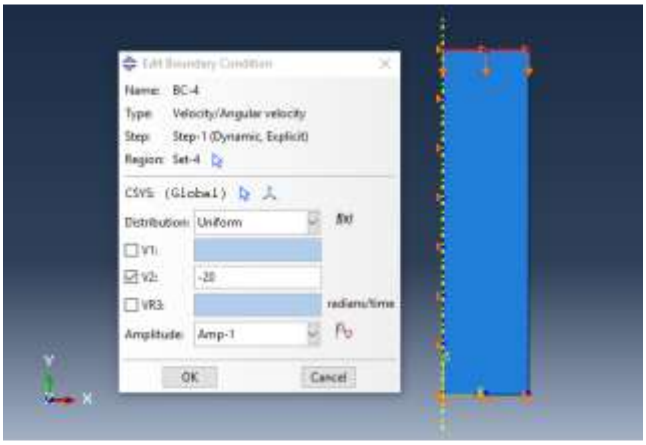
Part 2

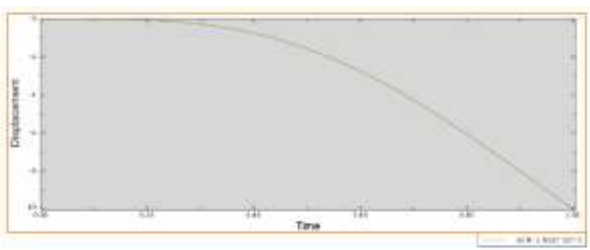
Model with stiff plattens

For stiff plattens we have applied boundary condition with displacement in x direction as 0.



For load we are applying displacement in the upper side of cylinder of 10mm in 1 sec . this displacement is applied quasi-statically





