Chapter 3

Verification of the working procedure:

First we have to check the method ,we are working with , with experimental data before applying on ship structures. The equation[1] on which the software is working on:

Time dependent strain graphs are fitted into power equation in order to define the expression for uniaxial creep strain in terms of uniaxial stress σ, time t and temperature T

$$\frac{d\varepsilon}{dt} = \frac{C\sigma^m}{d^b} e^{-\frac{Q}{kT}}$$

Є : creep strain

C : a constant dependent on the material and the particular creep mechanisms

m and b: exponent dependent on the creep mechanisms

Q : the activation energy of the creep mechanisms

σ: the applied stress

d: the grain size of the material

k: the Boltzmann's constant

T: absolute temperature

The power law equation is modified to Bailey-Norton law[13] in order to define the expression for unaxial creep strain in terms of unaxial stress , time and temperature :

$$\varepsilon^c = C_0\, \sigma^{(C_1)} t^{(C_2)} e^{(\frac{-C_T}{T})}$$

ε^c : creep strain

C_0, C_1, C_2 : material dependent constants ($C_1 > 1$ and $0 \leq C_2 \leq 1$)

C_T : material constant defining creep temperature dependency

T : is the absolute temperature in Kelvin

t : time in hours

A sample creep test data was extracted for Grades of Stainless Steel –Grade 310 from reference:

http://askzn.co.za/stainless-steel/tech-grade-310.htm

Creep data :

Stress to develop a creep rate of 1% at the indicated time at the indicated temperature

Table 1: Creep data

Time	Temperature(C)	550	600	650	700	750	800
10,000h	Stress in MPa	110	90	70	40	30	15
100,000h	Stress in MPa	90	75	50	30	20	10

$$\varepsilon^c = C_0 \sigma^{(C_1)} t^{(C_2)} e^{\left(\frac{-C_T}{T}\right)}$$

$C_T = 0$ no temperature dependency.

Assume $C_2 = 1$

Therefore $\varepsilon^c = C_0 \sigma^{(C_1)}$

For a temperature 550 degree C

$.01 = C_0(110E + 6)^{C_1}(10000*3600)$

$.01 = C_0(90E + 6)^{C_1}(100000*3600)$

Solving the equations, we get

$C_0 = 1.616E - 102$
$C_1 = 11.47$
$C_2 = 1$
$C_T = 0$

Using these constants we applied the stress and temperature for two separate time duration to see the results matching with the experimental data or not. We observed two analyses to see creep rate 1% is verified or not.

A rectangular bar (50mm*50mm*200mm) has undergone a normal stress 110MPa for 10,000 hours according previous test data. Symmetric boundary condition assumed. Creep strain rate should be 1%. Fig 3(i) is the whole model we are working with. Here test is done for one-forth of the steel bar.

We took a simple steel bar of specifications:
Length : 100 mm

Cross section : Rectangular 25mm*25mm

	Analysis 1:	Analysis 2:
Applied load:	110MPa	90MPa
Temperature:	550degree	550 degree
Time:	10,000hours	100,000 hours

