NUMERICAL SIMULATION OF PROJECTILE PENETRATION ON CONCRETE PANEL BY USING ABAQUS

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Under the supervision of

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to

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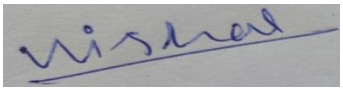
HIMACHAL PRADESH, INDIA

MAY, 2021

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitles **"Numerical simulation of Projectile Penetration on Concrete panel by using ABAQUS"** submitted for partial fulfillment of the requirements for the Master of Technology in Civil Engineering (Structural Engineering) at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Saurav.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project.



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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Numerical Simulation of Projectile Penetration of Concrete Panel by using ABAQUS"** in the partial fulfillment of the requirements for the award of the degree of Masters of Technology in Civil Engineering (Structural Engineering) submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Vishal (192654)** during the period from July 2019 to may 2020 under the supervision of **Dr. Saurav**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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ABSTRACT

A numerical simulation of a high velocity effect on a concrete structure is complicated problem in today's world. Protection of a structures in case of accidental and intentional extreme loading is become a serious trouble in the recent decades. The extreme loading or accidental loadings bordering our human life attracted more and more public attention, such as vehicle impact in traffic accident, ballistic impact in terrorist attack and natural earthquake. Concrete is one of most commonly used construction material in both defense engineering, civil engineering and its projectile impact properties such as the penetration depth, crack propagation and damage are always a proper concern. This numerical model is used to predicting the impact behavior of a concrete panel having reinforcement in their outer region; the concrete panel is penetrated by a two types of projectile having a velocity of 400m/s and 600m/s. The concrete panels have a dimension of 600mm x 300mm x 300mm. The comportment of a concrete panel is molded by utilize the Johnson- Holmquit (JH2) ceramic model which includes the damage of concrete panel, damage of reinforcement and penetration of a projectile. For a projectile-1 the length is 150mm and for a projectile- 2 the length is 160mm and both are deformable type. The internal energies, kinetic energies, strain energy and total energy are evaluated. The velocity is 400m/s and 600m/s for projectiles.

Keywords: Projectile penetration; Johnson- Holmquist (JH2) ceramic model; Damage in concrete panel and reinforcement; Reinforcement concrete panel; Velocity impact.

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LIST OF ACRONYMS

RC	Reinforced Concrete
JH2	Johnson- Holmquist 2
HEL	Hugonoit Elastic Limit
UHPC	Ultra High Performance Concrete
DOP	Depth of Penetration
UHPC-SF	Ultra High Performance Concrete- Steel Fiber
P-1	Projectile-1
UHPFR	Ultra High Performance Fiber Reinforced Concrete
P-2	Projectile-2
UHMWPE	Ultra High Molecular Weight Polyethylene Fiber
FEM	Finite Element Method

CHAPTER 1

INTRODUCTION

1.1 General

Concrete is a material which is widely used in components or structures all over the world. When we, studying the behavior of the reinforced concrete structures under a impact of large dynamic loads. Due to the cost material cost is sometimes high; it is not suitable for the large scale experiments. The numerical simulation is a technique commonly used to describing events related to the impact of high-speed projectiles on reinforced concrete slabs and concrete structures. The numerical simulation is the major understanding in both the computation mechanics and physical reality is required, towards accurate responses of material to reproduce. When modeling reinforced concrete, this becomes more apparent due to the bonding behavior of concrete, the complexity of concrete, and the problems related to the manufacture of embedded metal reinforcement**.**

1.2 Reinforced Concrete

Unfortunately the concrete has the main disadvantages it's very low ductility and it's weaker in tension. This will showing that the expansion of the reinforcement concrete (RC) where most concrete is cast round excessive tensile load carrying ability and greater ductility. RC is generally categorized as precast, forged in-place where concrete is poured into buildings or cast in recyclable mold in a good environment which is later transported.

1.3 Concrete Behavior under Impact Loads

The behavior of the cementitious material beneath a secure loading impact which can introduce on a high-rate loading conditions and they are depending on a variation of several constituent:

- The material elaborate in the experiment (the reinforced concrete and low/high strength properties of concrete).
- The geometry of a concrete targets and there reinforcement ratio/ position/ inclination

if reinforcement is include.

- The structure is meant to accommodate and contribute to system which is subjected to impression loading.
- The energy cause by bullet/ projectile and transferred to the structure of concrete is controlled along by speed, quality and elements of material, size (rigid/ hard or deformable/ soft) of missile used.

Because of a developing interest from each army and nuclear industry has advanced over a many years to uncover the phenomenological reaction of concrete systems impacted with the aid of the missiles, vast improvements were made in experiments characterization of concrete.

1.4 Concrete Material Models

The improvement of the numerically model and the improvement of the calculation method of the computing power of modern computer technique have made it possible along to simulate the ability to continuously record mechanical properties of the adhesive material with higher accuracy. The identity as for the concrete material is much compounded; this will show the development of the huge amount of the fundamental models. This models be classified at their elaboration of encompasses; they also include strain rate dependence, and shows the anisotropic properties. Even the maximum concrete various basic models are dependable order of quasistatic reproduction, where there is necessity of more research, decorate and develop the models for correctly capturing the nature of a concrete during the time of impact loading conditions. The improvement of the numerically model and the improvement of the calculation method of the computing power of modern computer technique have made it possible along to simulate the ability to continuously record mechanical properties of the adhesive material with higher accuracy.

Most concrete material models have been calculated widely with the numerical simulation impact to notice the fracture reaction of the cementitious materials models. Some basic models which has been produced in latest years which are Holmquist-Johnson II model. These material models are appropriate for the conduct of concrete and other brittle materials which can be subjected to effect conditions that produce a pressure, large strain rates and high strain rates.

1.5 Johnson-Holmquist (JH2) Ceramic Model

The JH2 model is the second repetition of the Johnson- Holmquist ceramic model it can correctly relate the phenomenological actions of brittle materials like pressure-strength dependence, strain-rate effects and dilation generate by damage (Johnson- Holmquist, 1993).

1.5.1 Strength

The JH2 model shows resistance determined by the state of material during the comparable stress period, considered the equation which are relate to every state. If material is undamaged, the value of D is equal to, the prototype displayed the magnification equation of complete material expressed and intact as:

$$\sigma_i^* = A(P^* + T^*)^N \ (1 + \ C ln\varepsilon^{\circ *} \ )$$

At time, when material is completely damaged (D=1), the model will follow resistance equation of the damaged material and displays as

$$\sigma_i^* = B(P^*)^M \ (1 + C ln\varepsilon^{\circ *} \ )$$

If the materials damage is found between the fractured and intact (0<D<1), the gov-ern-a-ble Calculation of strength is shows as

$$\sigma^* = \ \sigma_i^* - \ D \ (\sigma_i^* - \sigma_f^*)$$

All the power variables (A,B,C,M and N) and coefficients are the material parameters and $\varepsilon^{\circ *}$ is the strain rate which is are formalize by mention strain rate. The equations for the strength, which are made dimensionless by equalizing the stress at Hugonoit Elastic, limit (HEL), which are correlate with a uniaxial strain shock wave which overtake the elastic limit. The strength is normalized between

$$\sigma^* = \sigma \ / \ \sigma_{HEL}$$

The normalized pressure is defined as

$$P^* = \mathrm{P} / P_{HEL}$$

1.5.2 Damage

Alike to the concrete model HJC, the model JH2 will also further build up the damaging allying the summation of pressure which is equivalent, but not due to the volumetric compression, but through plastic deformation to separate all of them, thereby rupturing under constant pressure. The general calculation as shown below

$$\mathrm{D}= \sum \frac{\Delta \varepsilon_{\rho l}}{\varepsilon_f}$$

The breaking elongation equation of JH2 model is equivalent to breaking elongation equation of the JH2 model, the normalized pressure (P^*) is normalized by plastic deformation, and the maximum hydrostatic tensile strength is equal to the plastic deformation fracture T^* is equal to the plastic deformation fraction equation of the HJC model, the only difference is the standardized normalized pressure and the maximum hydrostatic tensile strength. Where D1and D2 are obtained via unconfined experimental compression test data, where the plastic strain ($\varepsilon_{\rho l}$), and fracture strain (ε_f) are used to obtain damage. The breaking elongation equation of JH2 model is equivalent to breaking elongation equation of the JH2 model, the normalized pressure (P^*) is normalized by plastic deformation, and the maximum hydrostatic tensile strength is equal to the plastic deformation fracture T^* is equal to the plastic deformation fraction equation of the HJC model, the only difference is the standardized normalized pressure and the maximum hydrostatic tensile strength.

$$\varepsilon_f = D1(P^* + T^*)^{D2}$$

1.5.3 Pressure

For a dynamic loading, the equation of states provides volume- pressure relationships for brittle materials can be shown as . For energetic loads, the equality states provides the volume pressure affiliation for breakable material shown as

$$P = (K_1 u + K_2 u^2) \quad \text{(Compression)}$$

$$P = (K_1 u) \quad \text{(Tension)}$$

The distant change of the K constant of the material in JH-2 model can be obtained when it when it collides with the plate. The model also including a pressure rise term that compensates for the loss of elastic energy when the material undergoes the plastic deformation.

$$P = K_1 u + K_2 u^2 + K_3 u^3 + \Delta P$$

When the material is transition from undamaged state to damaged state and starts to soften, the elastic energy (ΔU) of the sucker rod produced will decreasing. In order to retain the internal energy which is forgotten during the process, a pressure raise term is adding to reducing the loss of the kinetic energy by conversion elastic energy into potential hydrostatic energy. The following formula is :

$$\Delta P_{t+\Delta t} = -K_1 u_t + \sqrt{(K_1 u_t + \Delta P)^2 + 2\beta K_1 \Delta \cup}$$

β = The ratio of elastic energy converted into potential energy

u_t = Dilation of the current time step

CHAPTER 2

LITERATURE REVIEW

2.1 General

This chapter covers the brief review of the literature about the experimental including numerical simulation of concrete. Literature is regarding the several evaluation techniques are also discussed. In this chapter, discuss the various research conducted by the various researchers to study the different methodology. This chapter gives a complete review on the finding.

2.2 Review of Literature

Chahmi Oucif. [1] did a study on numerical simulation and experimental test on a concrete panel with the use of nose projectile. The concrete panel is 675mm x 675mm x 200mm in dimensions, where the bullet is 152mm long in length. The mass of a bullet is used much smaller in this modeling. The kinetic energies and internal energies are estimated in simulation. The velocity of ogive nosed projectile is 540m/s. The active energy of projectile is changed and it display reduction and as soon as projectile perforates in concrete panel. The panel is tends to absorb projectile energy, and strengthen or solidity of projectile. This simulation is done with the help of JH2 parameters.

Jian Liu, Ju Li [2] investigated the influence reaction of UHPC objective with 3 percent vol. ultra high molecular weight polyethylene fibers and UHPC destinations with 3 % in quantity metal fiber which are experimentally invested subjected to maximum- velocity bullet impact, where plain concrete objectives below the exact loading structure are also observe to control the instance for modified purposes, with the support of LS- DYNA software, a numerical study was carried out to simulate the projectile perforation system into the UHPC target. Numerical consequences in terms of intensity of penetration crater diameter, projectile corrosion and damages are compared with experimental observation. The numerical consequences reveal that fibers which are metallic reinforced in UHPC objectives have much more absorption capacity of energy as compared to UHMPWE fiber, where the UHPC-SF objectives has greater yield resistance to constrain the kinetic energy of bullet than UHPC-PF targets. The model which runs for simulation can completely express the DOP of UHPC targets, at a time of projectile impact.