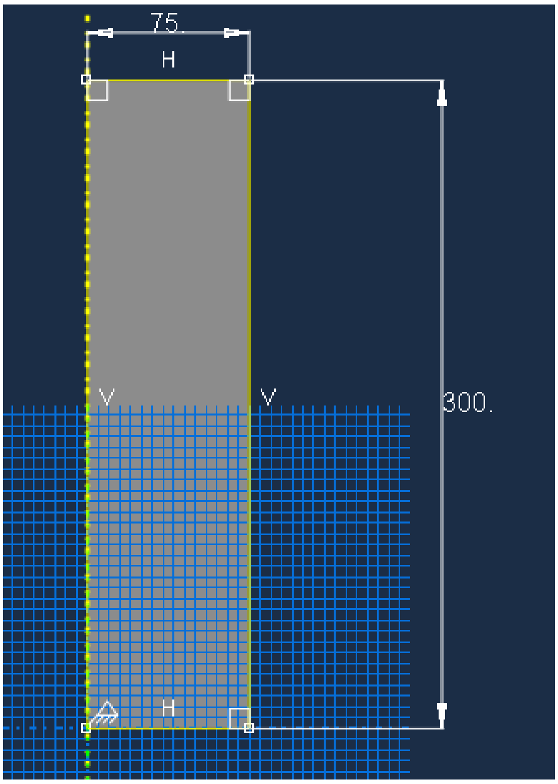
Part 2.a

(Height = 300mm) Stiff plattens

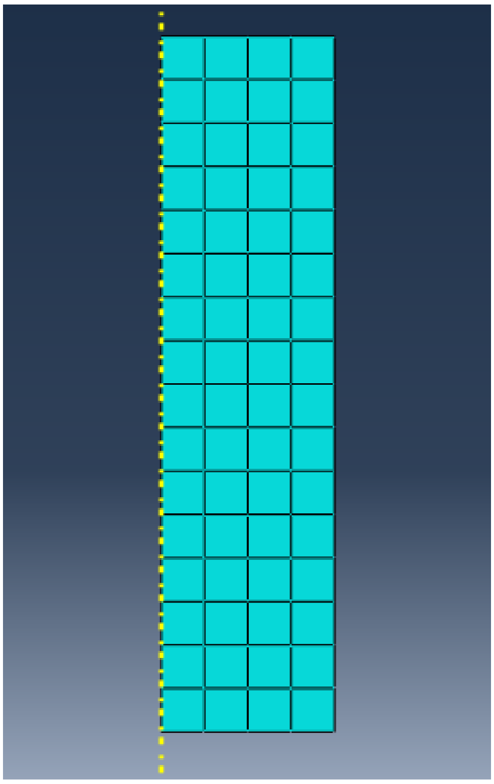
File - C300.cae

Model - axisymmetric finite element model

- Approximate global size for mesh – 18.75
- Technique – structured



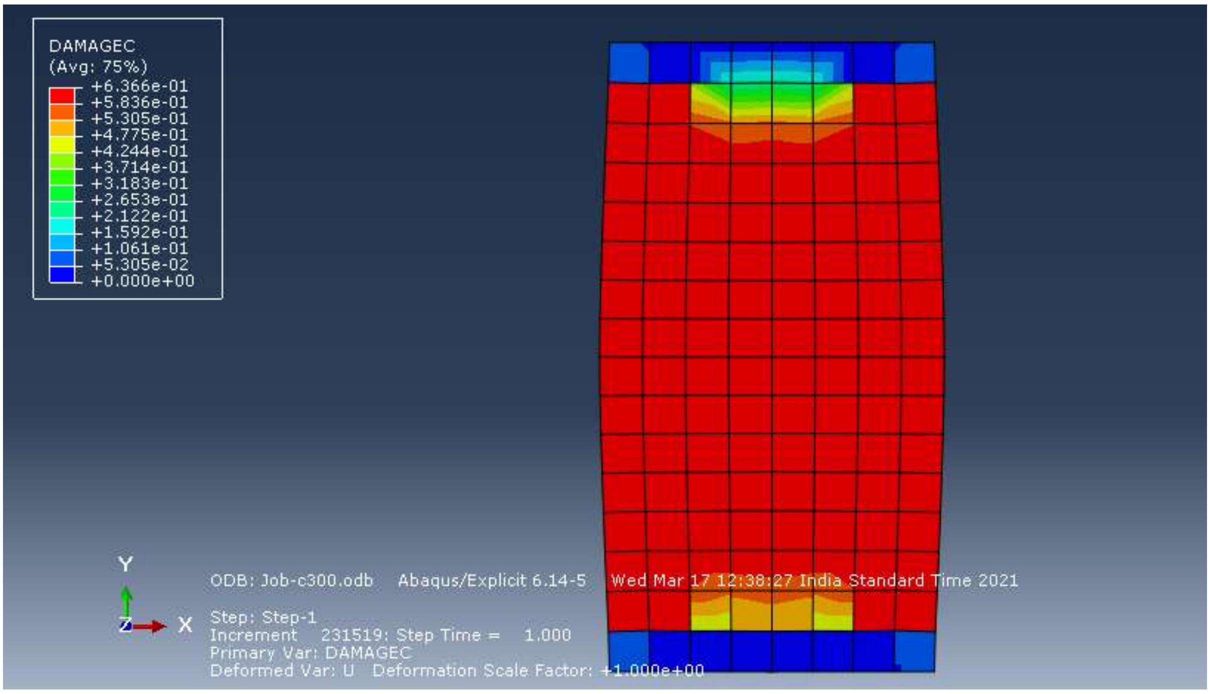
Section Sketch



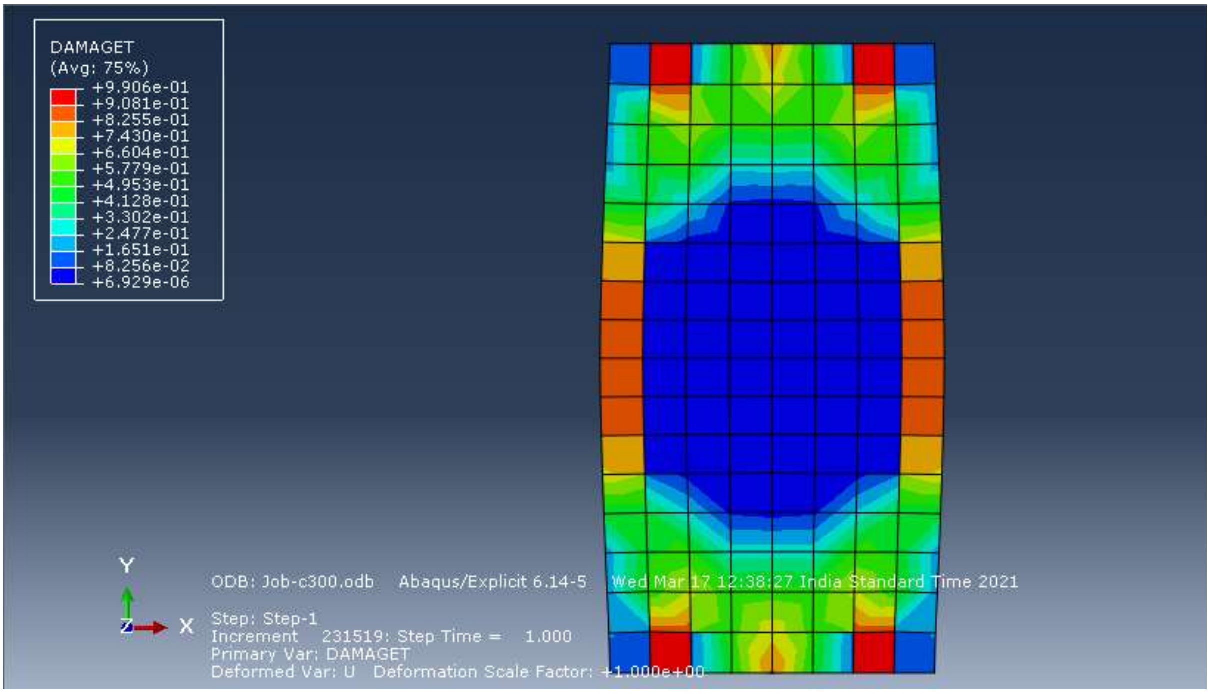
Mesh Sketch

Contour plots of the distribution of tensile & compressive damage

Compressive damage –



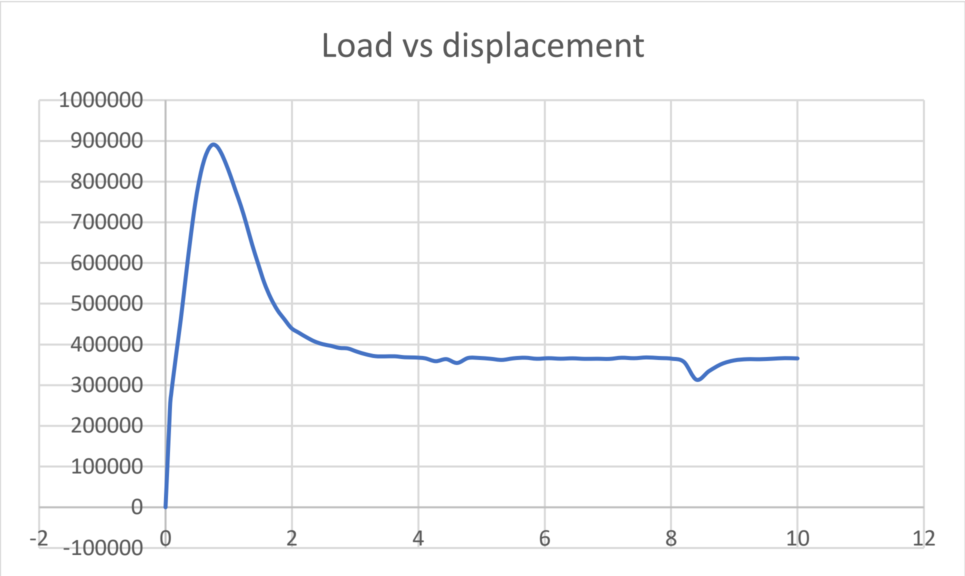
Tensile damage –



Comparison of the load-displacement curves

Reference table - 17CE31001 Load Displacement Table.xlsx

(Tab-C300)