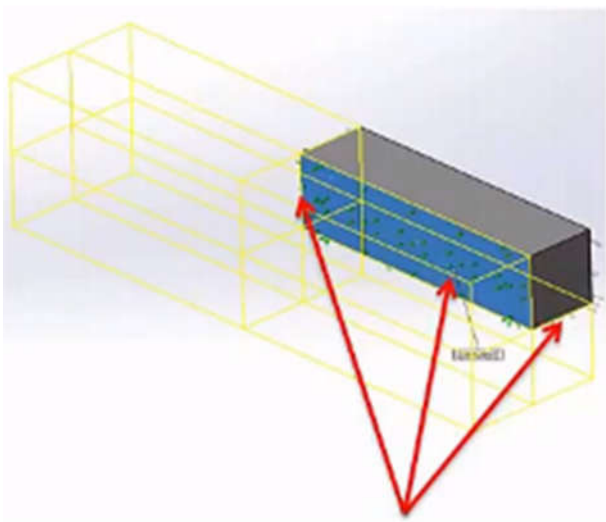


Fig 3(i): Drawing of the model

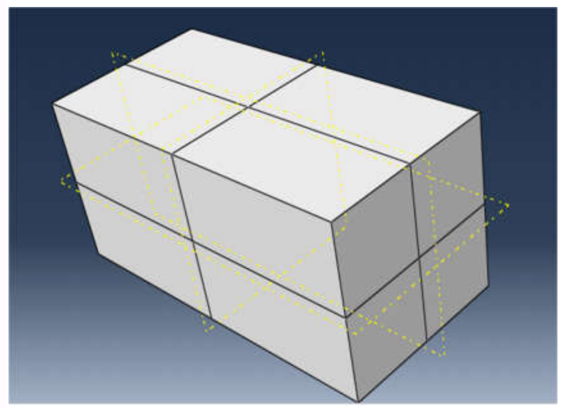


Fig 3(ii): Model generated in abaqus

3.1 Working procedure step by step:(Analysis 1):

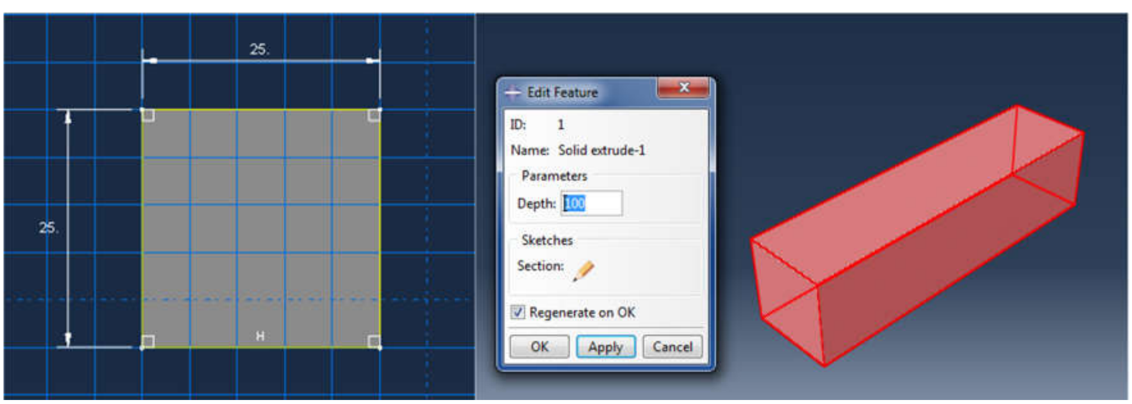


Fig 3.1(i): Step 1 : Part

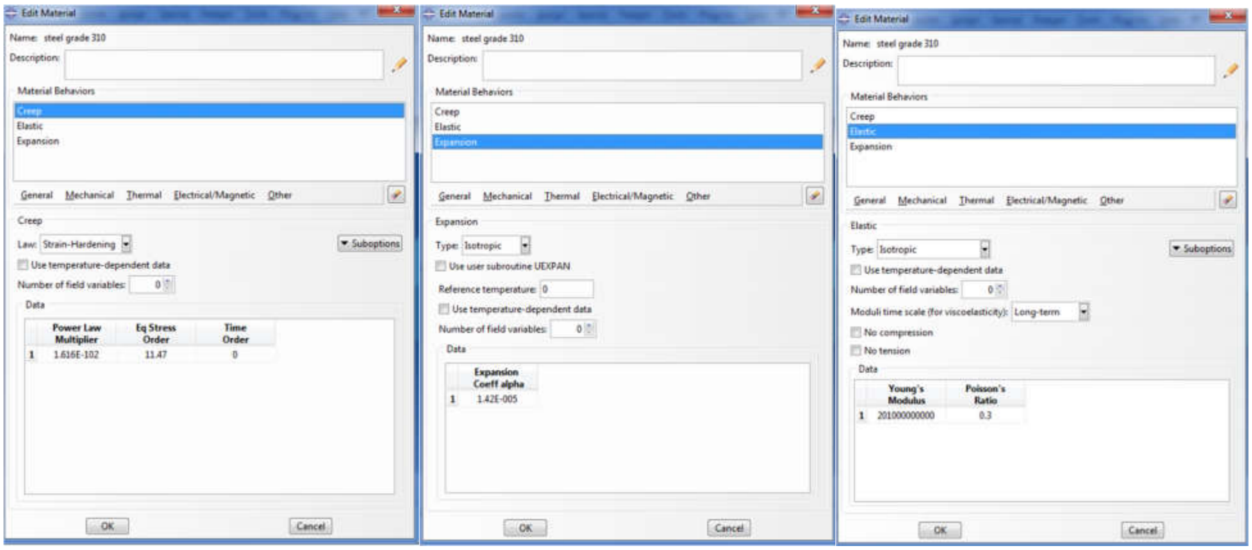


Fig 3.1(ii): Step 2 : Property

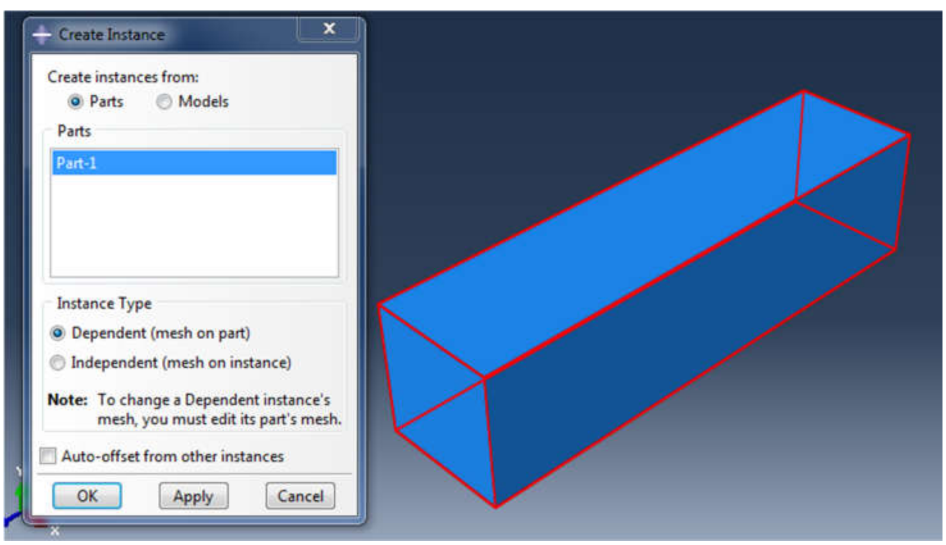


Fig 3.1 (iii): Step 3: Assembly

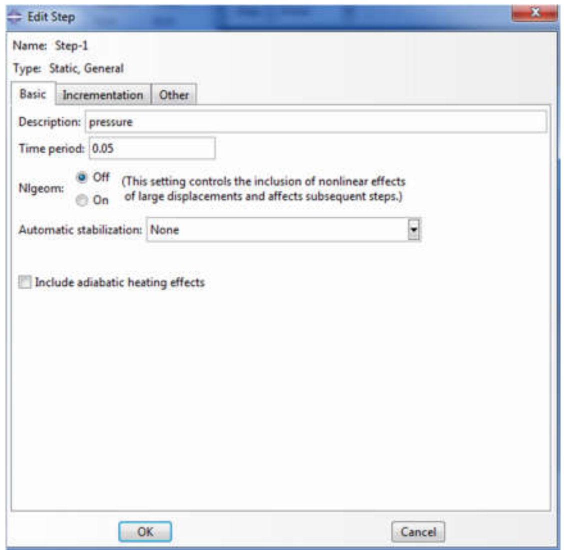


Fig 3.1(iv):Step 4: Static analysis step

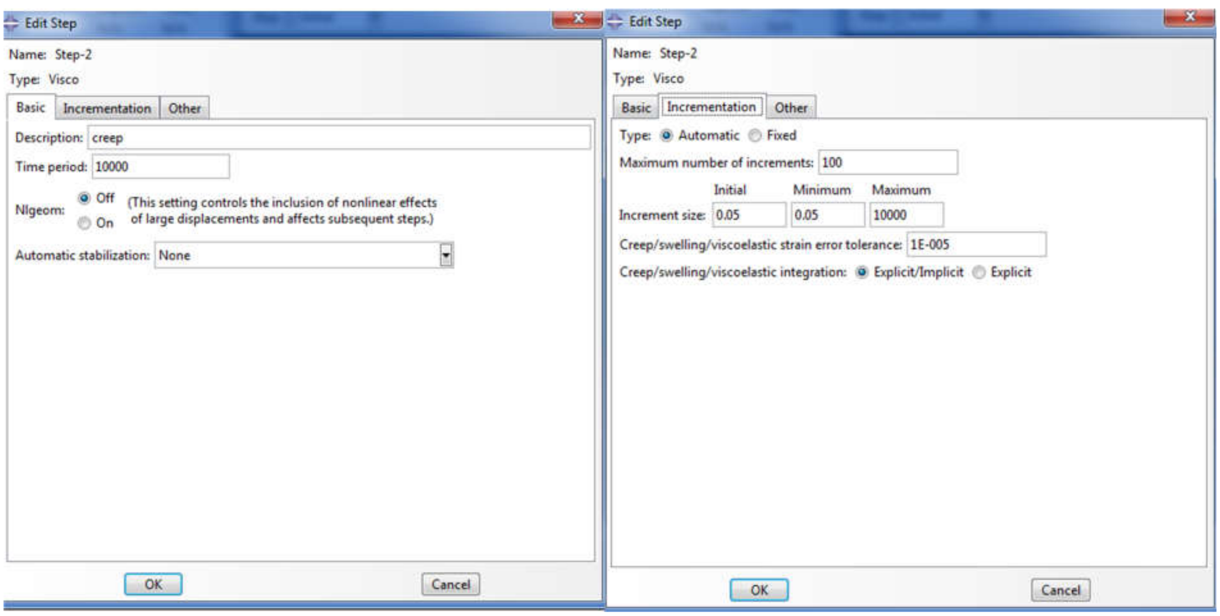


Fig 3.1(v):Step 5: Creep analysis step

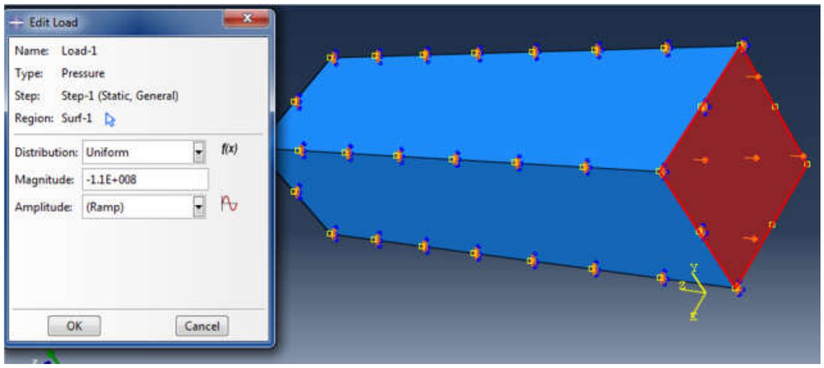


Fig 3.1(vi):Step 6: Load applied

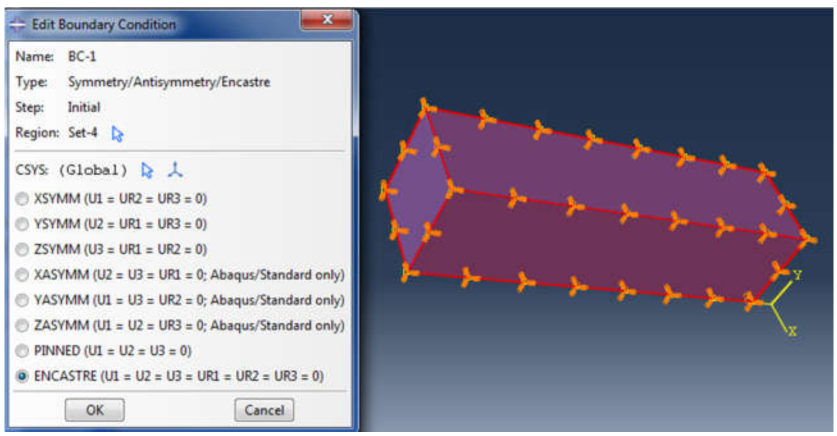


Fig 3.1(vii):Step 7: Boundary condition applied