The numerical model can show approximate depth of penetration (DOP) contrast with experimental observations.

M. H Zhang [3] research on a fiber effect, aggregate, flexural tensile strength of concrete panel under a projectile with the diameter 12.6mm and weight 15 gram. In this experiment the 1 % steel fiber, 1% polyethylene fibers, 1% polypropylene fiber are used in concrete. The velocity are used in this experiment are 600 to 700m/s. In the concrete the different types of fibers are used. The penetration depth is reducing with a increasing in compressive strength for concrete. When the strength is increasing, the crater diameter cannot reduce.

Wu et al [4] accomplished a research to study the impact of metallic steel fibers content and form of concrete. The results showed that the hooked end and crimped fiber had a much good impact on the compressive and tensile strengths rather than the straight fibers. The research also described the effect of fiber content on a peak loading and it showed that the fibers doesn't have a significant effect on the first crack.

P.P. Li [5] conducted a study of key design parameters of reinforced concrete on bullet. The dimensions of the bullet are 7.62 x 51mm. In the UHPFRC target having a larger thickness contribute a minimum DOP. The velocity for the bullet is 843m/s and 926 m/s.]

P. Maka [6] study to narrate the resistance of a ultra high performance concrete by projectile impact on concrete. The weight of projectile is 8 gram and the speed is 712m/s. The increasing of fiber which is more than 1% has a no such effect on the depth of penetration.

Radoslav Sovjak [7] conduct a research on unrelenting of a slim UHPFRC targets to projectile impact. The projectile effect is calculated on a slab to observe the consequences which is generated by explosion. The fiber content has volume minimum 2% is not good for UHPFRC targets because the reason is the higher potential of bullets.

Garas [8] showed that the use of fibers can reduce the drying shrinkage by over 100%.

CHAPTER 3

MATERIALS AND RESEARCH METHODOLOGY

3.1 General

The whole research is divided into the three parts. In the 1st part of the research work know about the review concept, theories and finding the previous research on a experimental and numerical modeling of projectile penetration on concrete. The 2nd part is modeling and validation of concrete and projectile and selection of the materials properties from the research. The 3rd part it is based on the design of different type of bullet impact on concrete at a different velocities, and check the analysis and comparison of a results. This chapter offers a entire review of the findings alongside guidelines for the future investigation.

3.1.1 Research Objective

- To simulates the penetration of projectile-1 and projectile-2 in concrete panel at velocity 400m/s and 600m/s.
- To evaluate the damage in concrete panel (V= 400m/s and 600m/s)
- To calculate, damage in inner region of panel (400m/s and 600m/s)

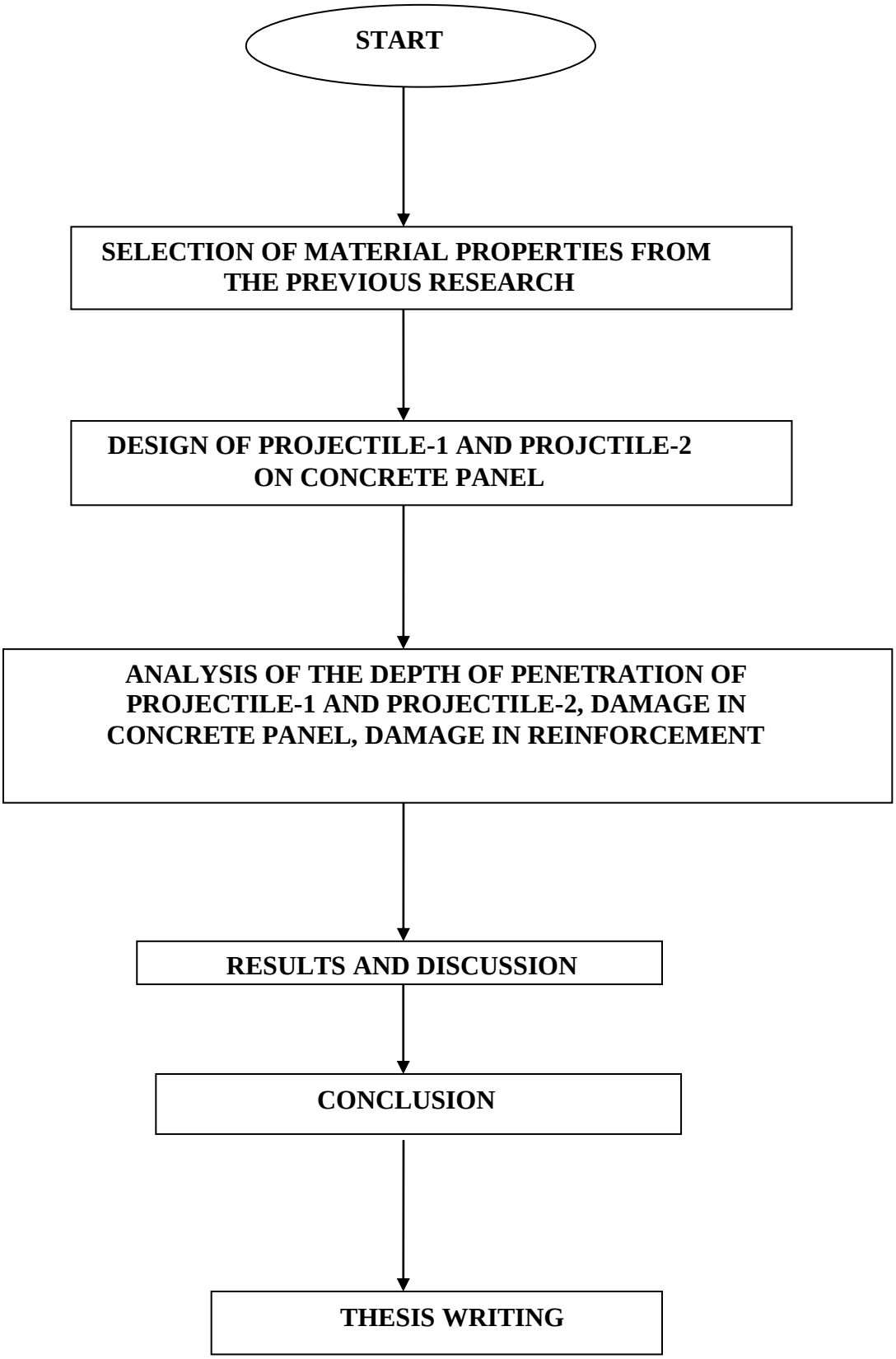


Fig.3.1 Methodology of project

3.2Numerical Simulation

3.2.1 General

In this part, the study of numerical modeling is carried out with the method of finite elements using the software ABAQUS. The objective of this study is to analyze the behavior of projectile penetration of concrete panel with reinforcement.

3.2.2 Finite element method

The Finite Element Method (FEM) is a method which is widely used to simulate the behavior of a various structures. . The finite element model consists of decrementing the actual geometric structure into a series of finite elements, where every element is a detached section of material structures.

3.2.3 Abaqus Software

In this part, the numerical simulation is done by Abaqus/ CAE which is used to model the concrete panel having a reinforcement which is penetrated by two projectiles with different shapes (projectile-1and projectile-2) at velocity 400m/s and 600m/s. Firstly we can creating a part in which the different parts are created for modeling. In this simulation the three parts are created concrete panel, reinforcement and proejectile-1, and also three parts are created for the projectile-2. After parts, we can assign the material properties for the each and every part. The properties for each material are accurate, at the end of property assigning the material property to the each part. In a third step assembly has been done between the parts. In a step part, the approximate time period is given for the simulation and field output request is created. After the step the interaction has been done for the model with the help of each part. Each part has his own interaction. In this model firstly the interaction is done between the reinforcement in the outer region of concrete panel then interaction of the projectile has been done. After the interaction the meshing has been done for the each part. In this research, the node displacements is of interest, from which the stress and strain of each element and how to obtain the stress and strain can be obtained, as a result all the overall behavior of the concrete and steel may be expected. It is

important that the user have appropriate concept of what could be doing, in a particular choice about a mesh size and element type which can choose for a problem.

In the ABAQUS/EXPLICIT the following steps are carried out for the modeling are:

- Part
- Property
- Assembly
- Step
- Interaction
- Load
- Mesh
- Optimization
- Job
- Visualization
- Sketch

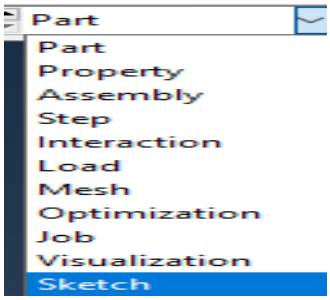


Fig.3.2. General steps of ABAQUS

3.3Part

The part is the first step in the modeling. In the part we can create the separate geometry of distinct material with their proper dimensions and create the models. In the part every material has there own configuration. In this simulation we can create a model of concrete panel, two types of projectiles with their reference points.

3.3.1 Concrete Panel, Reinforcement and Projectile geometry and model construction

The dimensions of the concrete panel and projectile are shown below:

Concrete Panel: 600mm x 300mm x 300mm

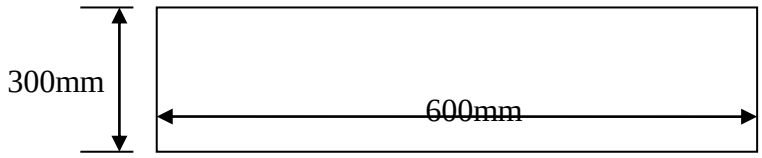


Fig.3.3. Sketch of Concrete Panel

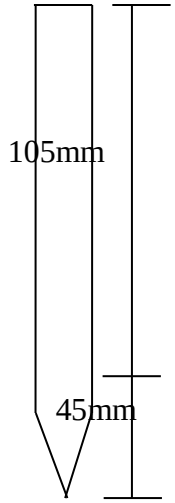


Fig.3.4.Sketch of Projectile-1

In the modeling of the concrete panel the steel reinforcement is used in their inner region. The dimensions of a concrete panel is 600mm X 300mm X 300mm, and the dimension of projectile-1 is 150mm in length and 15mm diameter and mass of a projectile is small.