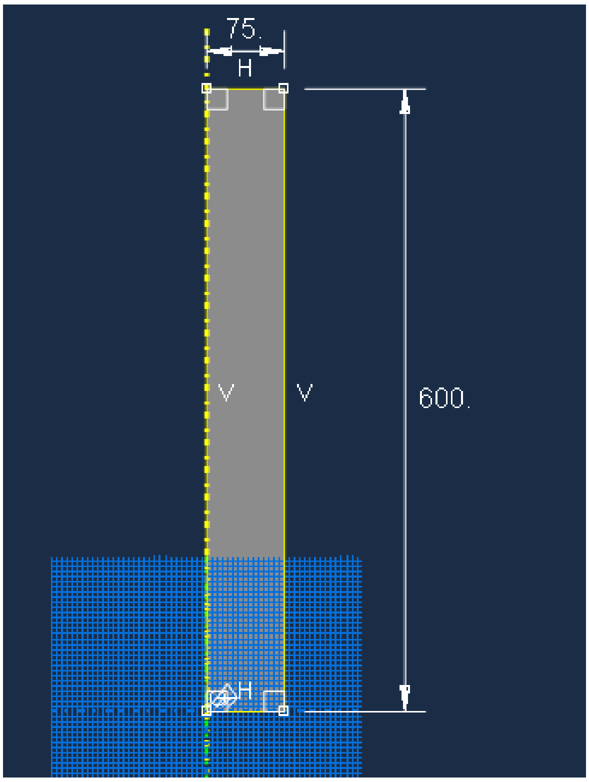
Part 2.b

(Height = 600mm) Stiff plattens

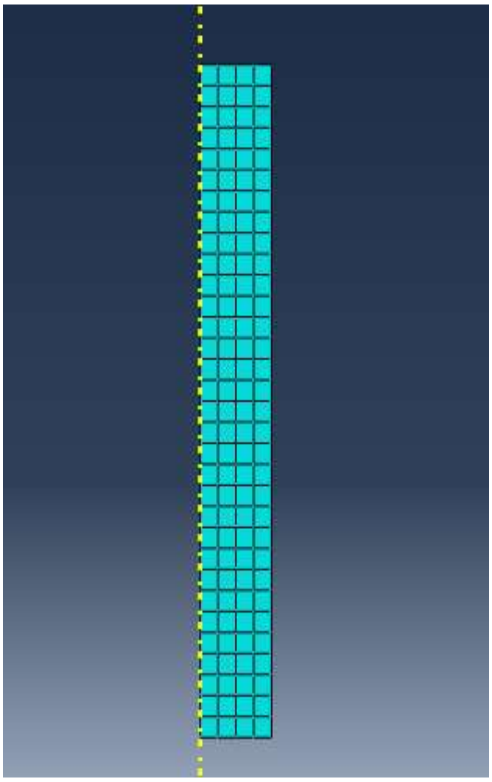
File - C600.cae

Model - axisymmetric finite element model

- Approximate global size for mesh – 18.75
- Technique – structured



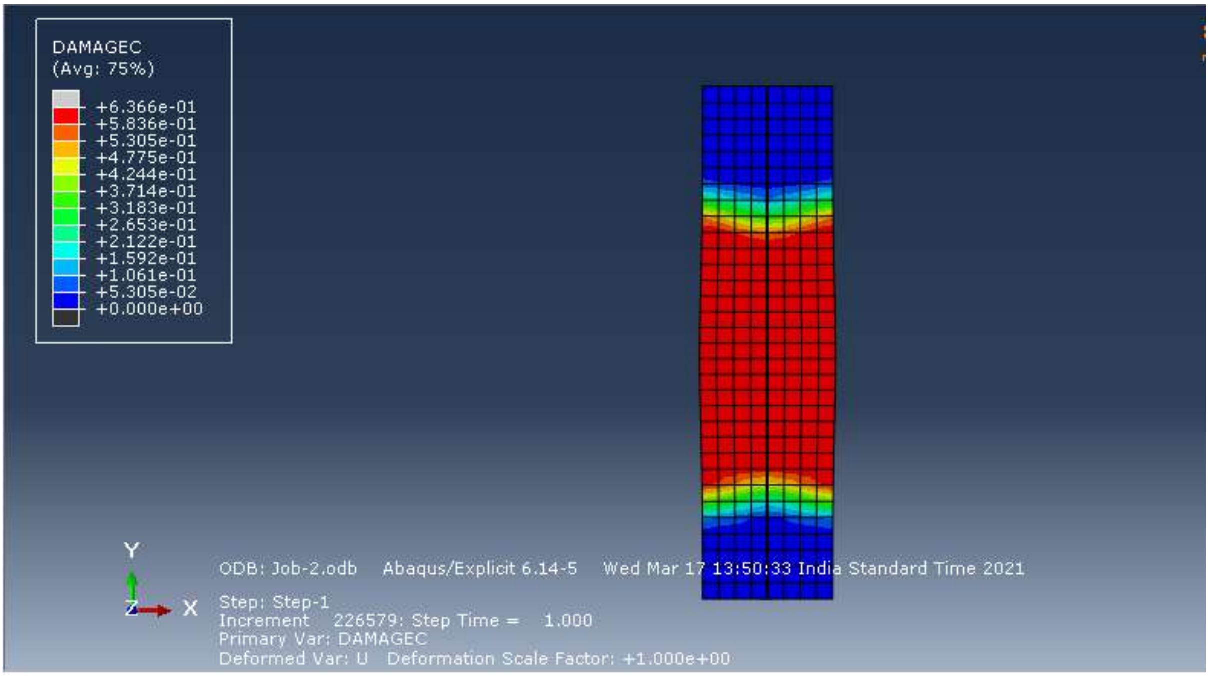
Section Sketch



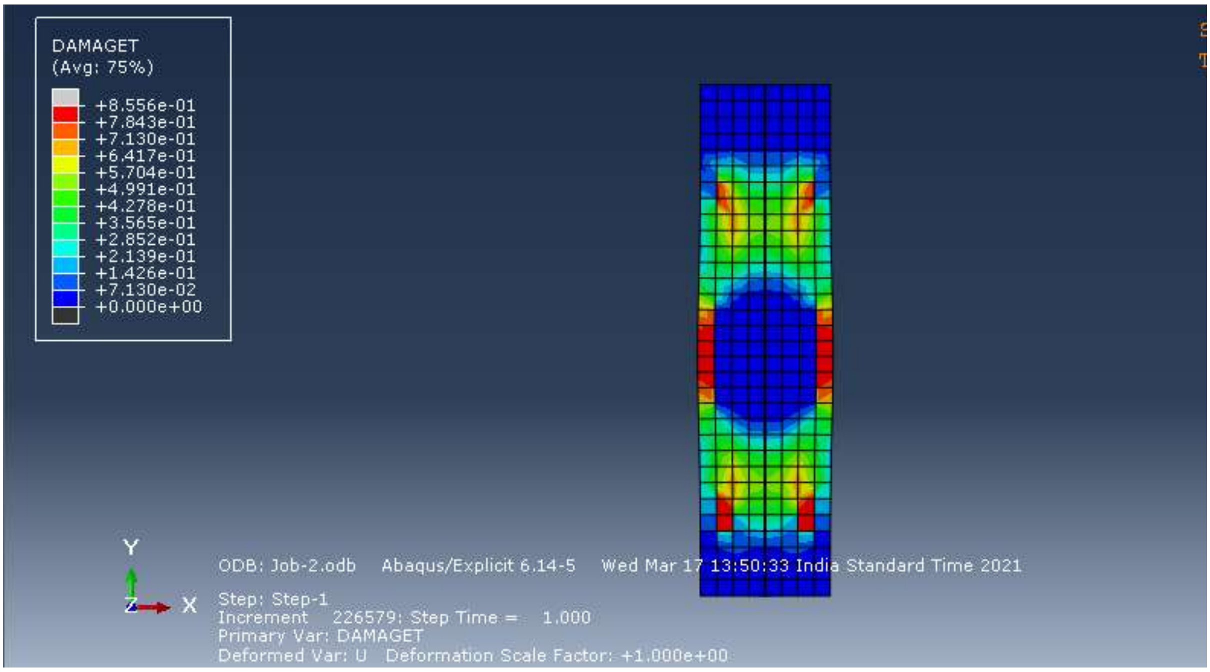
Mesh Sketch

Contour plots of the distribution of tensile & compressive damage

Compressive damage –



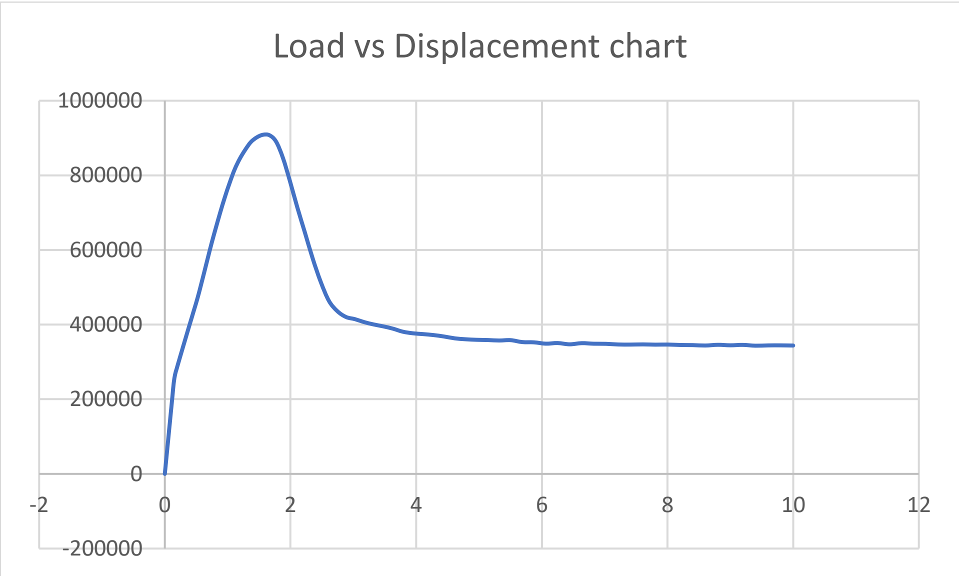
Tensile damage –



Comparison of the load-displacement curves

Reference table - 17CE31001 Load Displacement Table.xlsx

(Tab-C600)