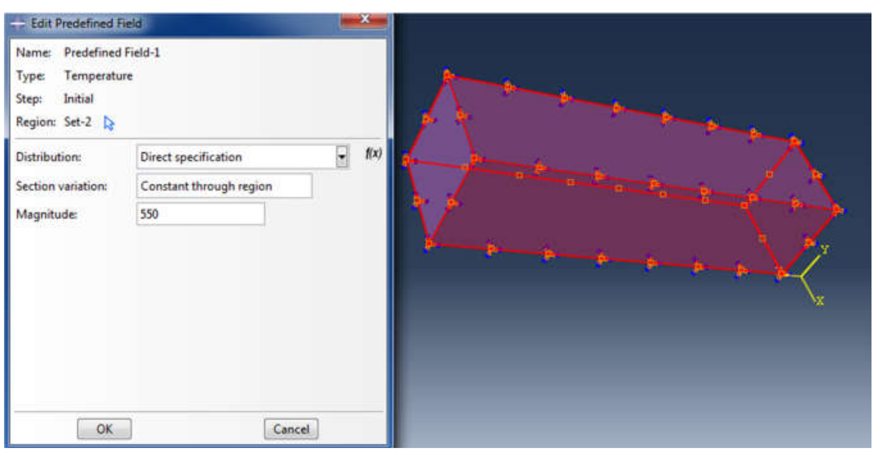


Fig 3.1(viii):Step 8: Temperature applied

3.1.1 Mesh sensibility test:

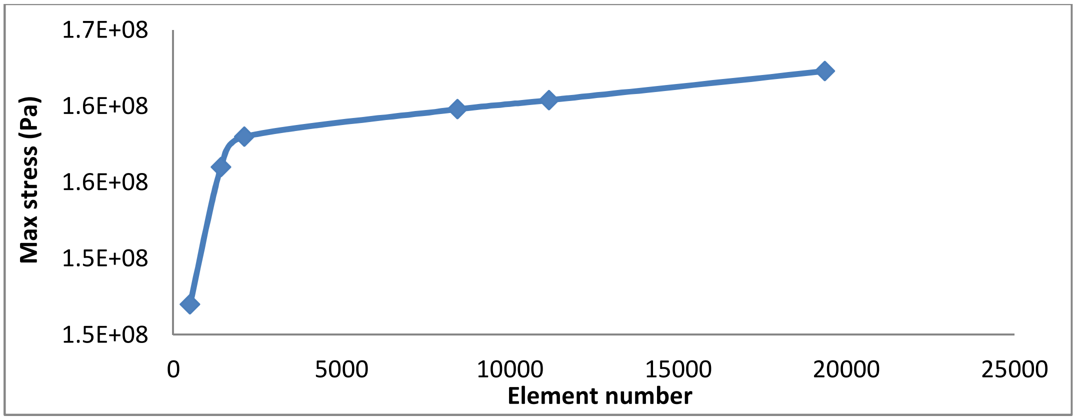


Fig 3.1.1(i): Max stress vs. element number

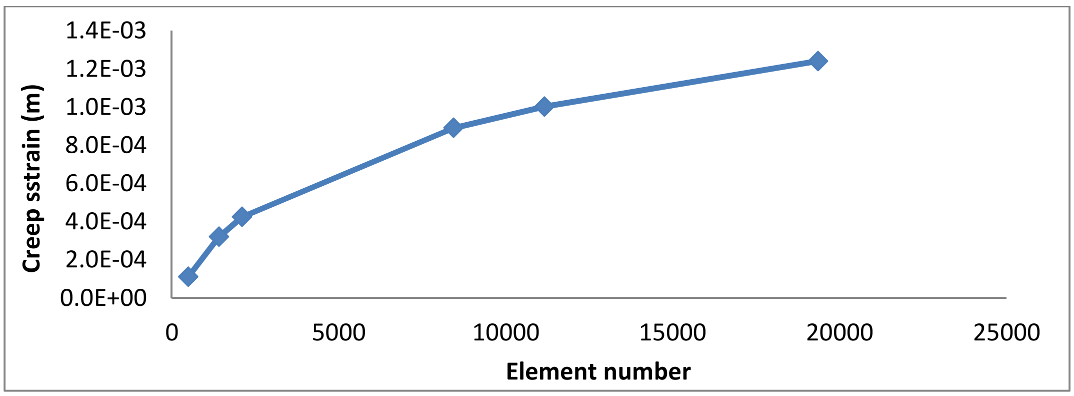


Fig 3.1.1(ii): Creep strain vs. element number

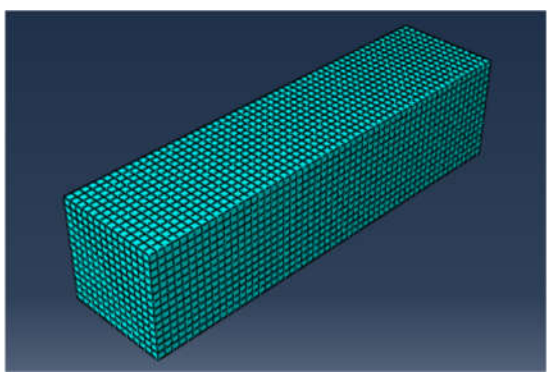


Fig 3.1.1 (iii): Step 9: Model is meshed

In the graph 3.1.1(ii), the slope of the curve reduces with increasing element number. After element number 11000 the slope reduces the most that means the change in the value of creep strain with increasing element number is the least. After considering fig: 3.1.1(i) and fig:3.1.1(ii) we choose to work with a model of mesh quality having 15872 elements.