3.3.2 Concrete Panel

In Abaqus/ CAE simulation, the parts are created to manufacture the model for the graphical user workflow in which we can creating the models, submitting the jobs for analysis we can create the input files for the monitor and at the end we can evaluating the results. The parts are creating in the Abaqus from the particular base feature, which can containing the geometry information and there is a rule which can governing the behavior of the geometry. In this simulation the geometry of concrete panel is created in the 3D modeling space which is deformable type and having a base feature solid which is extrusion type and approximate size is 2000. From the edit base extrusion the end conditions is blind type and depth is 300mm shown in Fig.3.5

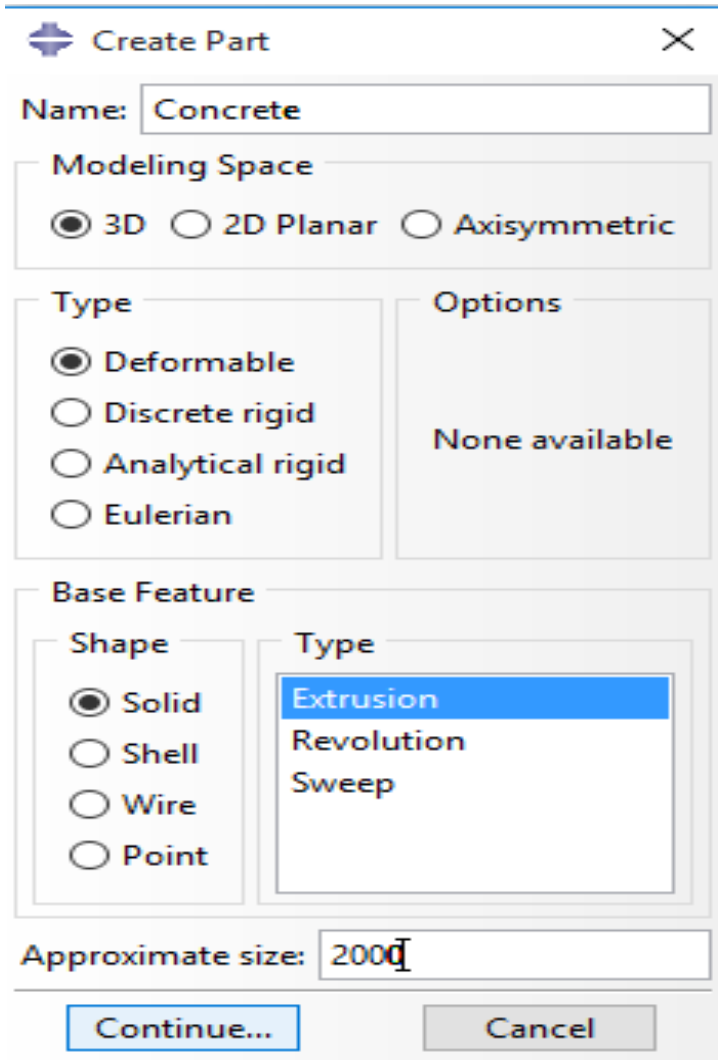


Fig.3.5. Create part-1: Concrete panel

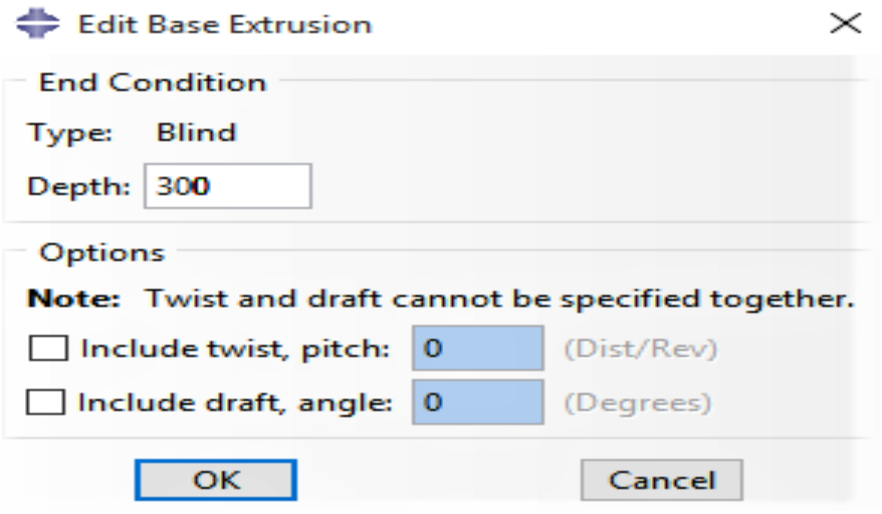


Fig.3.6. Edit base extrusion for concrete panel

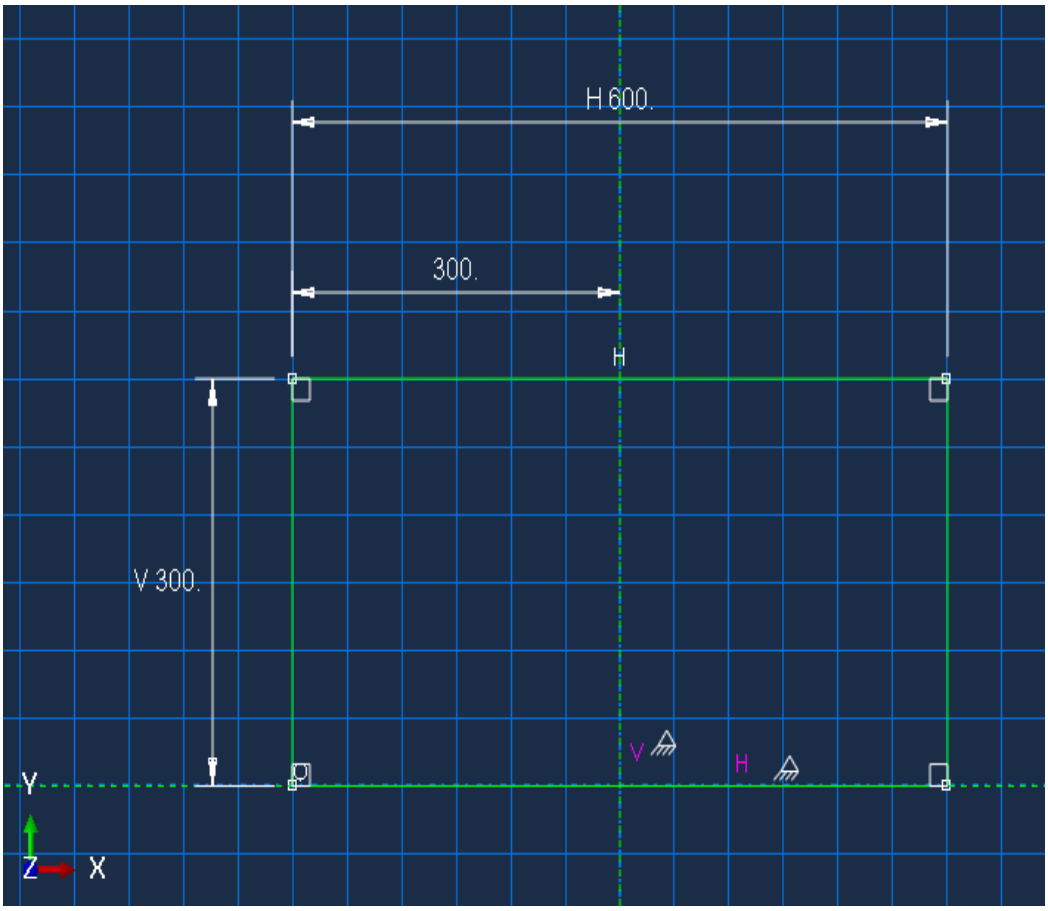


Fig.3.7. Geometry of concrete panel

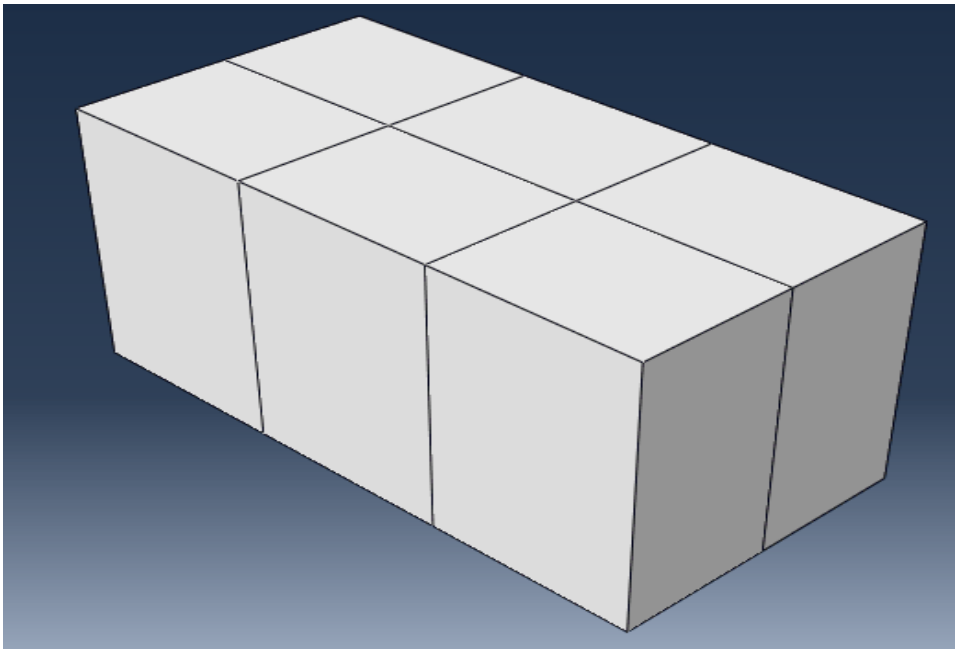


Fig.3.8. Model of concrete panel

3.3.3 Reinforcement

In this simulation modeling, the steel reinforcement is created for the concrete panel. The reinforcement is 3D modeling space which is deformable type and having a base feature wire which is planar type and approximate size is 2000.

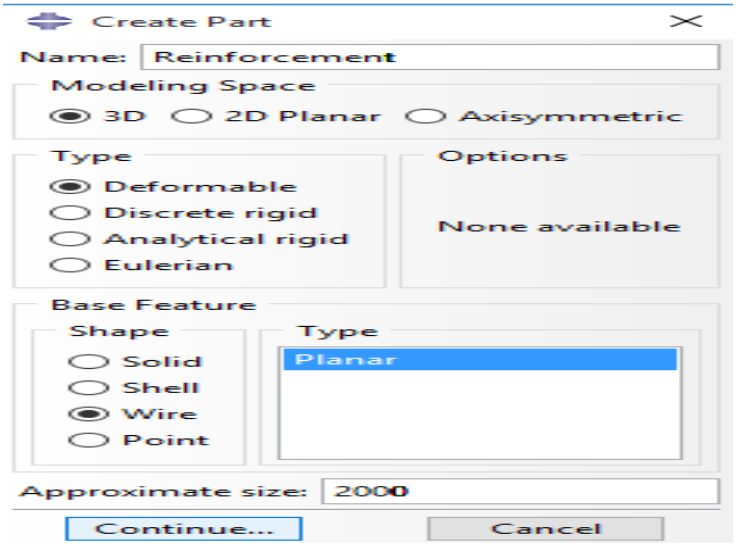


Fig.3.9. Create part-2: Reinforcement

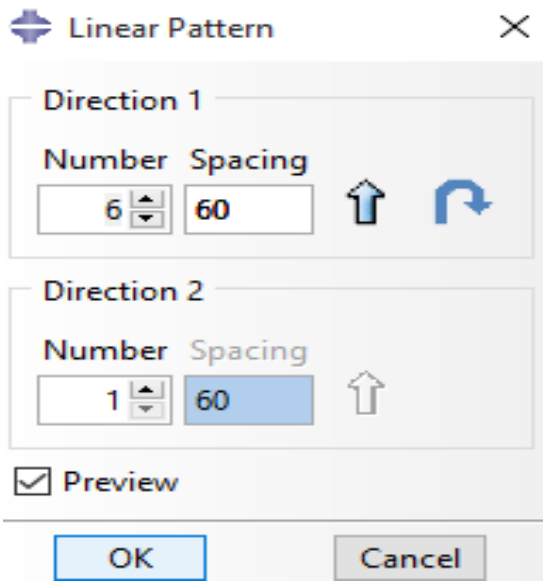


Fig.3.10. Create linear pattern of reinforcement in X-direction

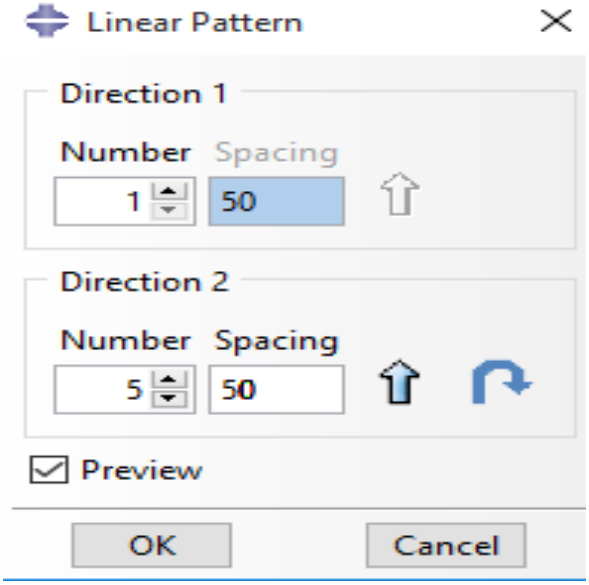


Fig.3.11. Create linear pattern of reinforcement in Y-direction

In the modeling of reinforcement the linear pattern is created in both X and Y directions. In X-direction there are 9 linear patterns having a 60mm of spacing between them. In Y-direction there are 5 linear patterns having a 50mm of spacing between them. The dimensions of reinforcement bar are 600mm in length and 300mm in width.