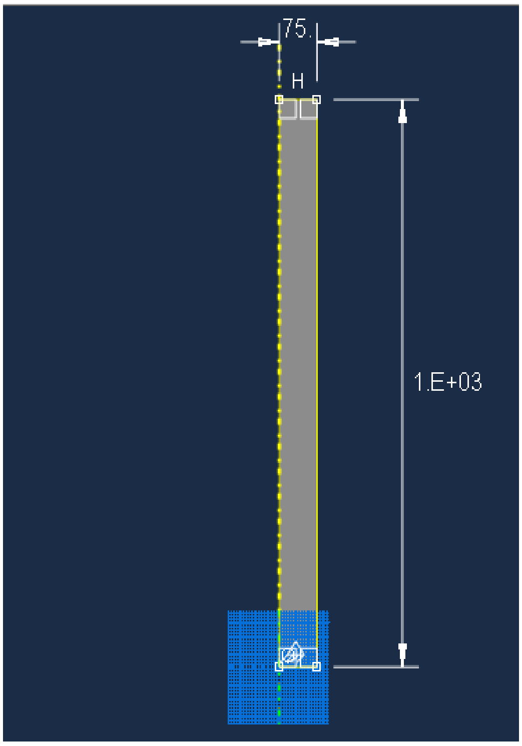
Part 2.c

(Height = 1000mm) Stiff plattens

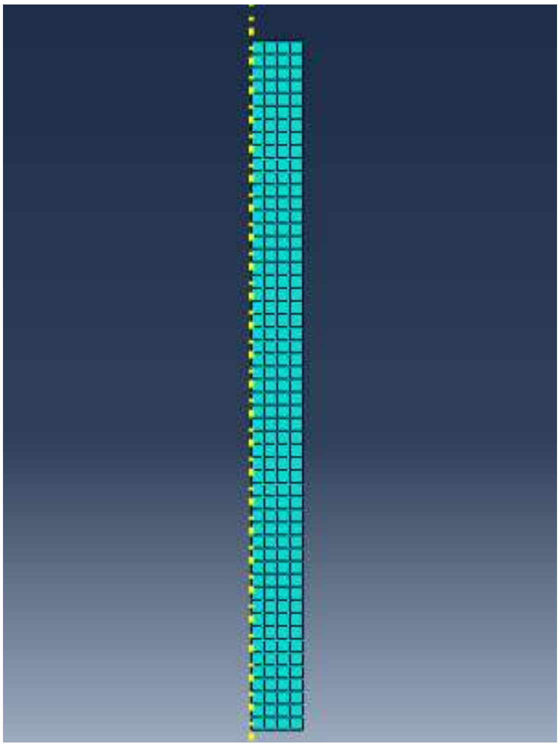
File - C1000.cae

Model - axisymmetric finite element model

- Approximate global size for mesh – 18.75
- Technique – structured



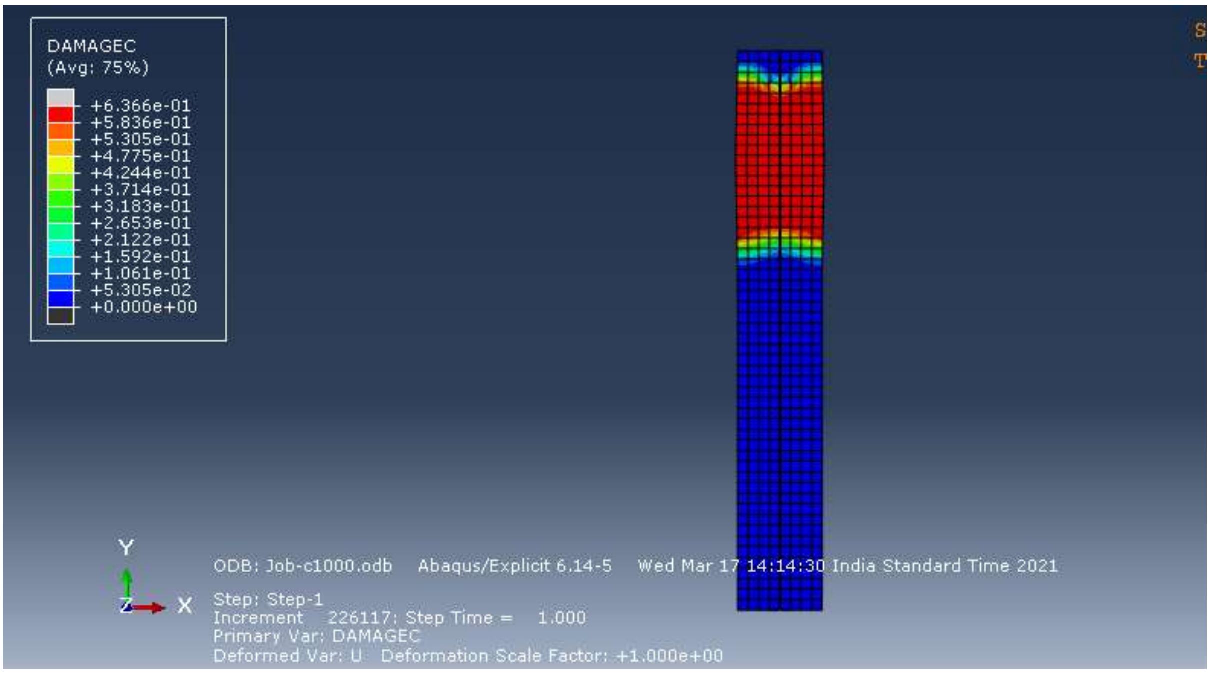
Section Sketch



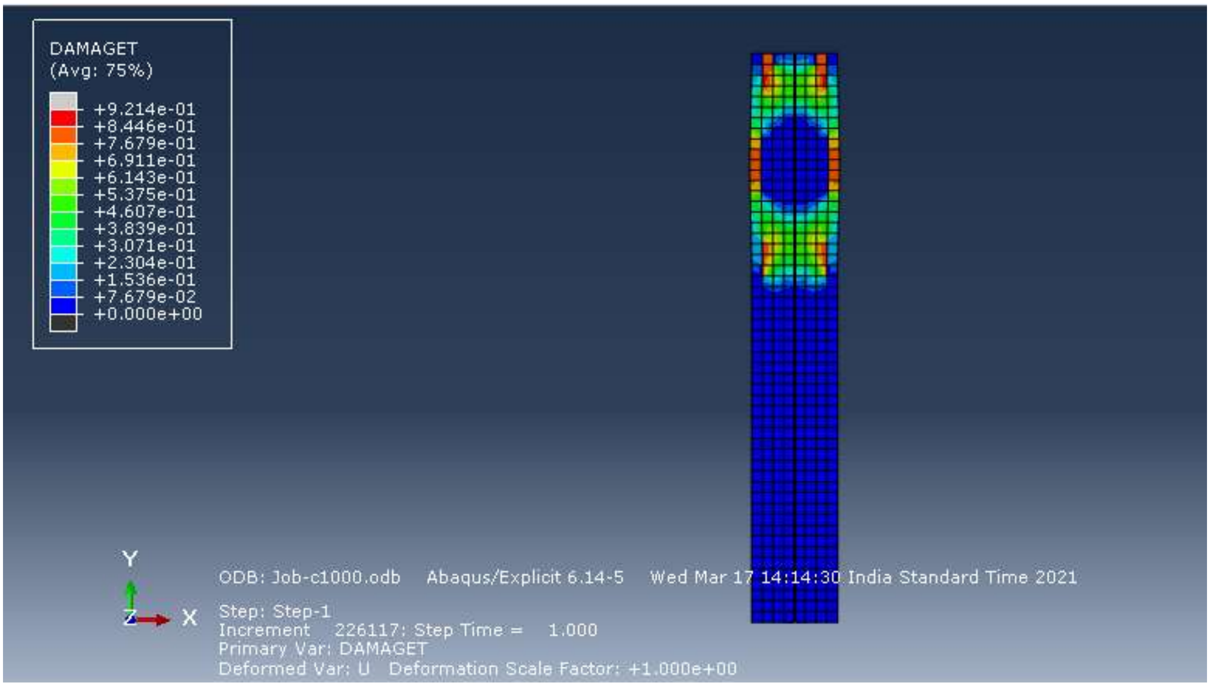
Mesh Sketch

Contour plots of the distribution of tensile & compressive damage

Compressive damage –



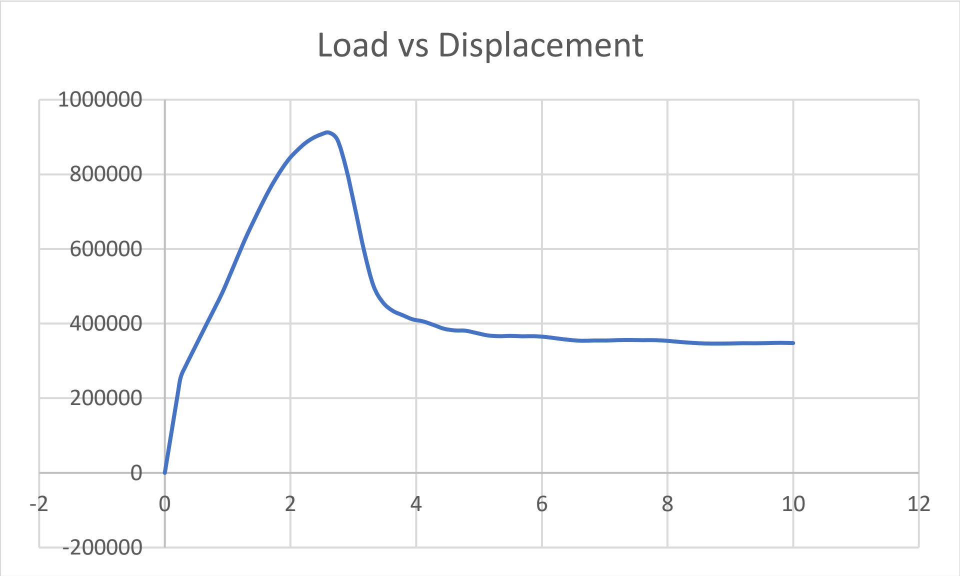
Tensile damage –



Comparison of the load-displacement curves

Reference table - 17CE31001 Load Displacement Table.xlsx

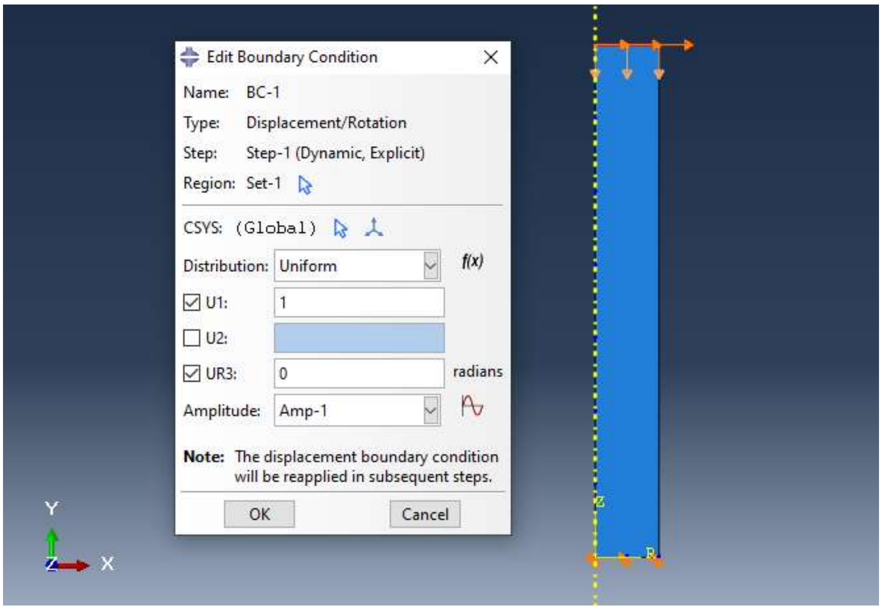
(Tab-C1000)



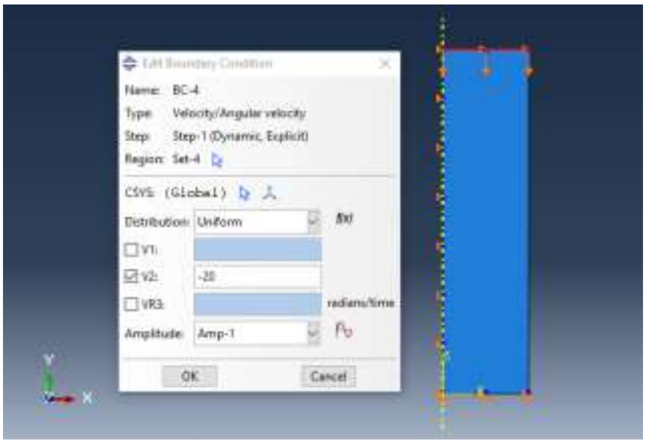
Part 3

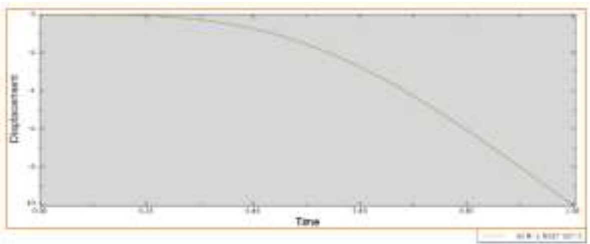
Model with flexible plattens

For flexible plattens we have applied boundary condition with displacement in x direction at 1mm .



For load we are applying displacement in the upper side of cylinder of 10mm in 1 sec . this displacement is applied quasi-statically