3.2 Results:

3.2.1 Visualization:

Analysis 1:

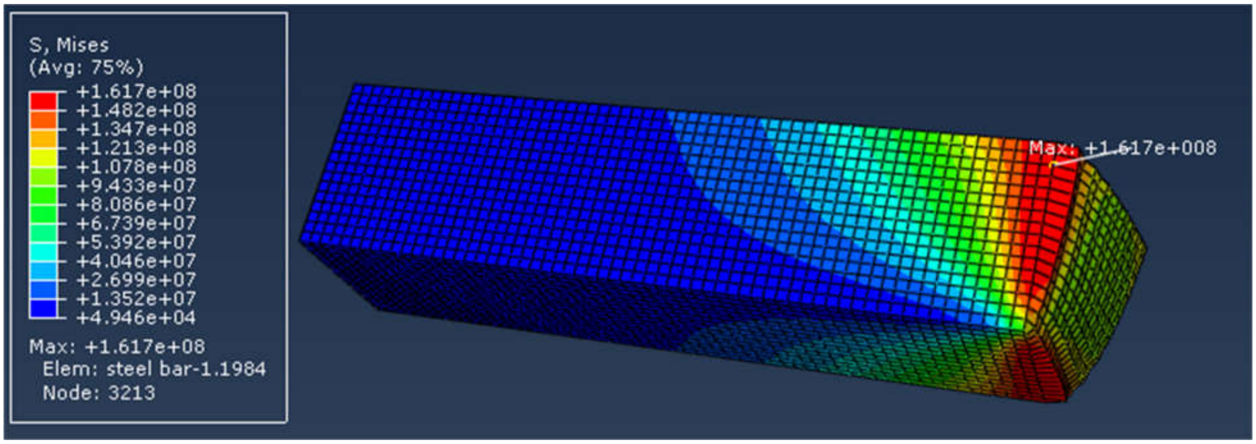


Fig 3.2(i): Static analysis results

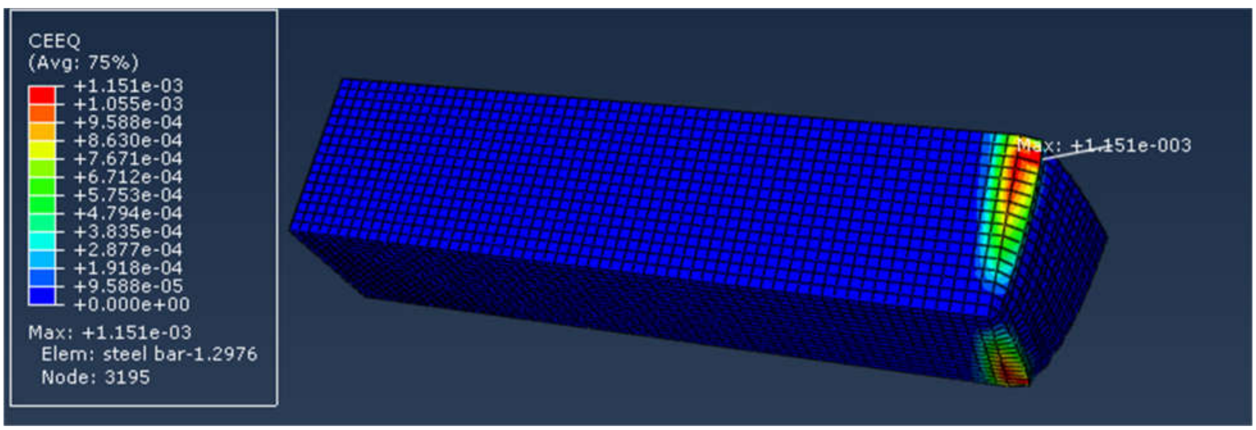


Fig 3.2(ii): Creep analysis results

Analysis 2:

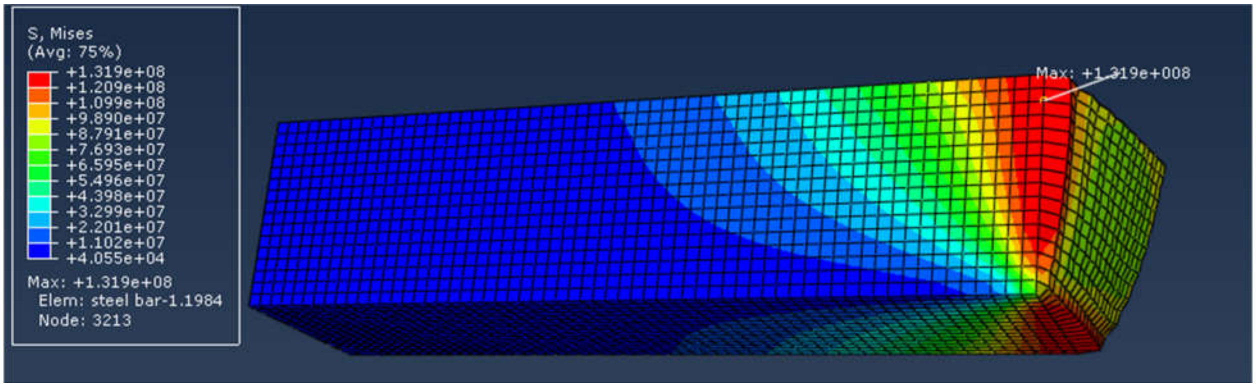


Fig 3.2(iii):Static analysis results

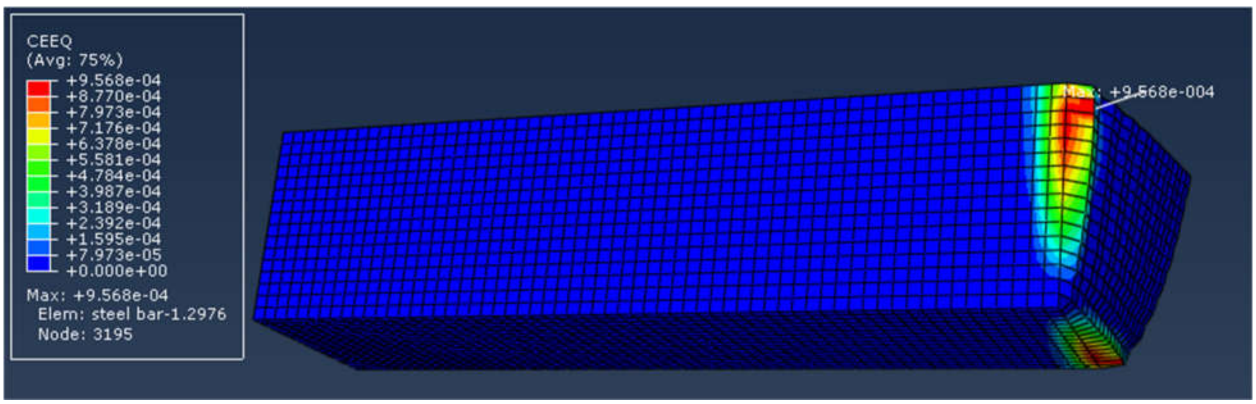


Fig 3.2(iv): Creep analysis results

We know the yield stress limit of steel is 250MPa and ultimate strength limit is between 400-550MPa. Fig:3.2(i) and fig:3.2(iii) shows the static analysis results for the steel bar for two analysis. Both the cases max. stress is below the yield stress limit.