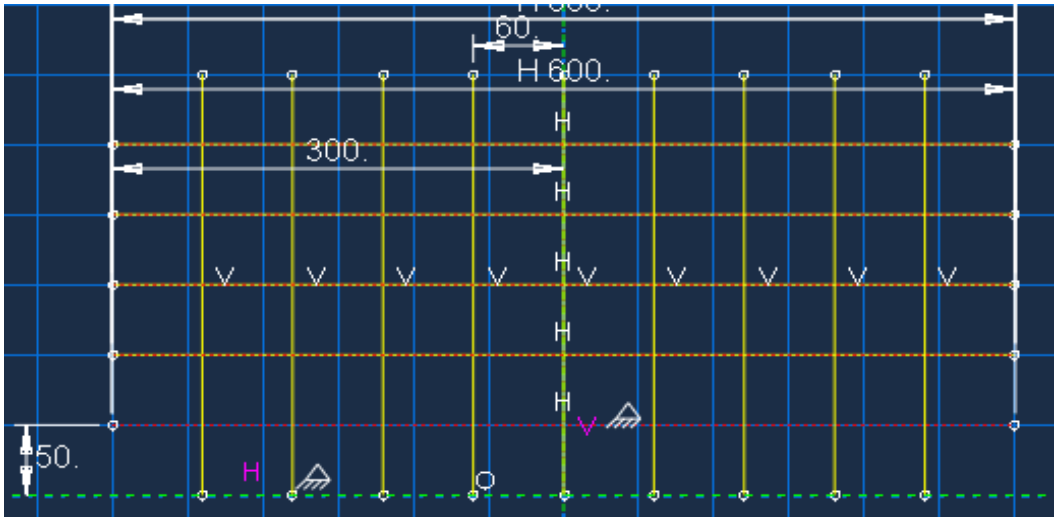


Fig.3.12. Geometry of Reinforcement

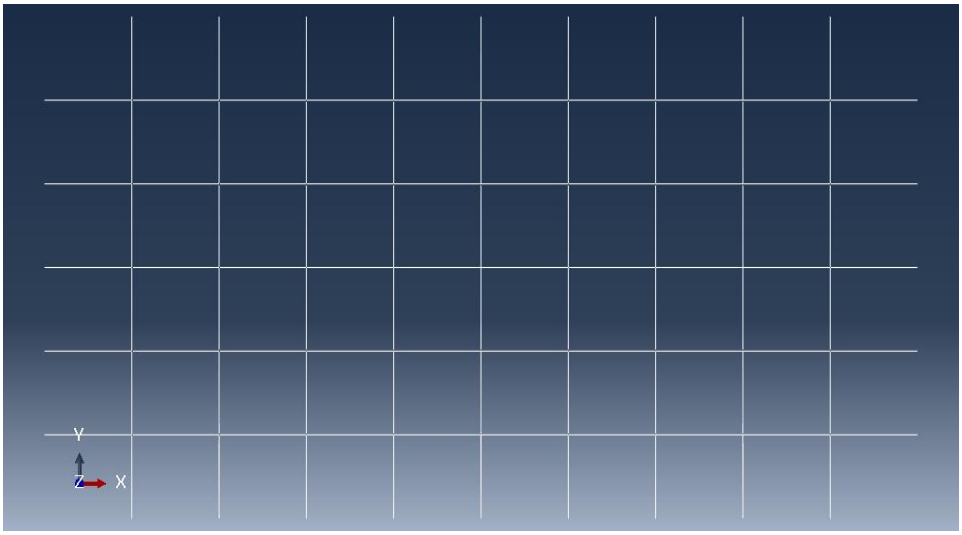


Fig.3.13. Model of Reinforcement

3.3.4 Projectile

To complete the model the steel projectile is modeled with 3D deformable solid part, construction of projectile is created using solid feature and revolution is created using solid feature. To complete the model the steel projectile is created with 3-D modeling space which is

deformable type and have a base feature is solid which revolution type. The approximate size of projectile is 500. The revolve axis of projectile is Y axis and angle is 180 degree.

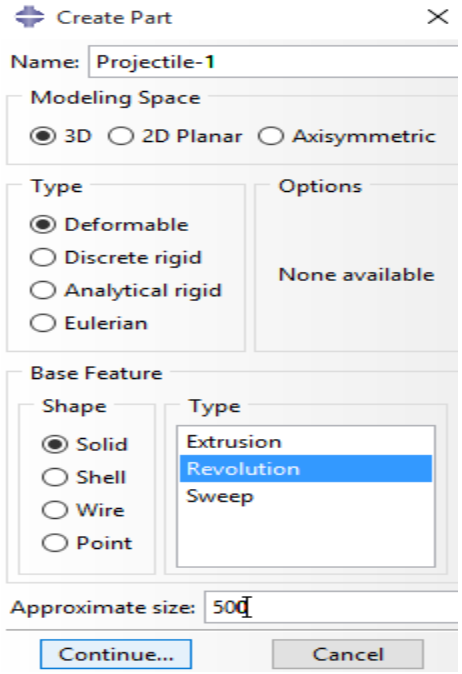


Fig.3.14. Create a Part 3: Projectile-1

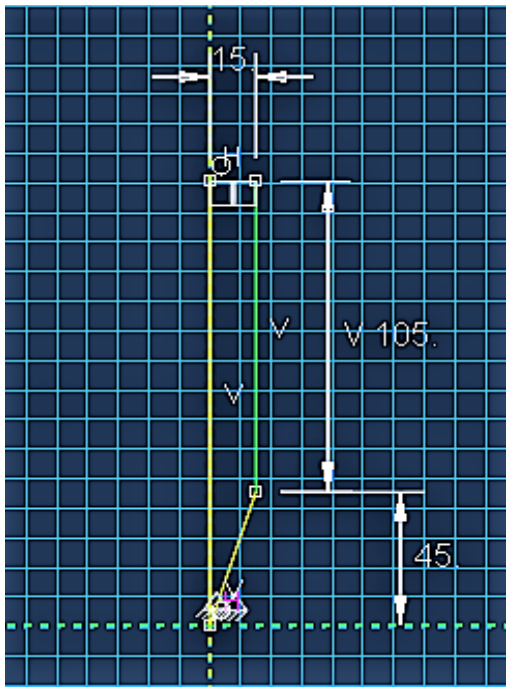


Fig3.15. Geometry of Projectile-1

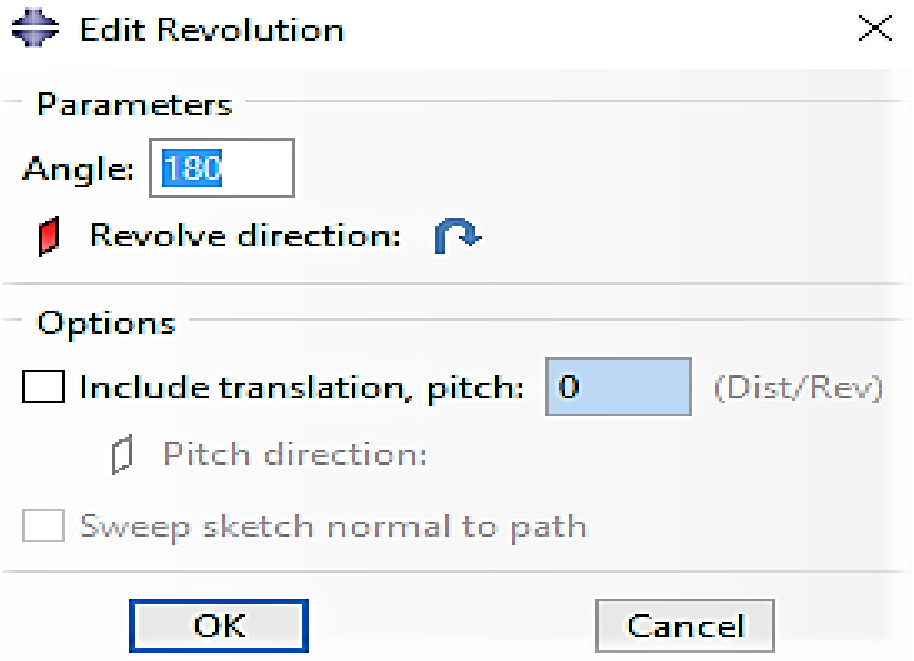


Fig3.16. Edit revolution for projectile- 1

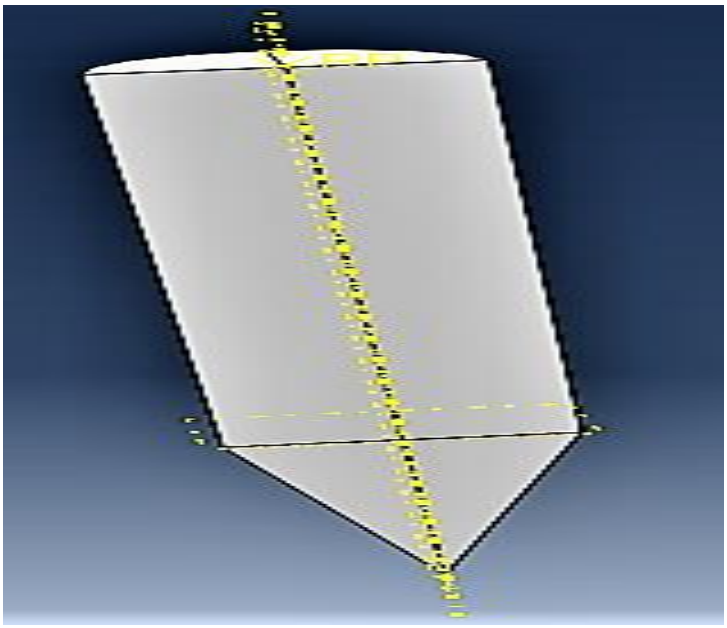


Fig3.17. Model of projectile-1

3.4 Material properties definition and assignment

For a finite element model in the Abaqus / CAE simulation to run successful it is necessary that the material behavior is accurate as possible. In this segment, several defining relationships have been developed to provide the required input data for each material are elaborated.