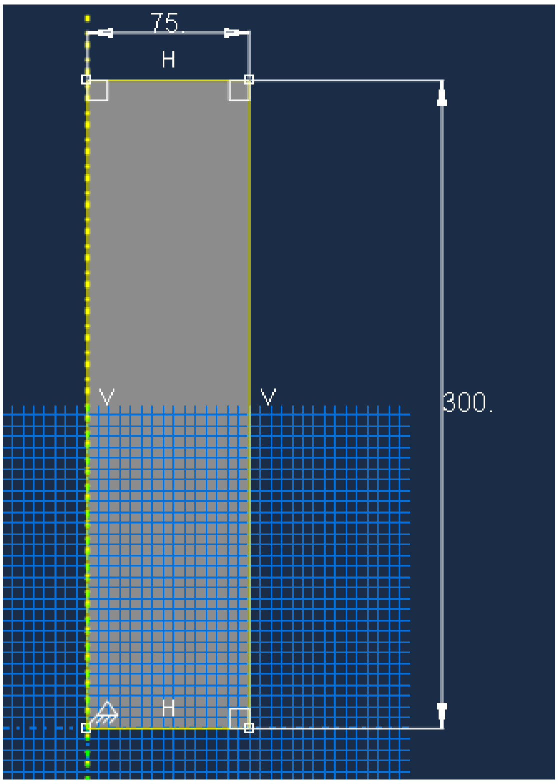
Part 3.a

(Height = 300mm) Flexible plattens

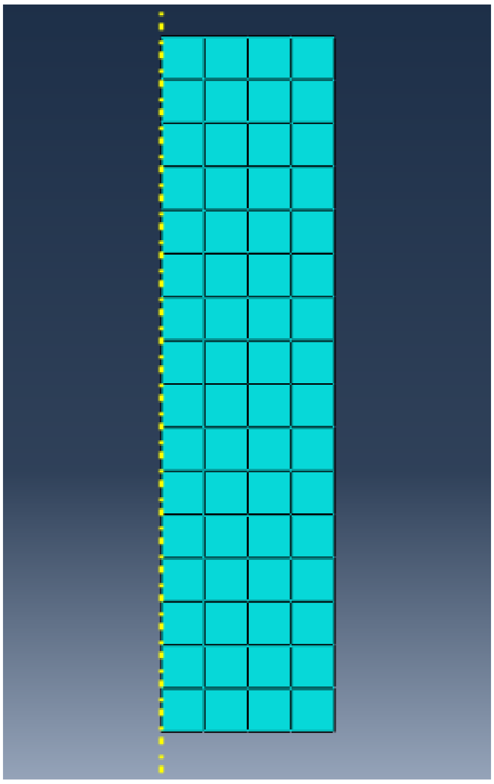
File - F300.cae

Model - axisymmetric finite element model

- Approximate global size for mesh – 18.75
- Technique – structure



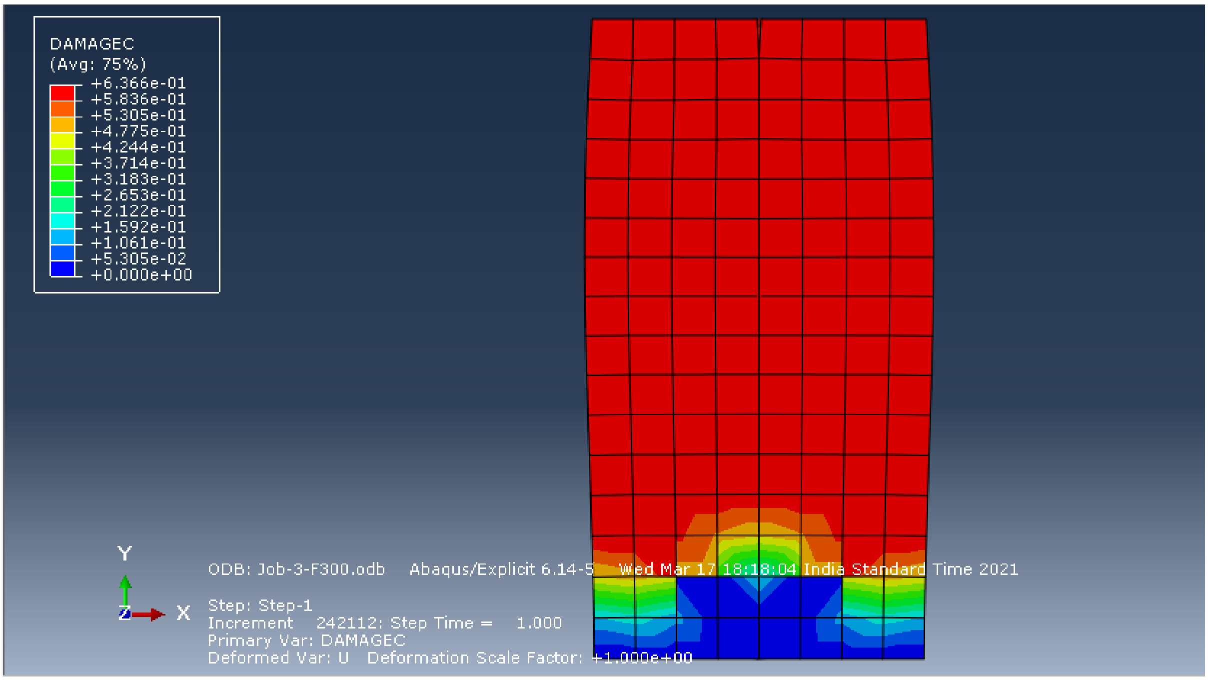
Section Sketch



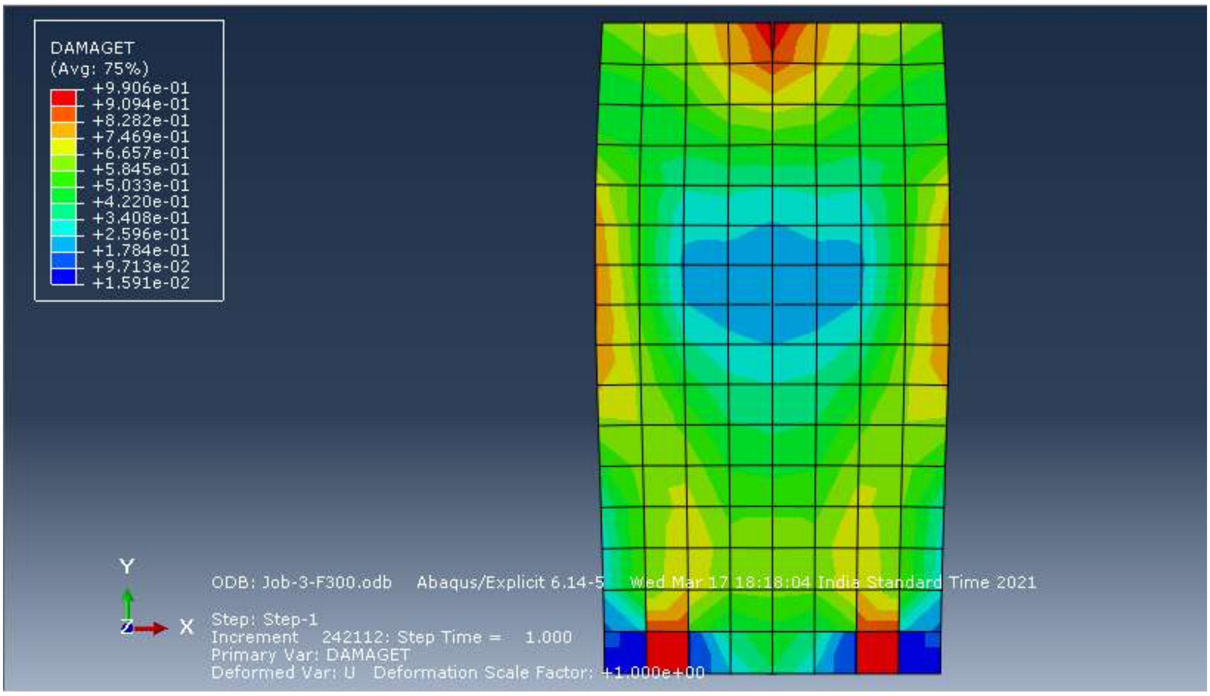
Mesh Sketch

Contour plots of the distribution of tensile & compressive damage

Compressive damage –



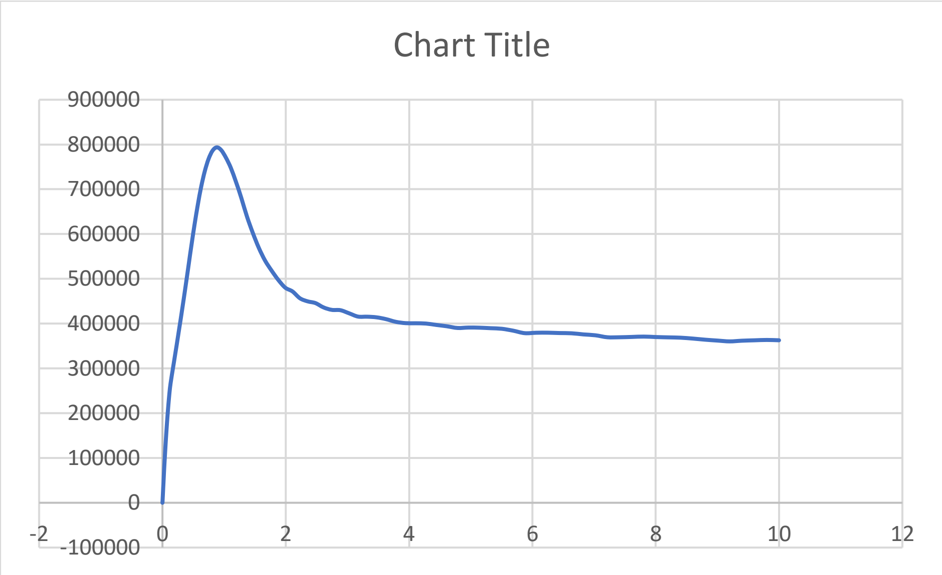
Tensile damage –



Comparison of the load-displacement curves

Reference table - 17CE31001 Load Displacement Table.xlsx

(Tab-F300)



In case of Flexible plattens failure start from the top whereas in case of stiff plattens failure starts in middle of column.

In case of flexible plattens, plattens have low stiffness and undergo high lateral deformation. It result in outward directed shear forces. Which led to development of splitting cracks at the end of column.