Fig:3.2(ii) and fig:3.2(iv) show creep behavior of the steel bar for two analysis. Both the cases creep rate is almost 1%.

3.2.2 Graphical representation:

Analysis 1:

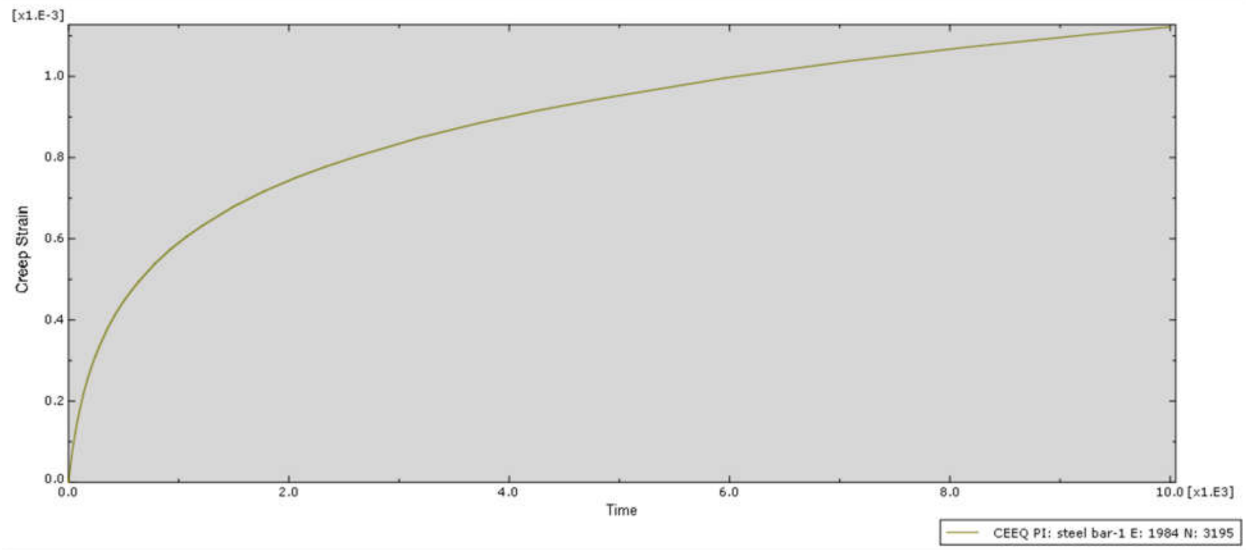


Fig 3.3(i): Creep strain(m) vs. time(hours) for the node maximum creep occurs

Analysis 2:

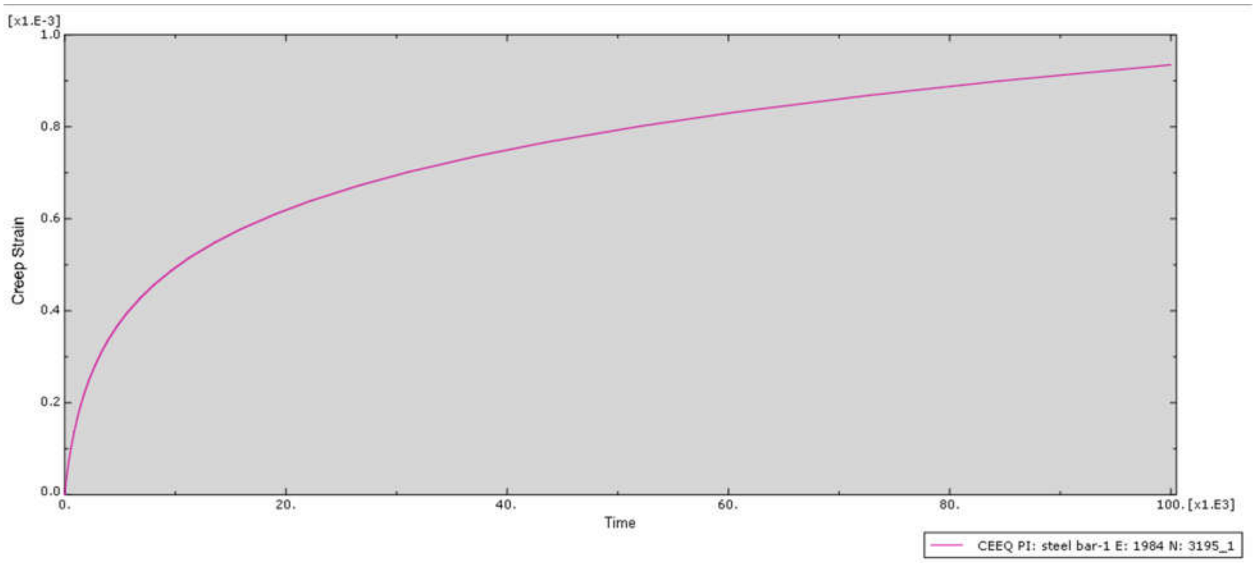


Fig 3.3(ii): Creep strain(m) vs. time(hours) for the node maximum creep occurs

3.3 Further analysis:

Further analysis was to generate curves of creep strain at various loads, temperatures and time.

As a result, we can use these graphs to predict creep strain for a given limit of loads, temperatures and time periods.
Here curves are generated for the node where creep strain value is maximum in each case