3.4.1Concrete

While the concrete is recognizable by its microstructure heterogeneity, The concrete is identifiable by its microstructure heterogeneity, at the microscopic level, allowing material properties such as density, young modulus, material parameters, factor of safety, maximum and minimum strength limits are implemented in this model. In this model we can use the material parameters for the concrete (Holmquist and Johnson), 1993. The JH2 ceramic model is the secondary iteration of the Johnson- Holmquist ceramic model which can accurately shows the grammatical behavior of a crumbly material such as affects elongation (strain rate effect), damage, penetration, pressure strength subordination. The material constants, material parameters is also used. According to the Johnson Holmquist ceramic model, 1993, the material parameters are shown in a table given below

Density (ρ)	2.4e-0.9
Young Modulus(G)	16400
Material Parameters (A)	0.30
Material Parameters (N)	0.79
Material Parameters (B)	1.73
Material Parameters (M)	0.61
Material Parameters (C)	0.005
Ėɵ (edot Ɵ)	1.0
Maximum Tensile pressure (T)	2.4
Strength Limits (σi^{max})	9.5
Strength limits (σf^{max})	1.1
Hugoniot Elastic Limit (HEL)	80
Pressure at HEL (P_{HEL})	45
Fraction of elastic energy (β)	1.0
Material constants (D1)	0.04
Material Constants (D2)	1.0
Material Constants (K1)	116000
Material Constants (K2)	-243000
Material Constants (K3)	506000
Factor of safety	0.2
L Damage	Ɵ

Table .1 Material parameters of concrete panel (Acc. JH2,1993 model)

Fig.3.18 (a), 3.18(b) and Fig show the properties that are used in this simulation. For a abq_jh2_concrete the user material have a 32 mechanical constraints and number of solution-dependent variable is 8.

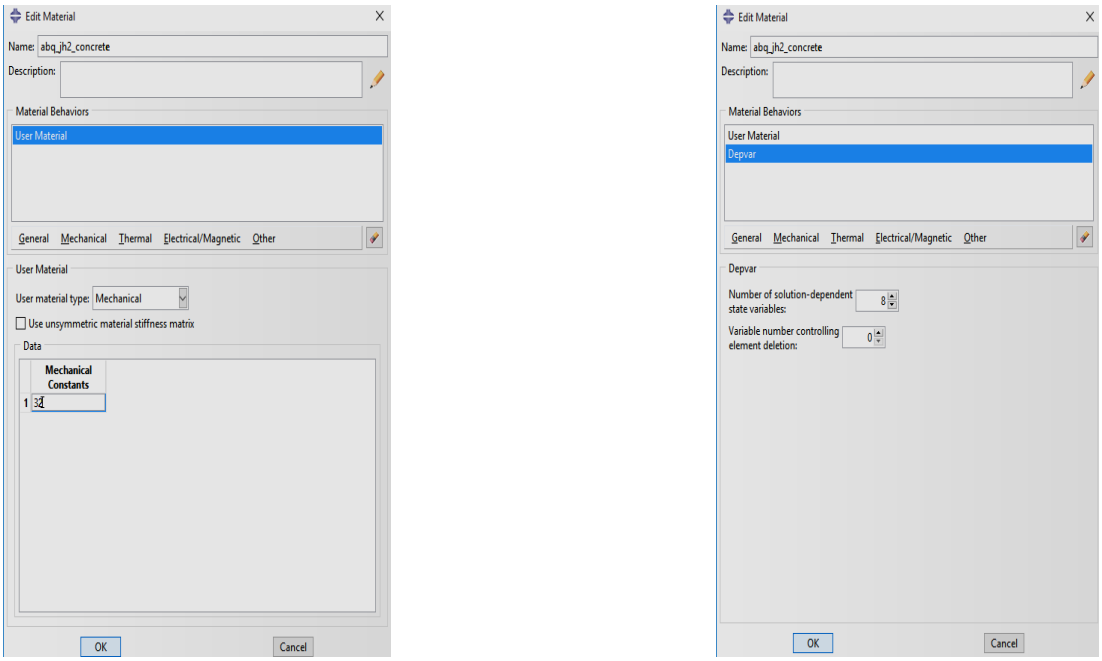


Fig.3.18(a),3.18(b). Create properties of concrete panel (according to JH2,1993)

After giving the properties for concrete, now we can create a section for assigning the properties to concrete panel. In a create section the category is solid type and it is homogeneous type. At the end we can create a edit section assignment for assigning the property for a concrete panel. In the edit section assignment the region is set-1 and section is concrete where it is solid, homogeneous type where the material is abq_jh2_concrete.

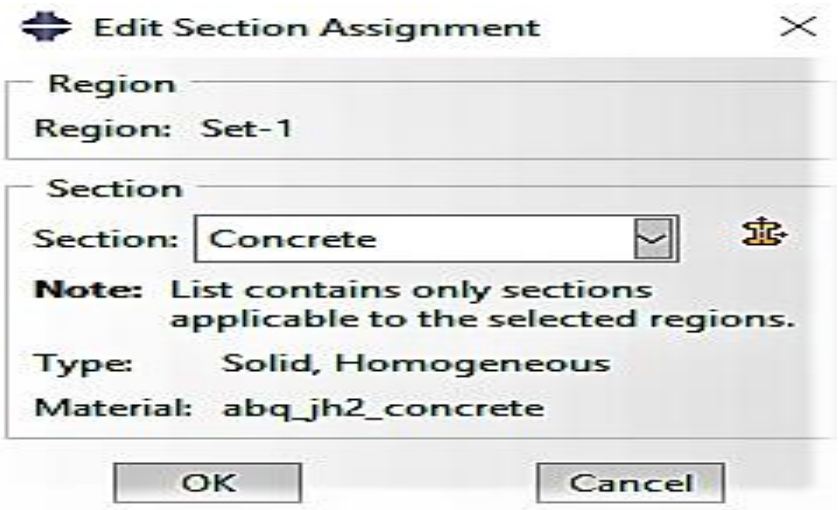


Fig.3.19. Edit section assignment for concrete panel

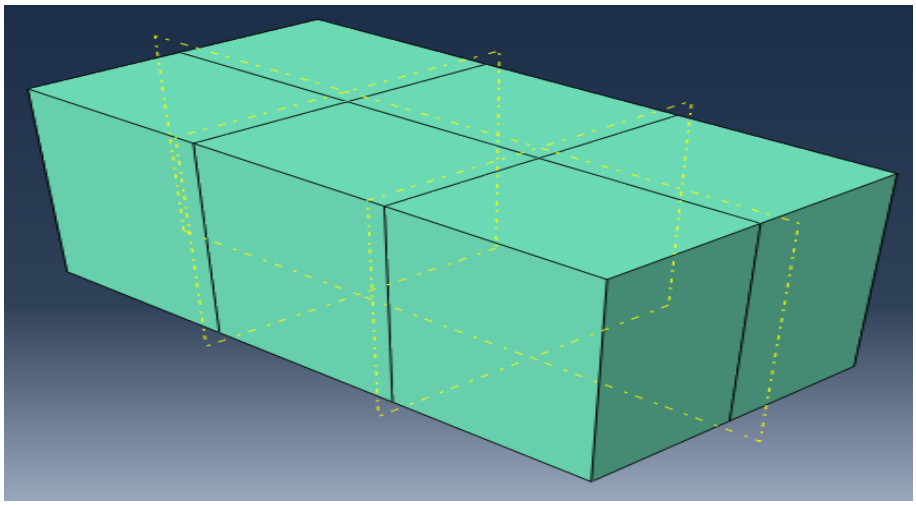


Fig 3.20. Assigning properties to concrete panel

3.4.2 Steel

In this model the property of steel is behave as plastic and elastic material. The density of steel also applied. The elastic properties such as the young modulus and Poisson ratio are applied in the model. The plastic properties of steel such as yield stress and plastic strain are also applied. The elastic properties and plastic properties of steel are shown in the table 1 and table 2 shown below:

Density	Elastic Properties	
Mass Density	Young Modulus	Poisson Ratio
8.05e-009	210000	0.3

Table.2 Density and Elastic properties of steel

Yield Stress	Plastic Strain
251	0
264	0.024
295	0.049

316	0.074
326	0.099
334	0.124
336	0.149
339	0.174

Table.3. Plastic properties of steel

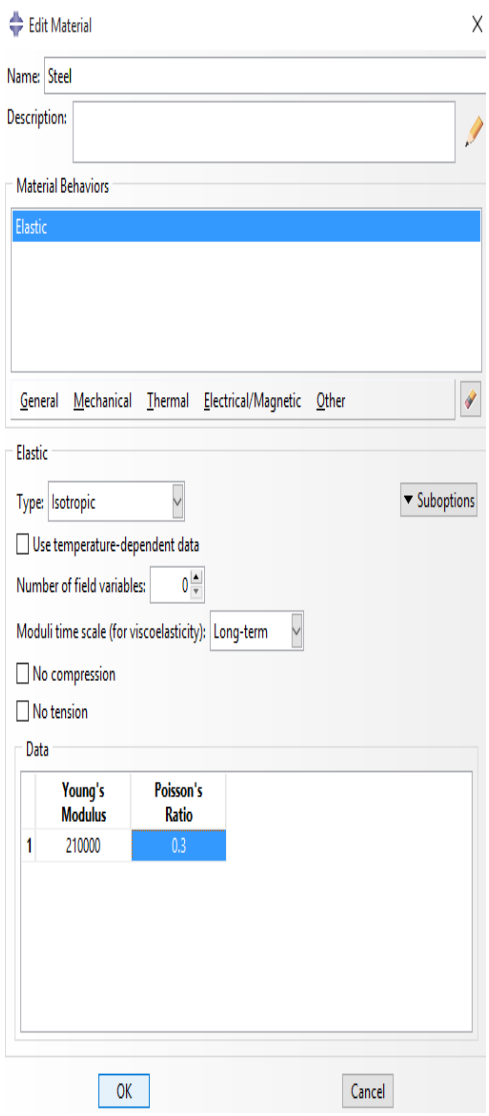


Fig.3.21(a). Create elastic property of steel

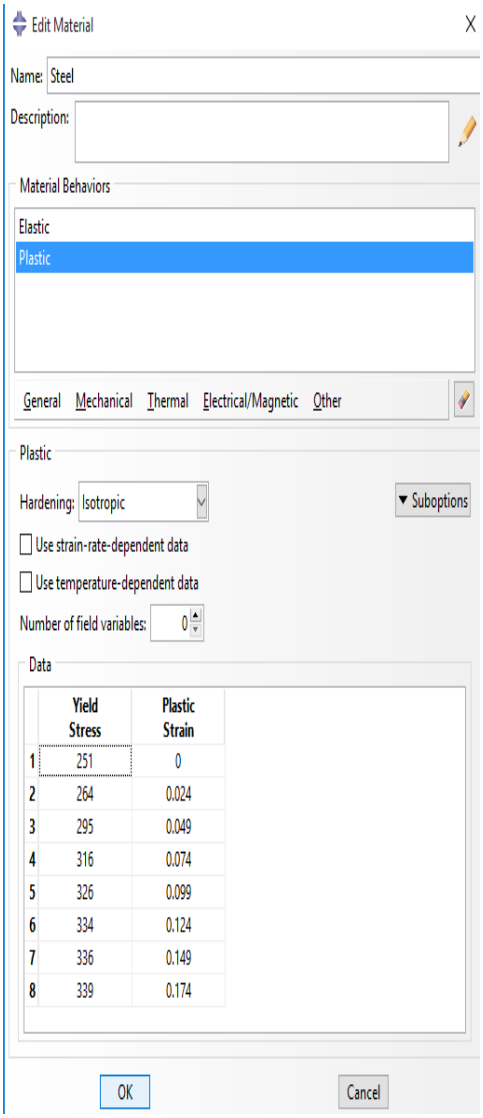


Fig.3.21(b). Plastic property of steel

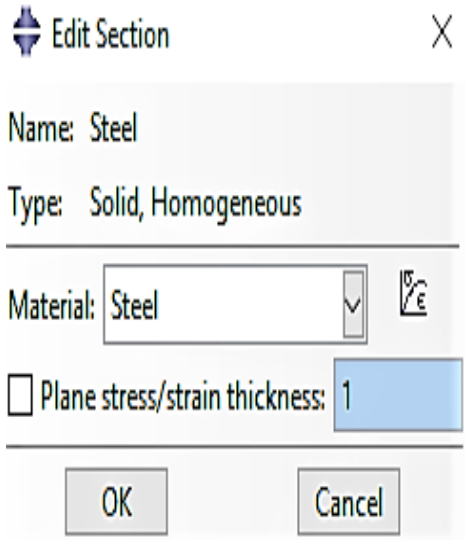


Fig.3.22. Create edit section for projectile-1

Now, create a section for the bullet-1 is named as steel, and of solid category which is homogeneous type. The edit section of a bullet-1 is solid, homogeneous type and material is steel.