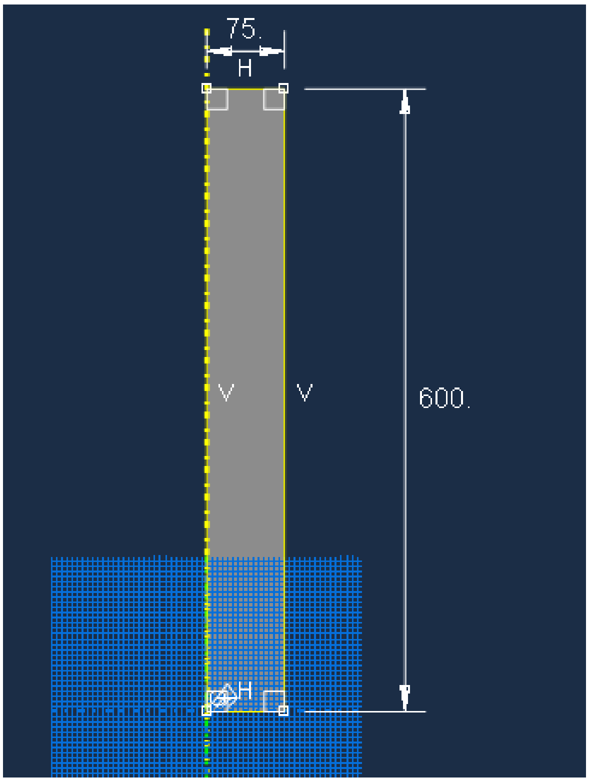
Part 3.b

(Height = 600mm) Flexible plattens

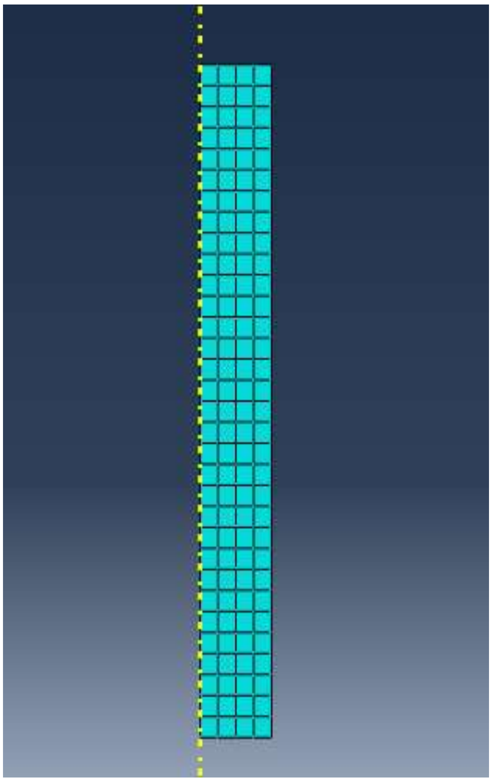
File - F600.cae

Model - axisymmetric finite element model

- Approximate global size for mesh – 18.75
- Technique – structure



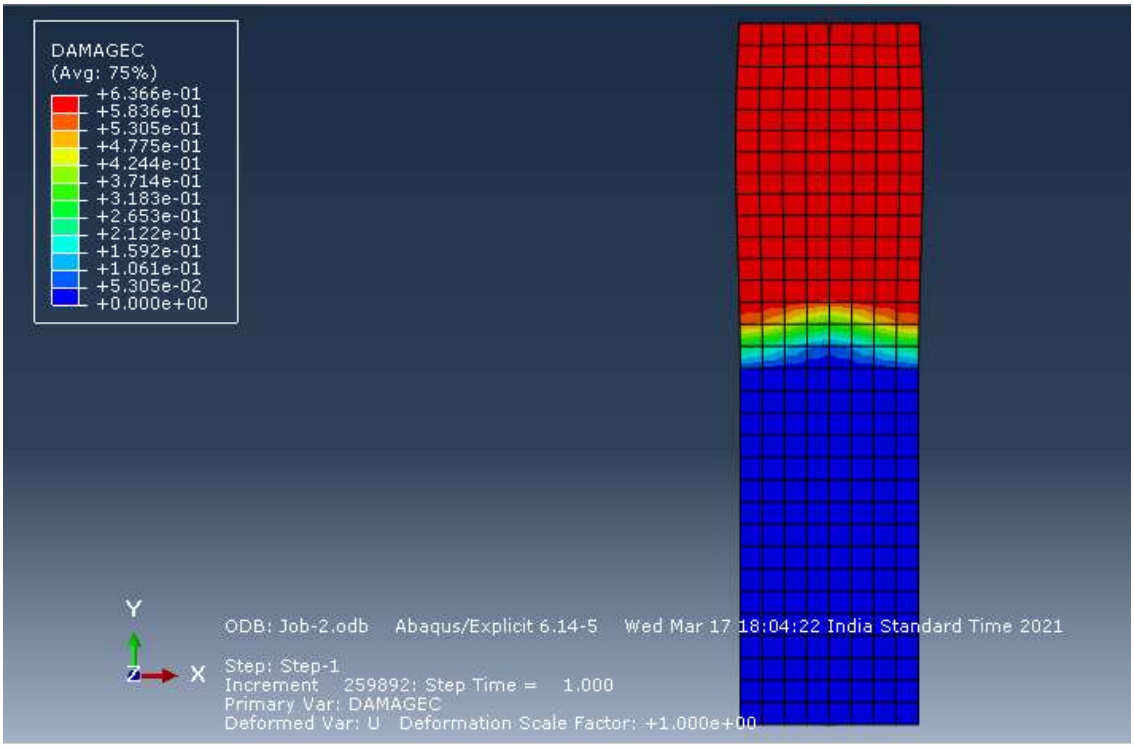
Section Sketch



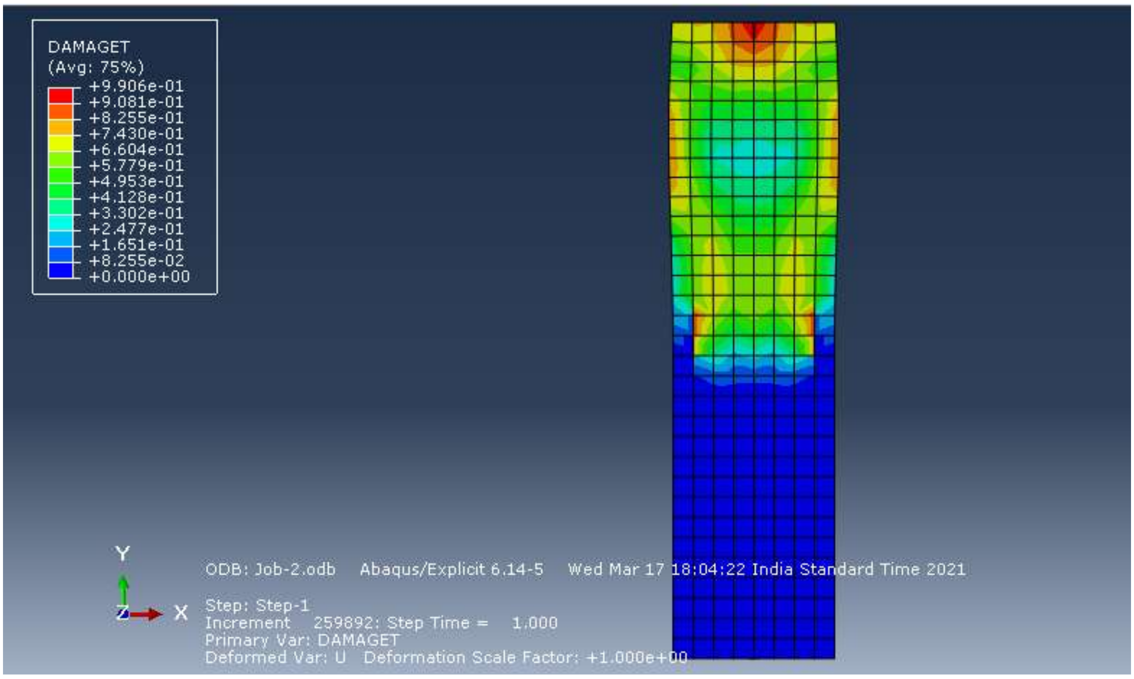
Mesh Sketch

Contour plots of the distribution of tensile & compressive damage

Compressive damage –



Tensile damage –



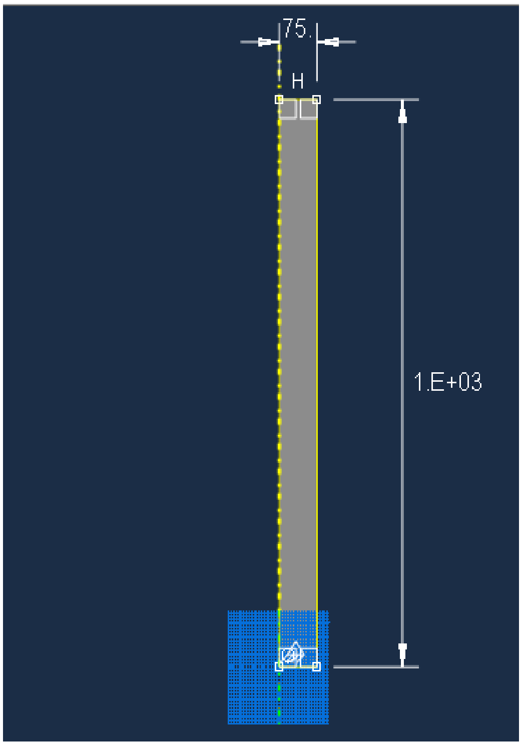
Part 3.c

(Height = 1000mm) Flexible plattens

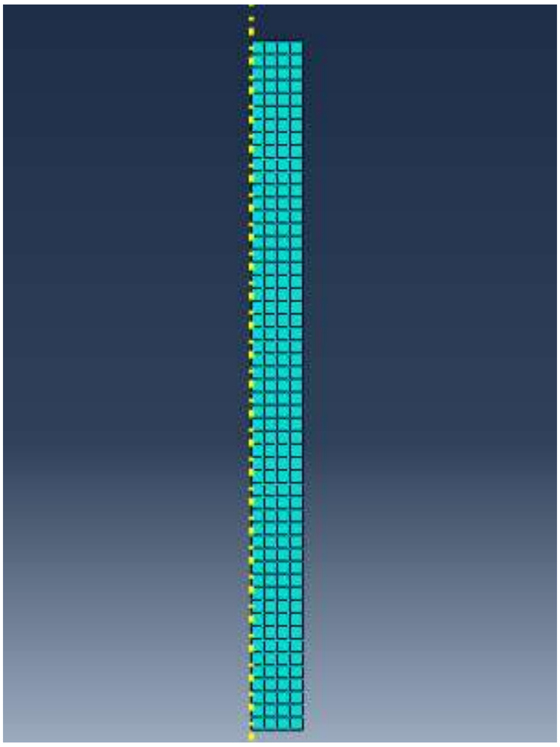
File - F1000.cae

Model - axisymmetric finite element model