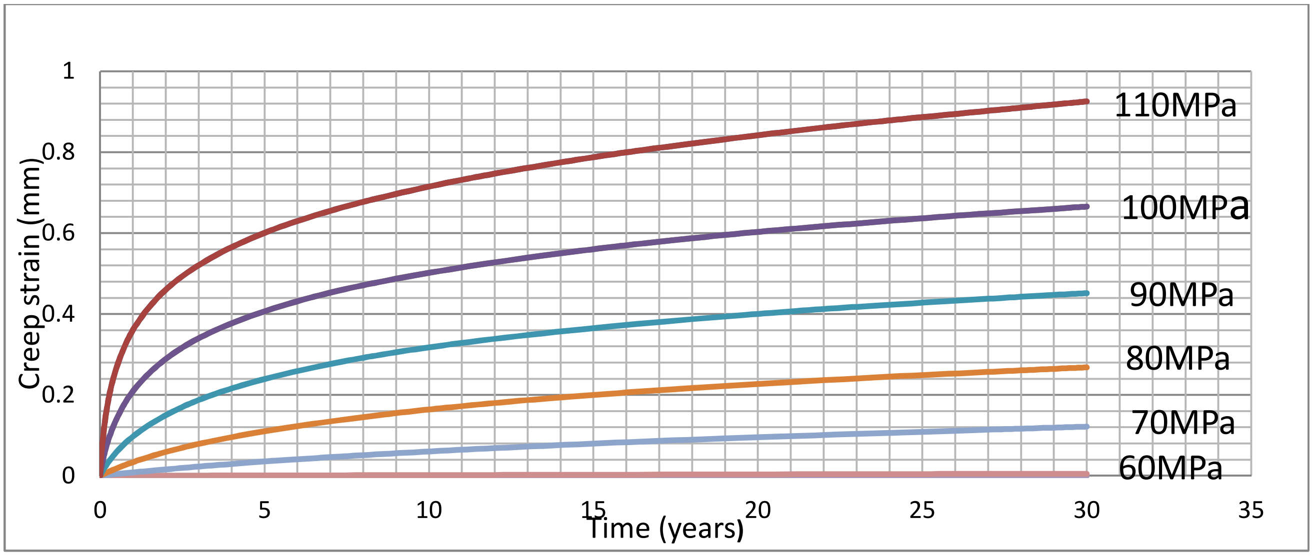


Fig 3.2.1: Creep strain vs. Time at 100 degree Celsius

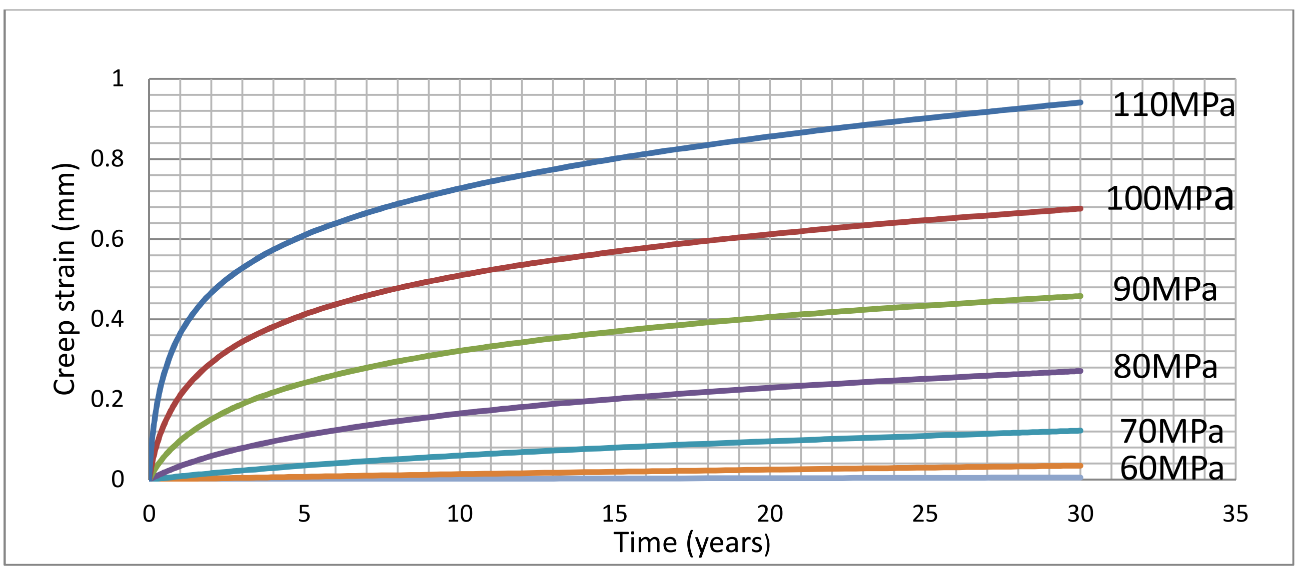


Fig 3.2.2 Creep strain vs. Time at 200 degree Celsius

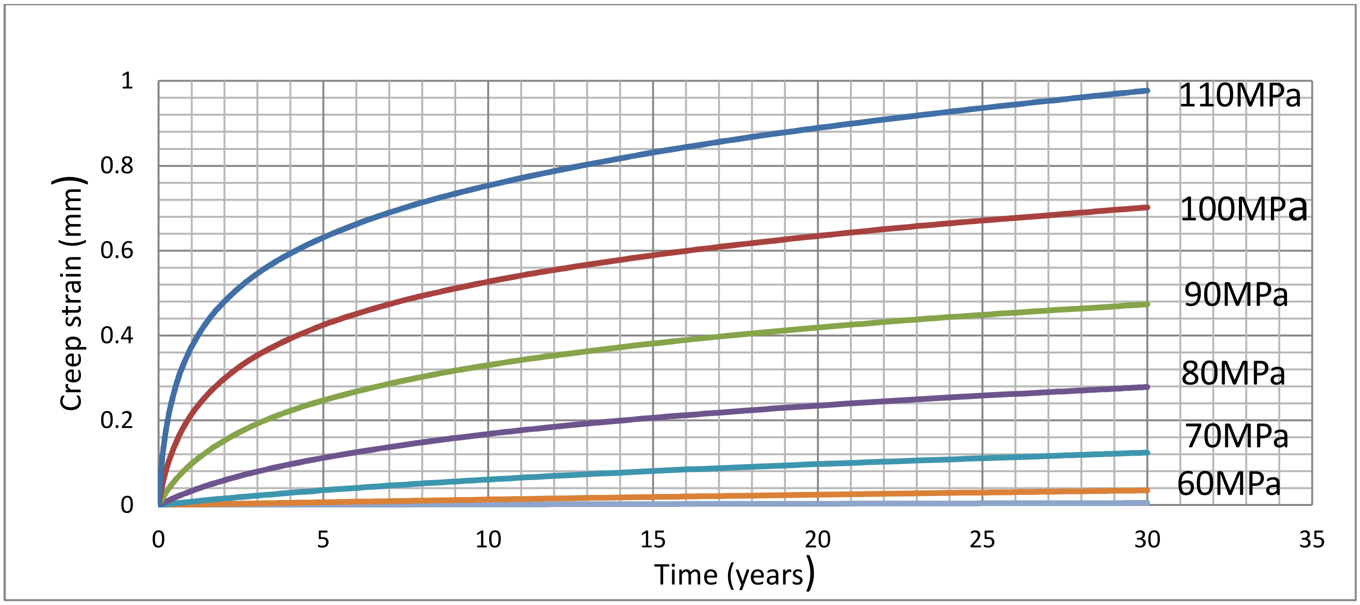


Fig 3.2.3: Creep strain vs. Time at 300 degree Celsius

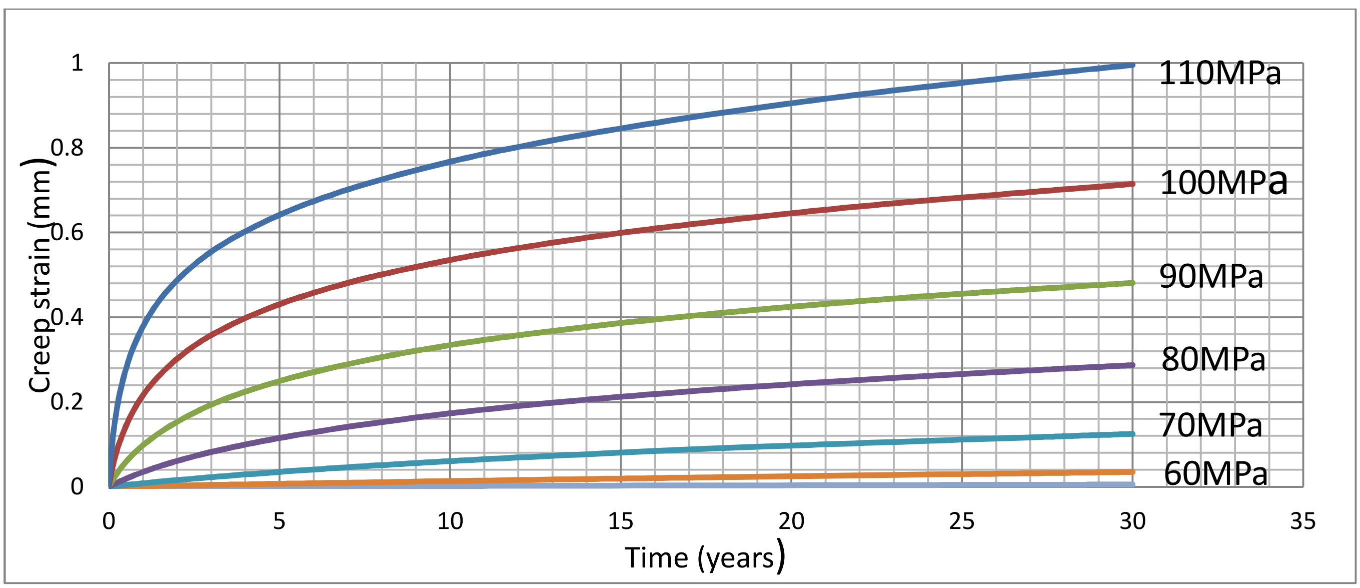


Fig 3.2.4 :Creep strain vs. Time at 400 degree Celsius

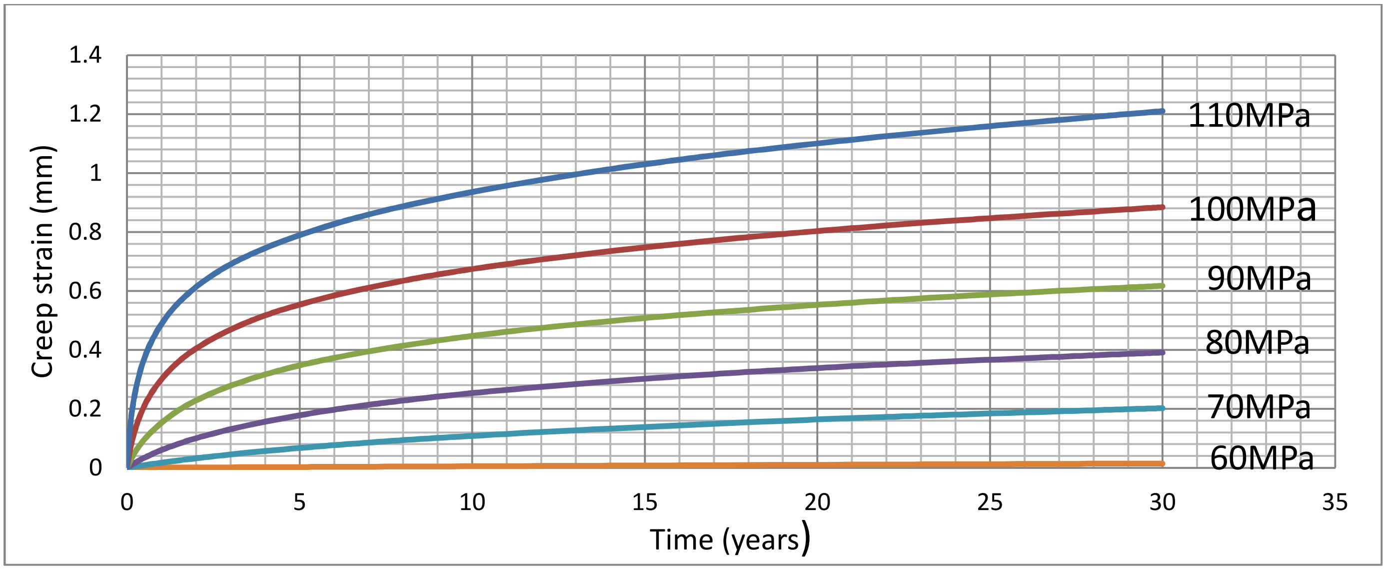


Fig 3.2.5: Creep strain vs. Time at 500 degree Celsius

3.4 Results and discussion:

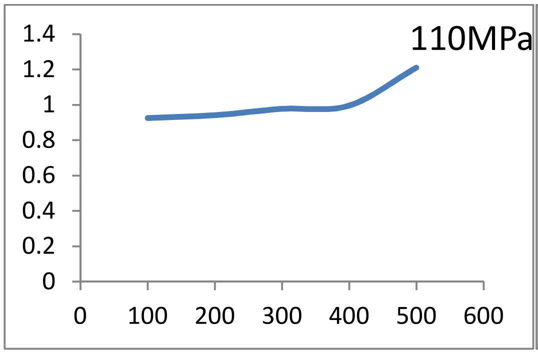
Table 2: Effects of load and temperature on creep strain

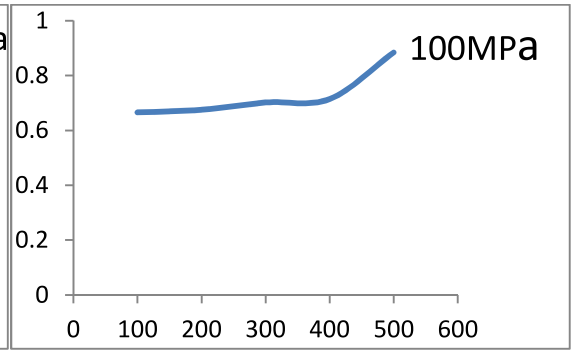
				Load			
Temperature	110MPa	100MPa	90MPa	80MPa	70MPa	60MPa	50MPa
100	0.9255	0.6657	0.4516	0.2682	0.1217	0.0054	1.50E-07