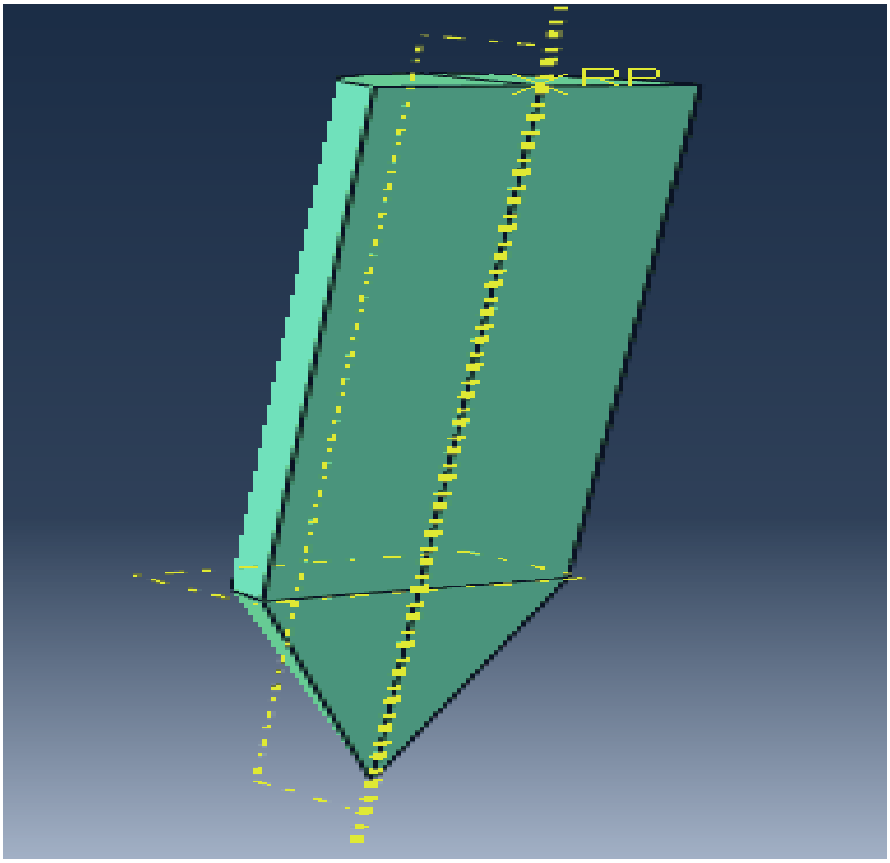


Fig 3.23. Model of projectile after assigning steel properties

3.4.3 Reinforcement

For the reinforcement the properties of the steel are used. In the create section the reinforcement is beam category and beam type where it is circular in shape and having radius which is 5mm.

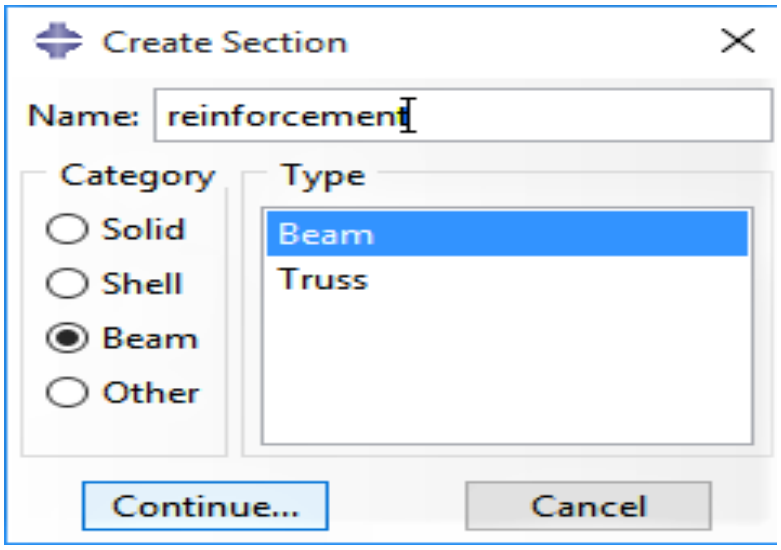


Fig 3.24. Create section for reinforcement

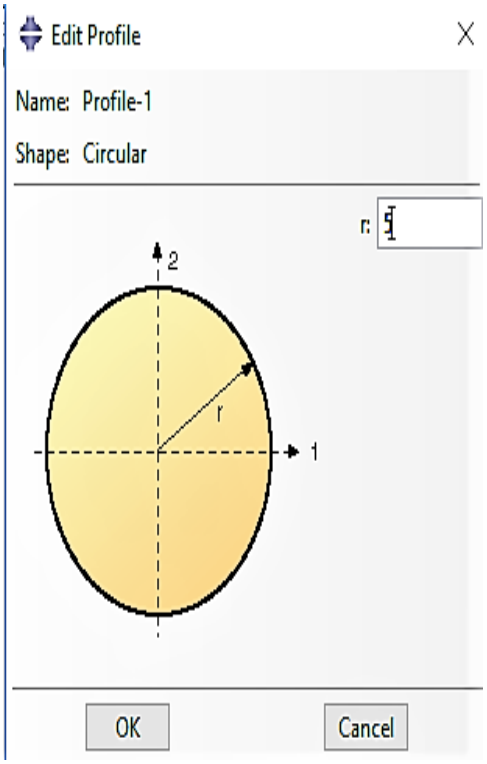


Fig 3.25. Create profile for reinforcement

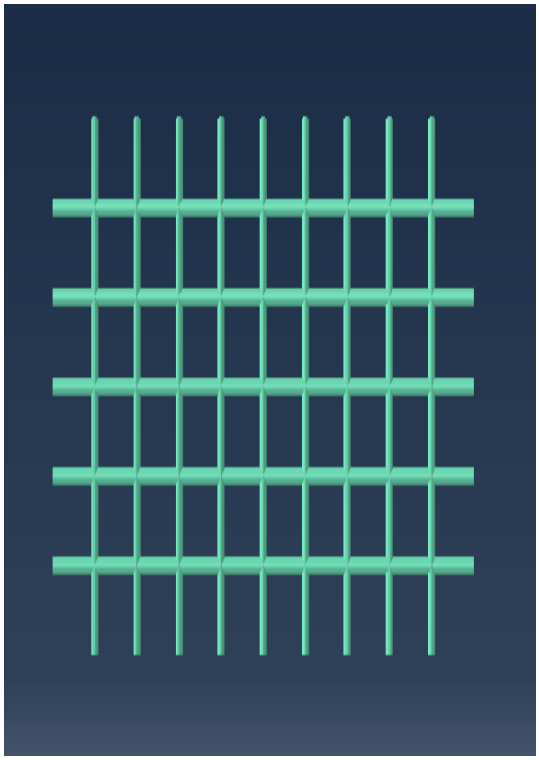


Fig 3.26. Reinforcement property model

3.5 Assembly

In the Abaqus / CAE, every part is generally known as part instances. For the manufacturing of a model it is necessary to assemble the different part instances. In this step firstly we can assemble the concrete panel and giving the reinforcement in a concrete panel. The reinforcement is provided in the inner region of a concrete panel at a distance of 60mm.

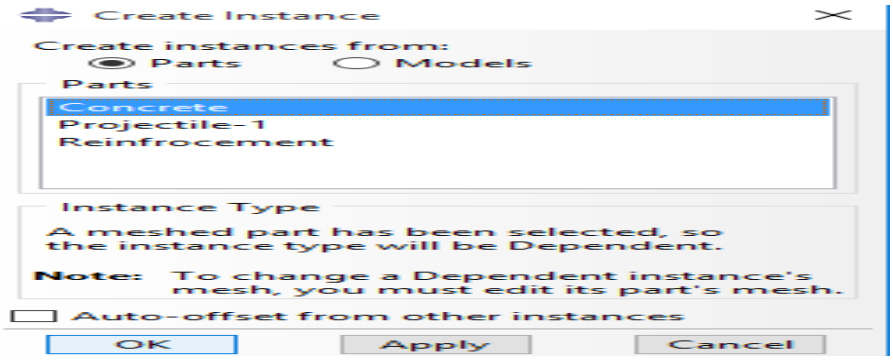


Fig. 3.27. Create assembly 1: concrete panel and reinforcement

In this step firstly we can select concrete panel and then select reinforcement by activating the auto-offset from other instance then apply. After selecting the reinforcement and concrete panel we can apply the datum planes axes option deactivating from assembly display option so that there is no datum planes between reinforcement and concrete panel.

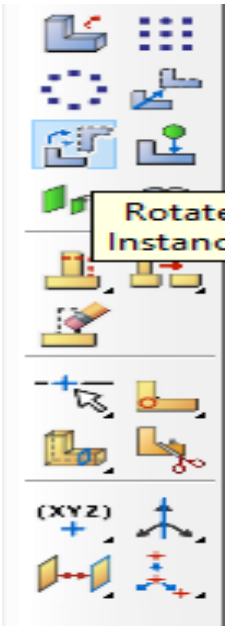


Fig.3.28. Create rotate instance

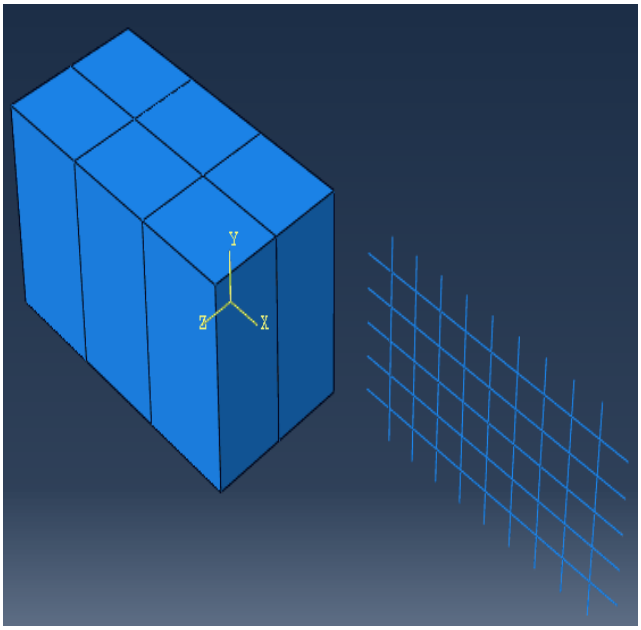


Fig.3.29. Rotation of Reinforcement on concrete panel

Now we can select the first end of first horizontal bar and selecting the first point of concrete panel for providing reinforcement in the outer region of concrete panel.

After rotation of reinforcement over concrete now we can giving the reinforcement in the outer region of concrete panel by using translate instances and linear pattern option. With the use of translate instance we can move the reinforcement in the outer region of concrete panel. Firstly we can select the reinforcement then giving the values of translation vector. For the start point of translation vector (X, Y, Z) the values is (0, 0, 0) and for the end point of translation vector the values for (X, Y, Z) is (0,-60, 0).