- Approximate global size for mesh – 18.75
- Technique – structure



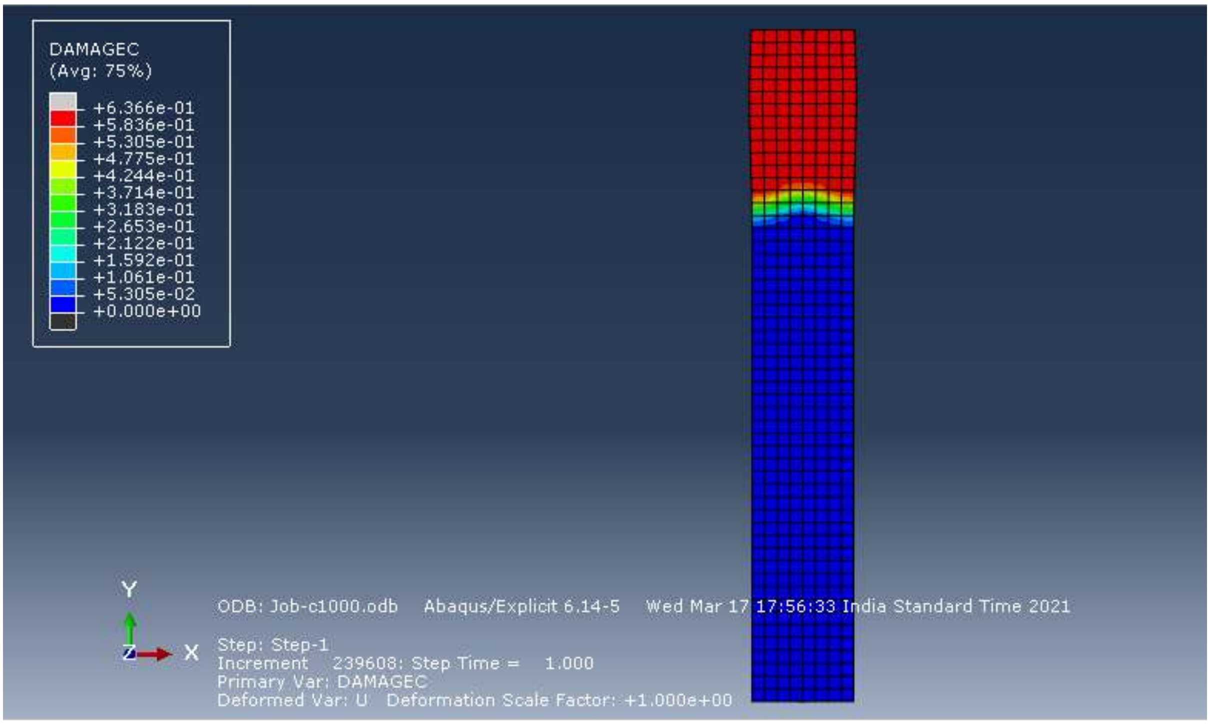
Section Sketch



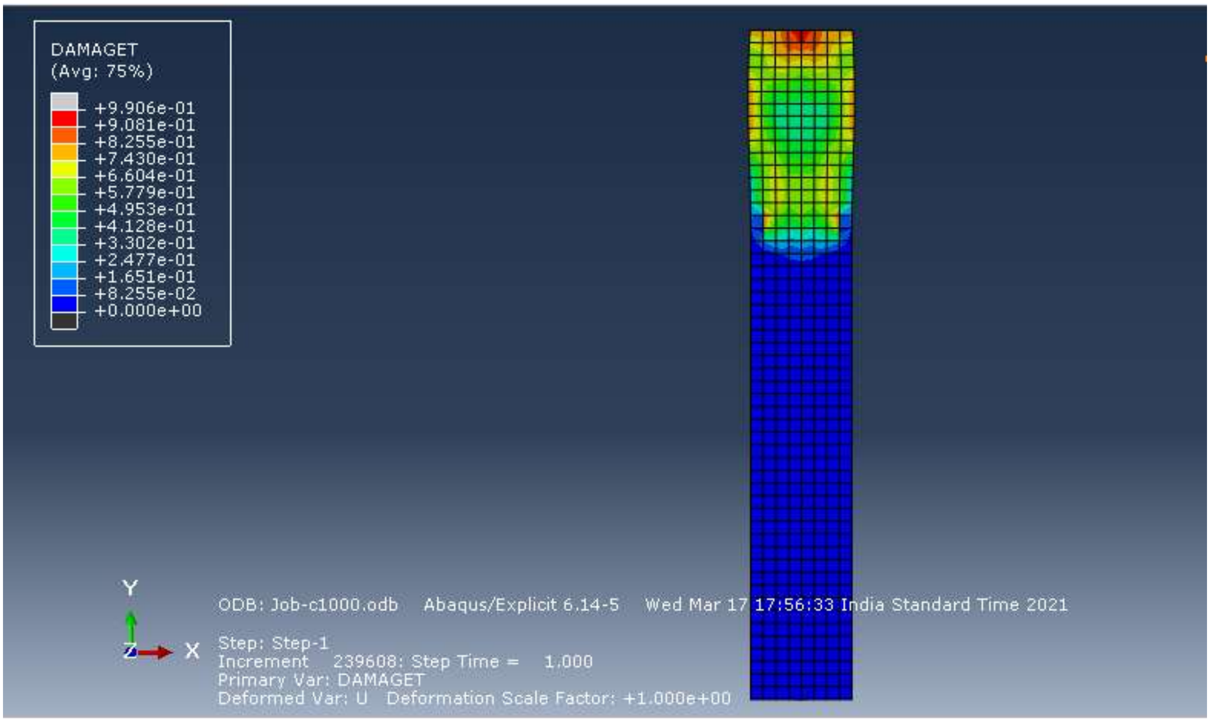
Mesh Sketch

Contour plots of the distribution of tensile & compressive damage

Compressive damage –



Tensile damage –



Part 4

Mesh dependence in the solution

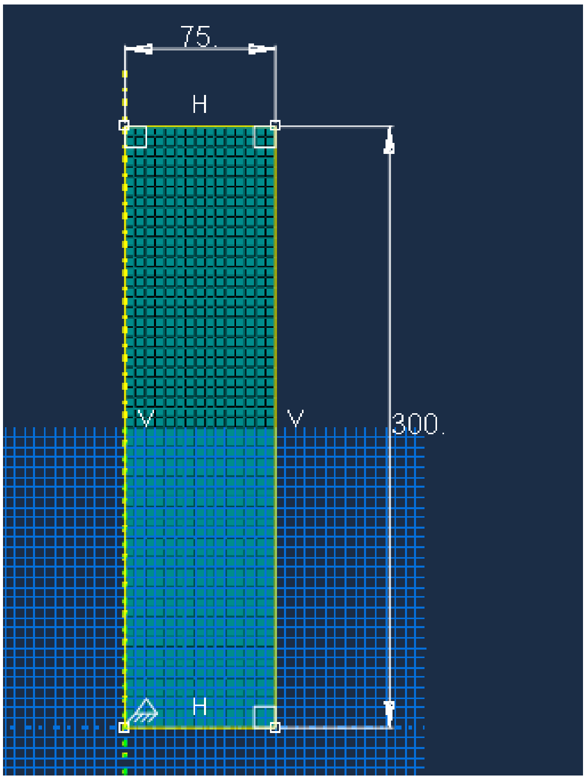
File used – C300_2.cae

For evaluating mesh dependence we again created new model with

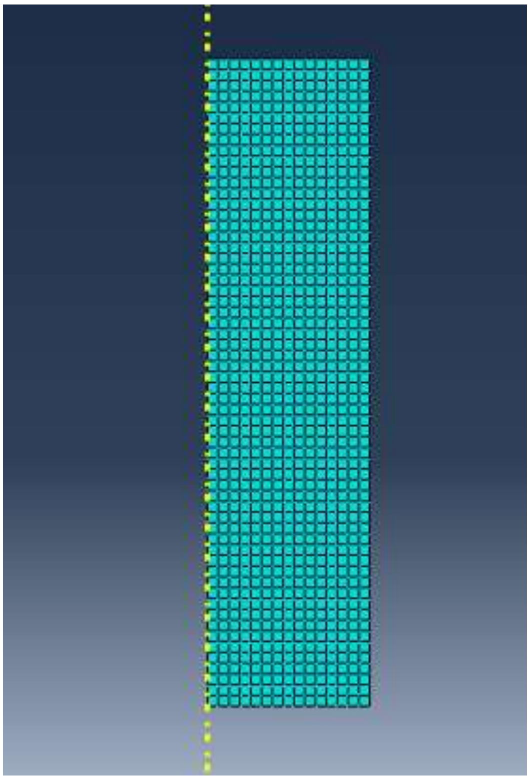
Radius =75mm and height = 300mm

But this time we used mesh Approximate global size = 5mm

This increases the no. of mesh which led to increase in computational time but we get more precise result