200	0.9413	0.675	0.4582	0.271	0.1222	0.0349	0.0053
300	0.977	0.7019	0.4735	0.2785	0.1241	0.035	0.0057
400	0.9955	0.7146	0.4811	0.2869	0.1247	0.0348	0.0052
500	1.21	0.8843	0.6176	0.3912	0.2023	0.0719	0.0146

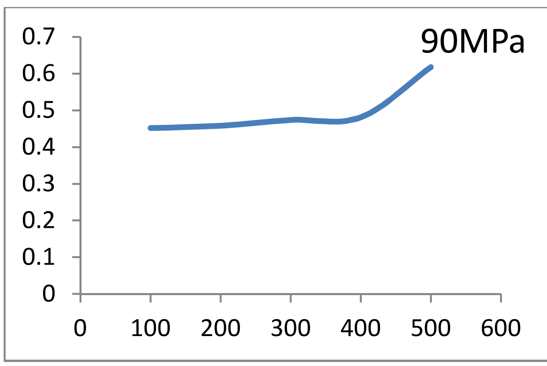
Creep strain vs. time graphs are shown in the fig 3.2.1-3.2.5. In the figure 3.2.1 curves are generated for 100 degree Celsius at different loads for 30 years. Fig: 1.2.4 in the basic concepts show the increasing creep strain with increasing load for a constant temperature. Here curves generated from results also show the same relation. We also observed the increasing instantaneous strain for increasing load. Fig :3.2.2-3.2.5 are for temperatures 200,300,400 and 500 degree Celsius respectively.