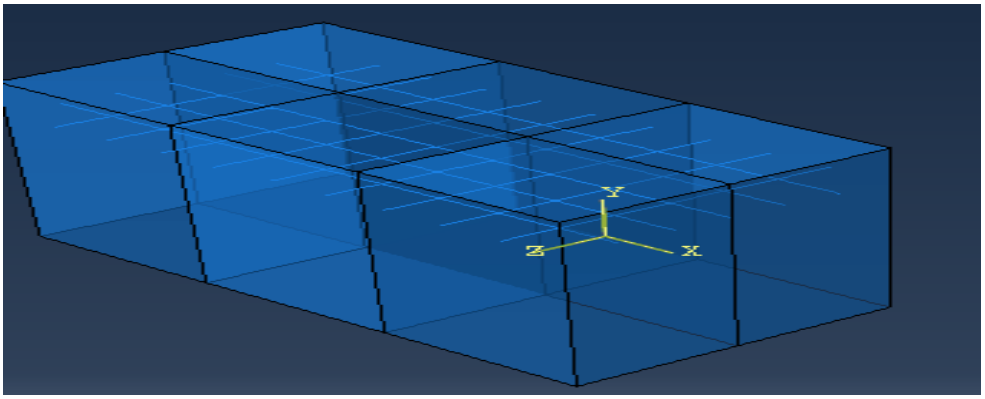


Fig.3.30. Assembly of reinforcement in outer region of concrete panel

By using linear pattern we can easily giving the reinforcement in the outer region of concrete panel. In the linear pattern there are 4 reinforcement is provided at a equal distance of 60mm between them.

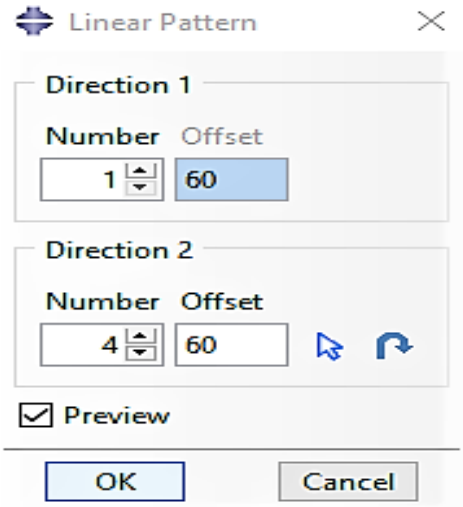


Fig.3.31. Create linear pattern for reinforcement

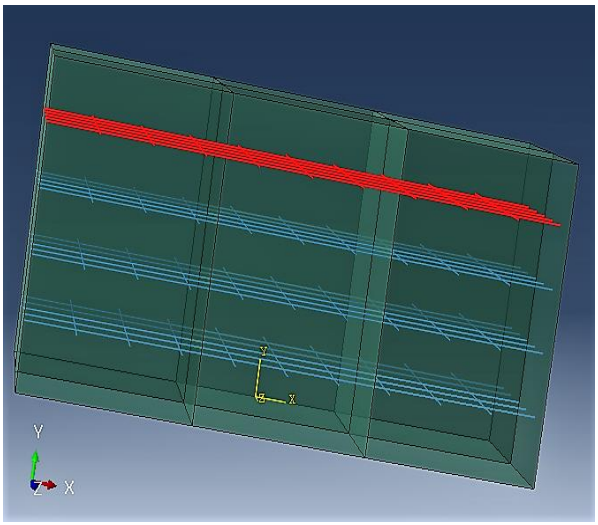


Fig.3.32. Reinforcement in outer region of concrete panel

The merging of a reinforcement and concrete panel has been taking place. For merging of reinforcement, firstly selecting the tools then create set which is embedded and geometry type, for concrete the set is region and this is also a geometry type. After the assembly of reinforcement in a outer region of concrete panel then the projectile is assembled over a concrete panel by using create instances. For the assembly of projectile over concrete panel, the projectile is rotated along Y- axis by using rotate instances, the start point for the axis of rotation (X,Y,Z) is (0,0,0) and the end point for the axis of rotation (X,Y,Z) is (0,1,0) ,the angle of rotation is 180 degree. Now selecting a create constraint coincident point option from simulation then selecting a needle point of projectile and the center edge point of concrete panel. The figure shows the assembly of whole model given below:

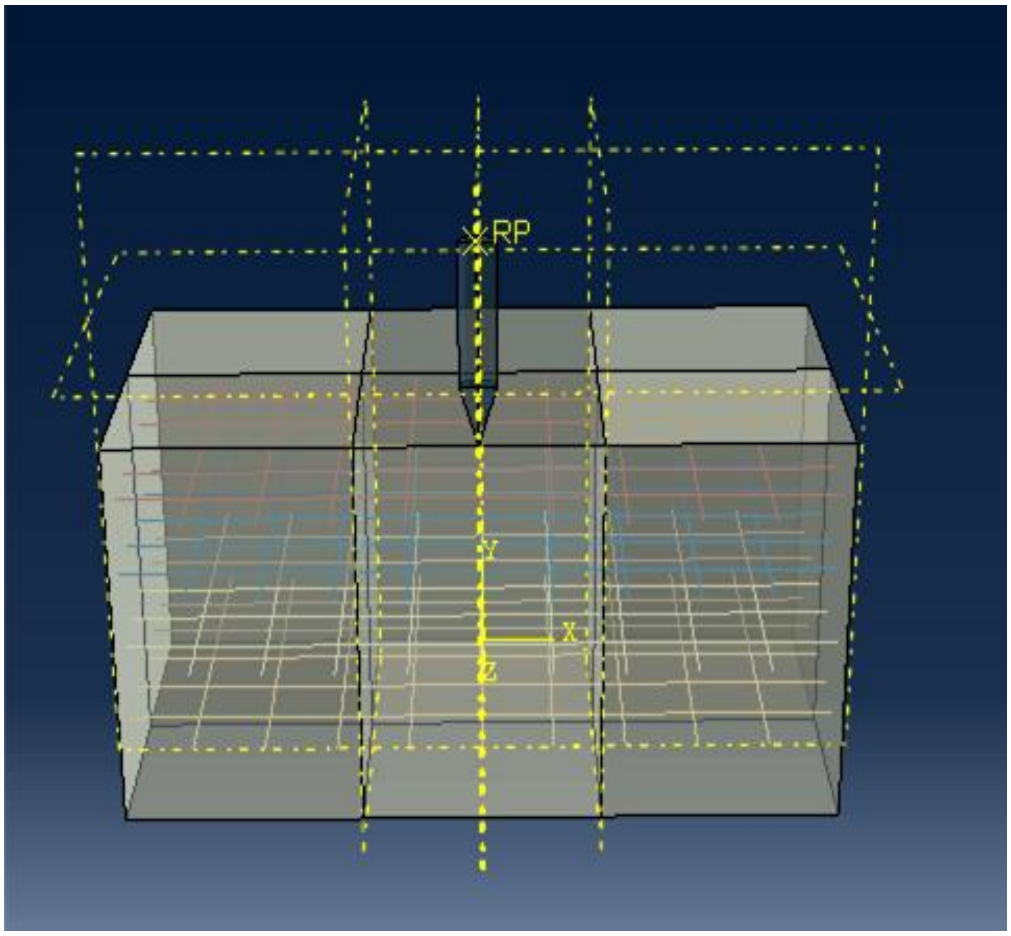


Fig.3.33. Assembly of whole Model

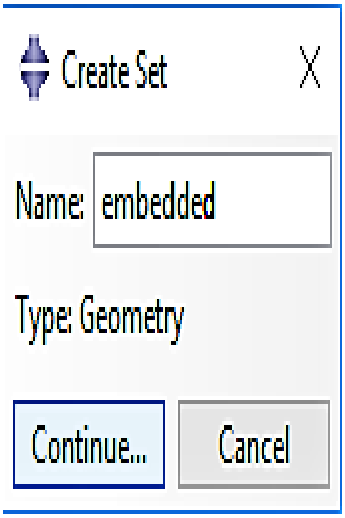


Fig.3.34. Create set for embedded part

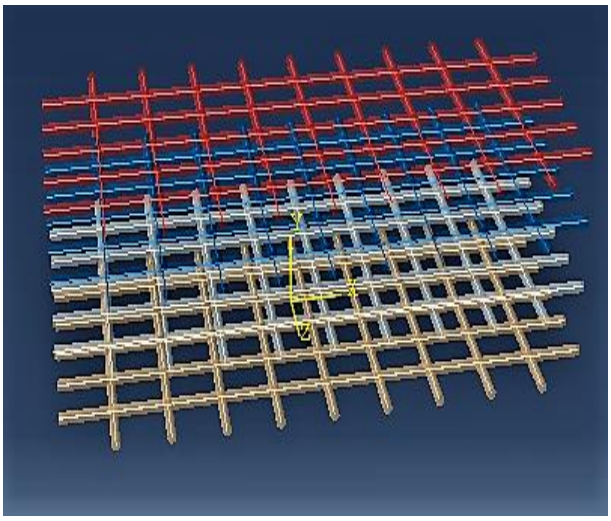


Fig.3.35. Applying set to embedded

At the end, in the assembly we can create a set for both embedded and region. For the embedded the set is geometry type and for the region it is also geometry type.

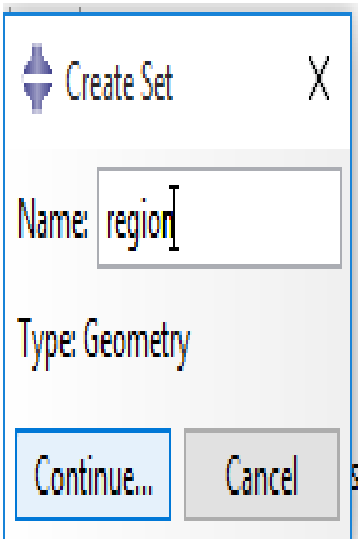


Fig.3.36. Create set for region part

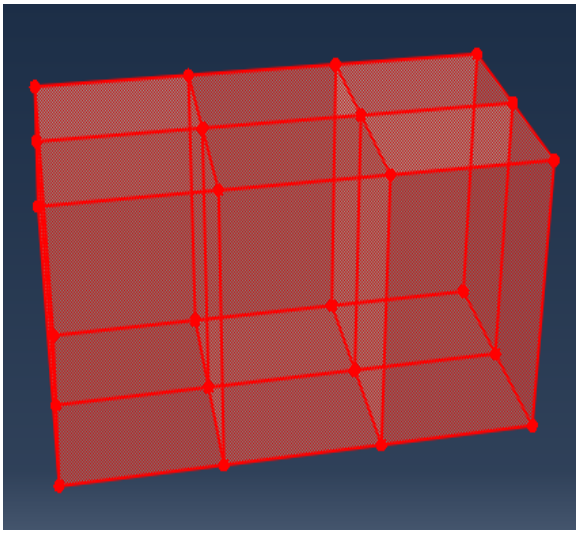


Fig.3.37. Applying set to region

3.6 Step

In this part firstly creating a step-1 which is dynamic, explicit and the time period is 0.0007, this means that the projectile take 0.0007s to completely penetrated in a concrete panel and with the help of the field output manager creating the output for this model. There are 8 output parameters for this modeling.