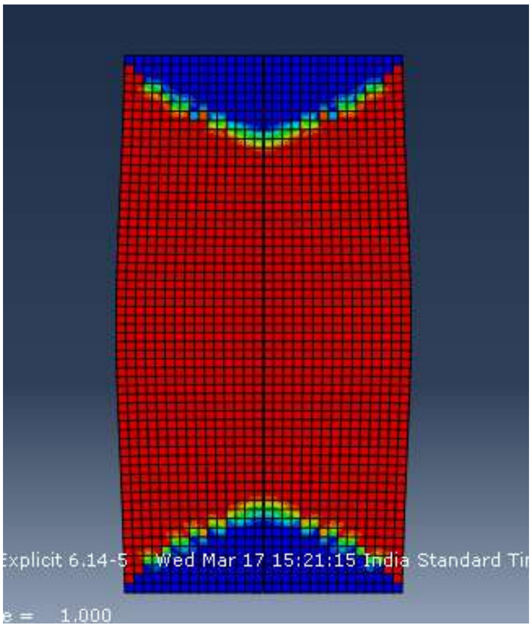
Section Sketch



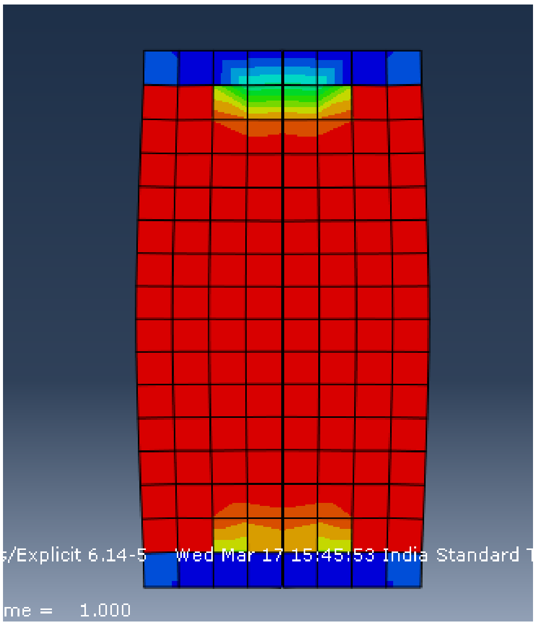
Mesh Sketch

- **Comparison in results -**

Compressive damage

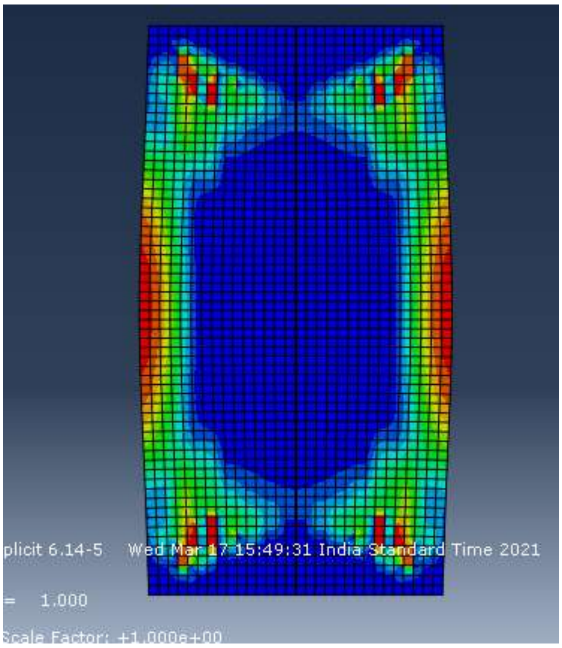


Mesh size = 5mm

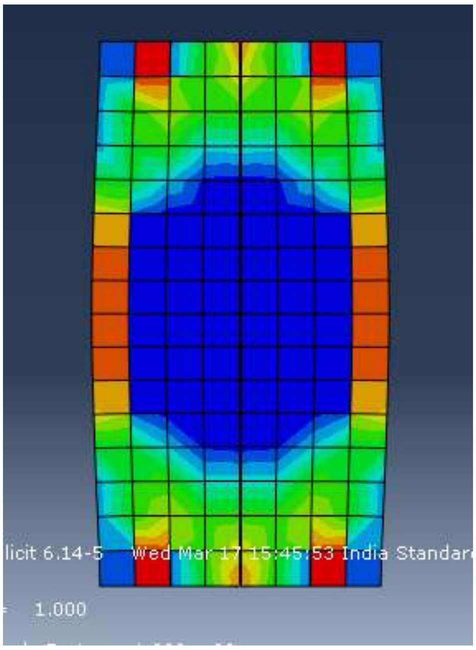


Mesh size = 18.75mm

Tensile damage



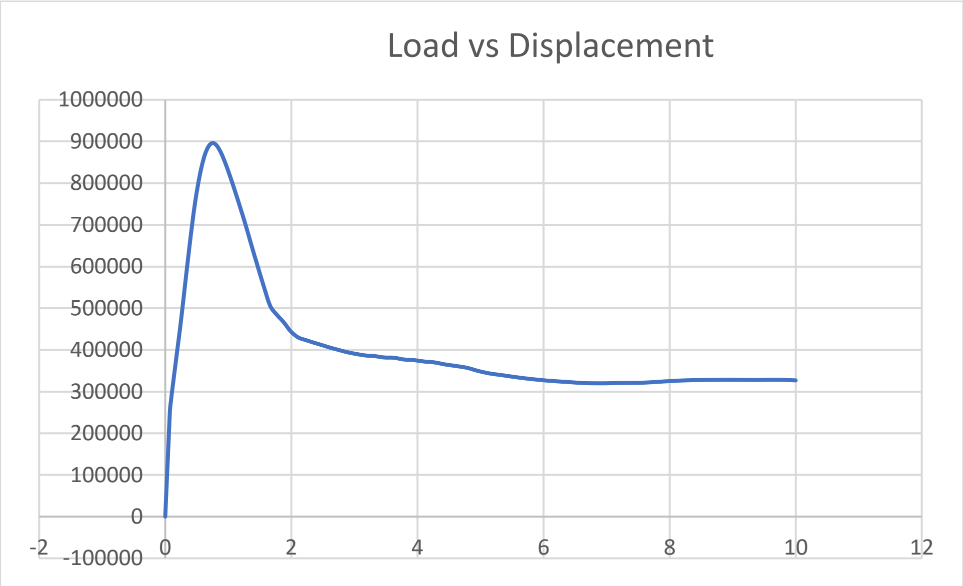
Mesh size = 5mm



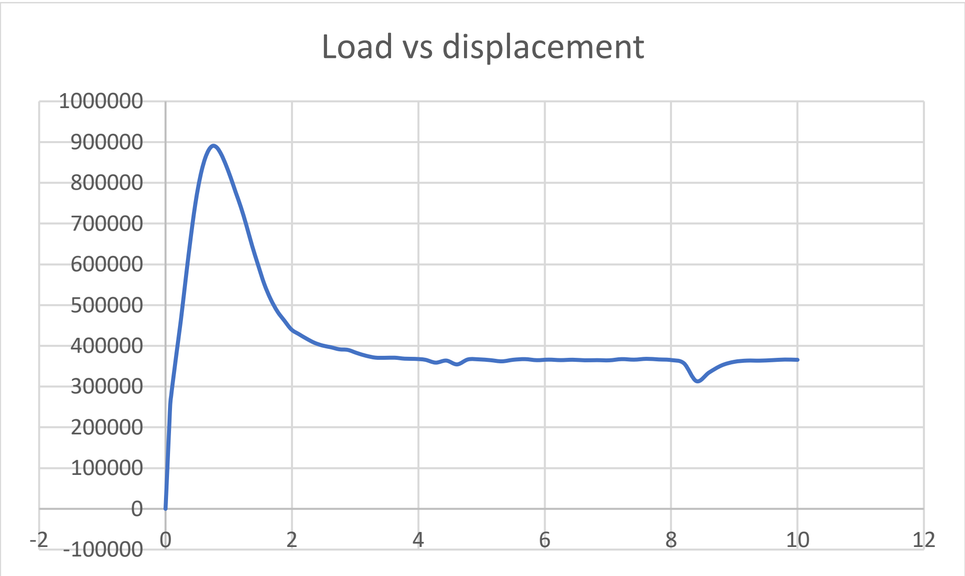
Mesh size = 18.75mm

- **Load vs displacement graph –**

Mesh size = 5mm



Mesh size = 18.75mm



Results are approximately same in both case but in case of finer mesh (mesh size = 5mm) results are more precise.

Part 5

Reference

- ABAQUS Analysis User’s Manual, v6.9, Simulia Corp., Providence, Rhode Island.

- “A Numerical Approach to the Complete Stress Strain Curve of Concrete”, Popovics S., *Cement and Concrete Research*, 3, 1973.

- “Local approach to Fatigue”, Hordijk, P. A, Doctoral thesis, Delft University of Technology, 1991.

- Concrete damaged plasticity - https://abaqus-docs.mit.edu/2017/English/SIMACAEMATRefMap/simamat-c-concretedamaged.htm#simamat-c-concretedamaged-compressivehardening