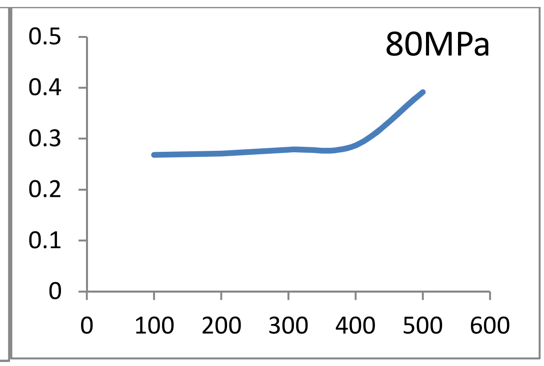
Table: 1 shows the effect the of load and temperature altogether. For example for a constant load 100MPa increasing creep strain with increasing temperature is observed.

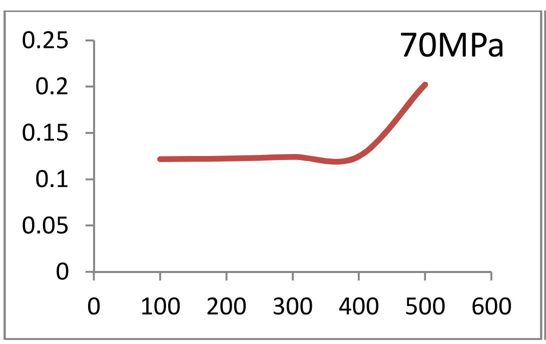
3.5 Creep strain vs. temperature graphs:

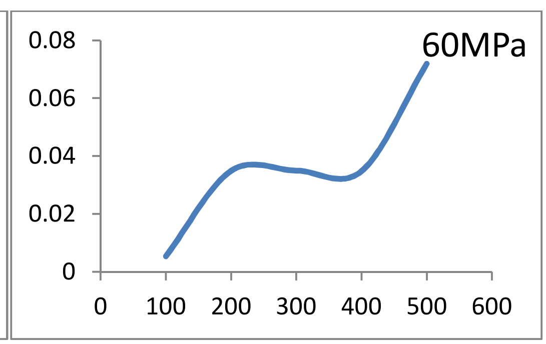












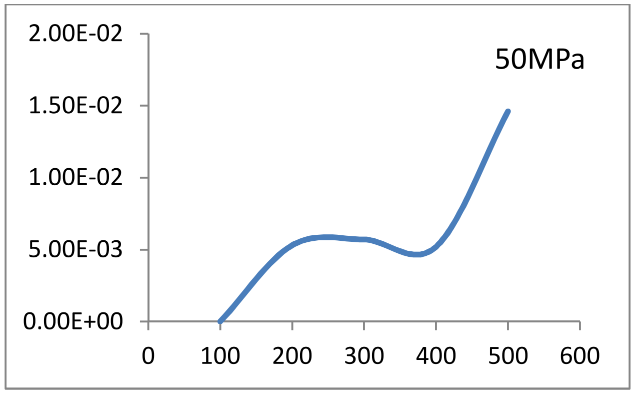


Fig 3.4.1:Creep strain vs. temperature for different loads

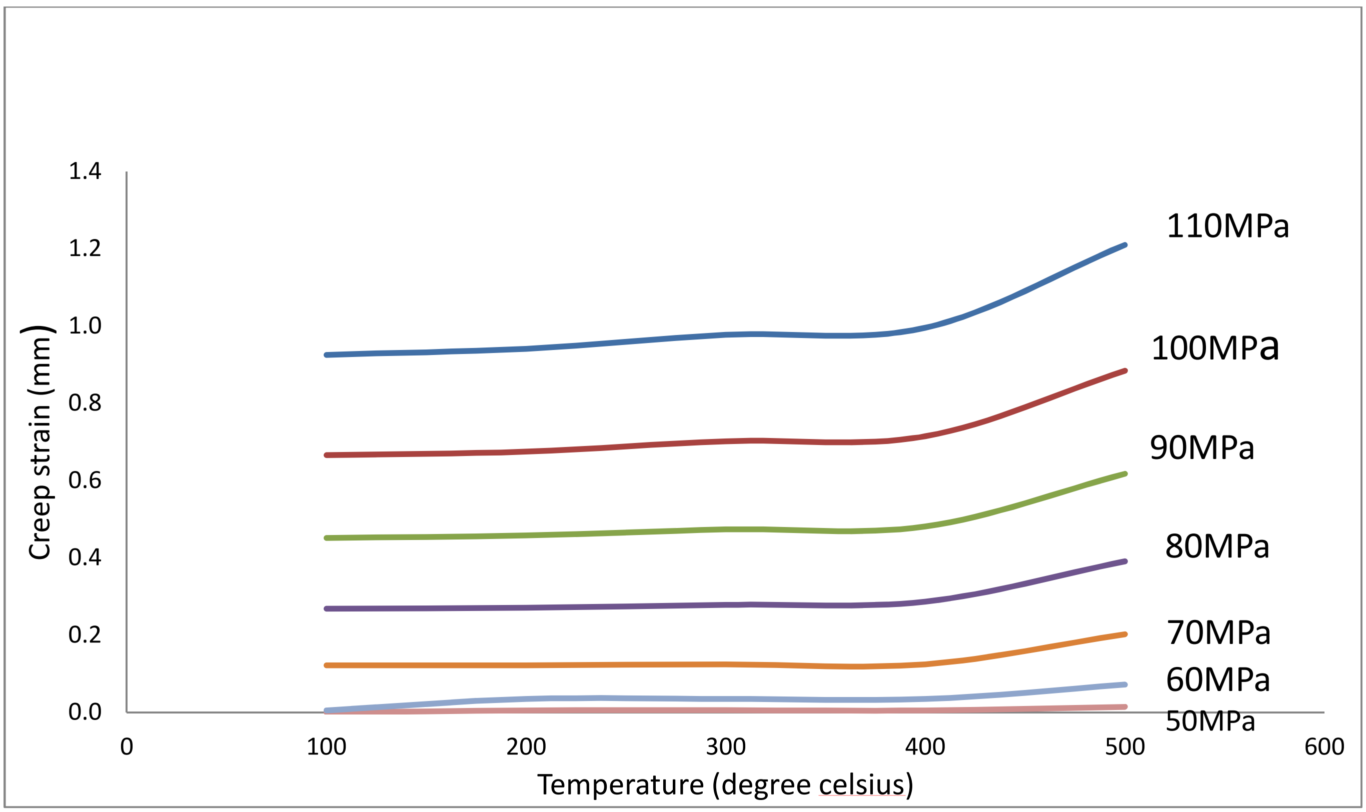


Fig 3.4.2 :Creep strain vs. Temperature curves at different loads.

Fig 3.4.1 shows how creep strain increases with temperature for a constant load. All the figures are accumulated in the fig 3.4.2 for seven different loads. Using these curves creep strain values for any other temperature between 100 to 500 degree Celsius can be predicted.