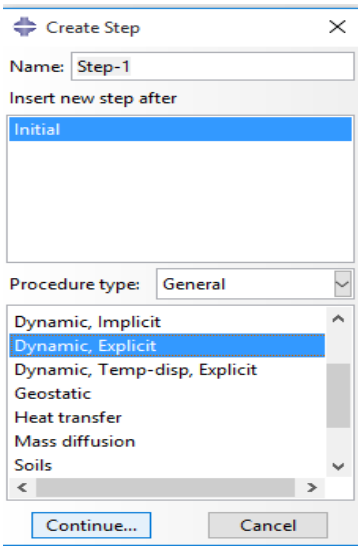


Fig.3.38. Create step-1

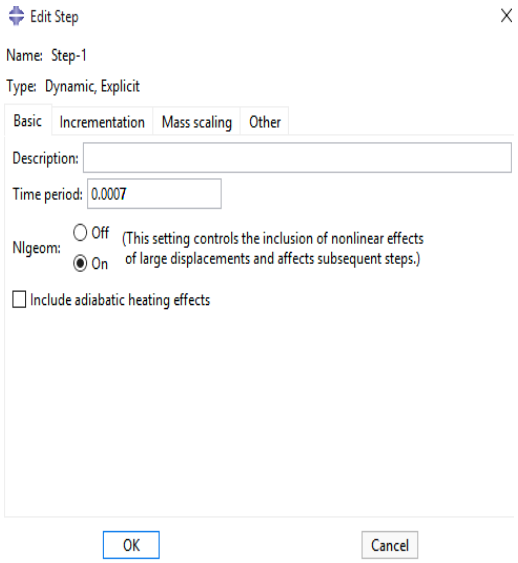


Fig.3.39. Time period for projectile-1penetration

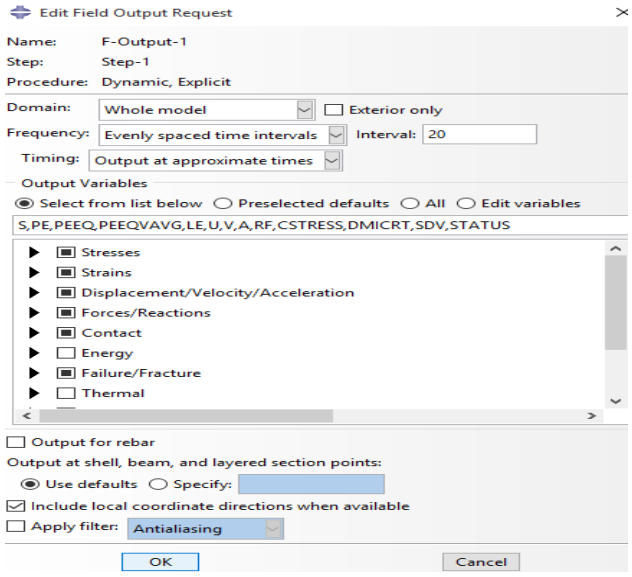


Fig.3.40. Field output request manager for simulation

3.7 Interaction

In the Abaqus/ CAE numerical simulation, the interactions are step dependent objects in which it can states that you have to explain them, you must have to allow that they are activated for the analysis. In this simulation model, firstly the interaction is created for the embedded part and region part by using creating constraints-1. For the embedded region which is embedded and for

the host region which is region the weight factor round off tolerance is 1E-006 and the absolute exterior tolerance is 0. The fractional exterior tolerance is 0.005.

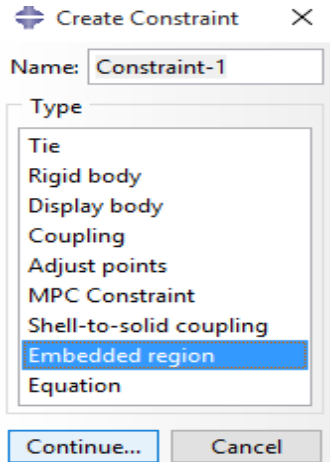


Fig.3.41. Create constraint-1

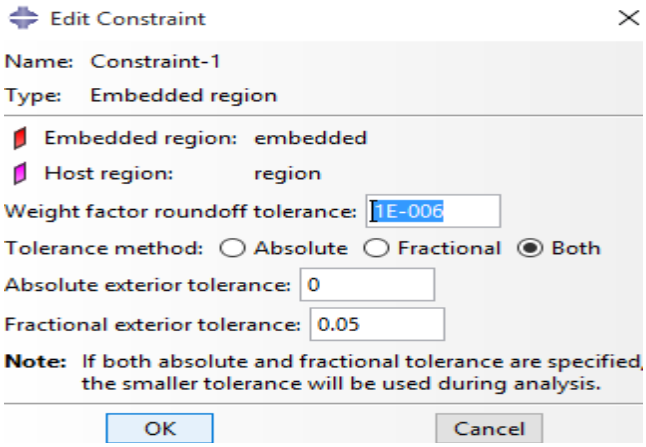


Fig.3.42. Constraint for embedded and region

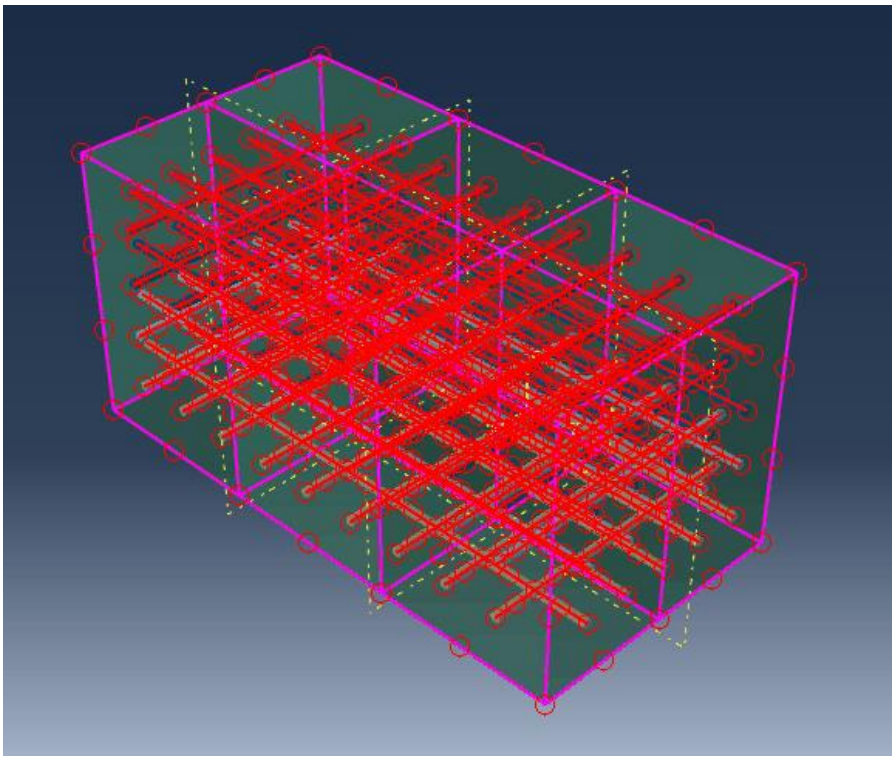


Fig.3.43. Interaction of embedded and region

After the interaction of embedded and region, now creating constraint-2 for the projectile-1 which is of body type and there region type is body and reference point is selected for the interaction of projectile-1 with the concrete panel.

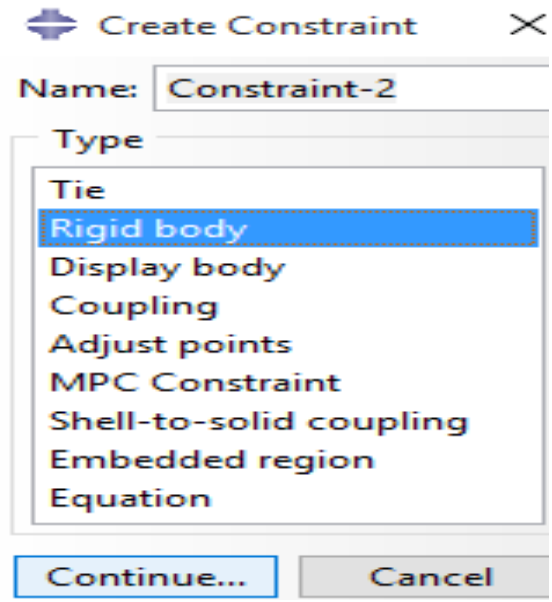


Fig.3.44. Create constraint-2

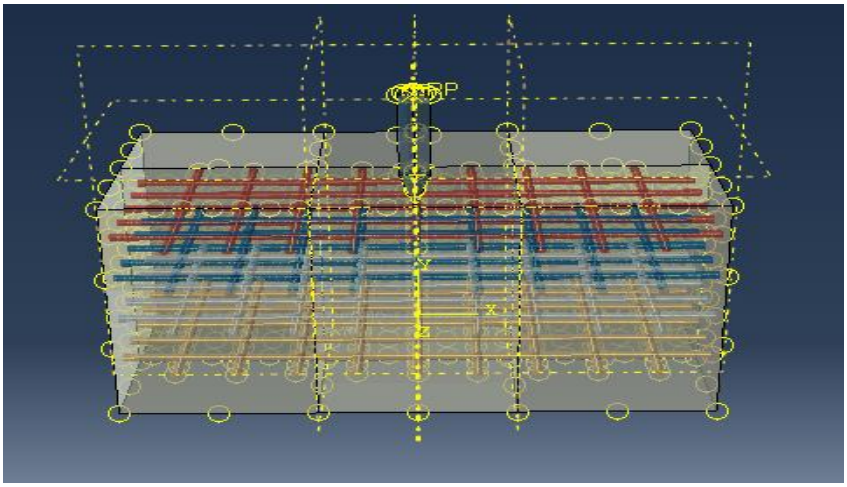


Fig.3.45. Interaction of projectile-1 on concrete panel

3.8 Load

In the numerical simulation, the surfaces is express the collection of geometric faces and edges or collection of the edges and the element faces, this can used for the many element types in which the valid surface is defined. In the load section firstly we can create the boundary condition-1 for a concrete panel which is mechanical in category and are of symmetry, antisymmetry, encastre type. These boundary conditions are done for the back face, right face and left face of concrete panel. The boundary condition-2 is creating for the front face of concrete panel which is also symmetry, antisymmetry, encastre type and run in the z-direction.

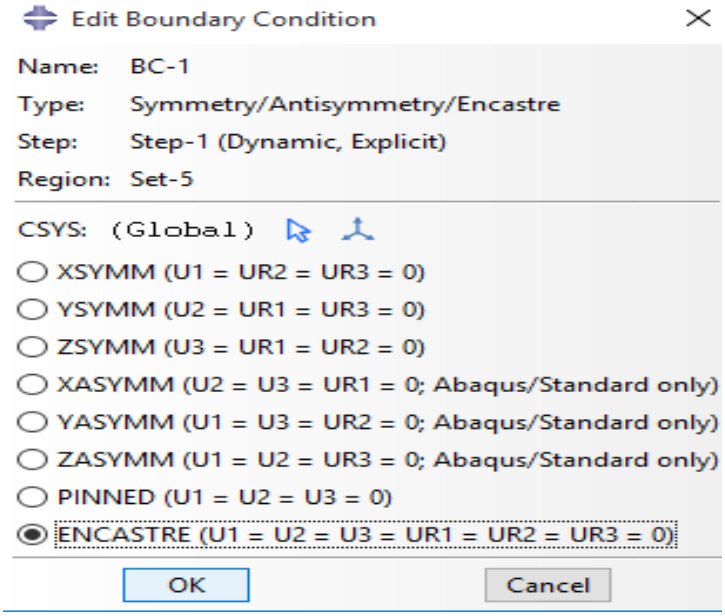


Fig.3.46. Boundary condition-1 of concrete panel

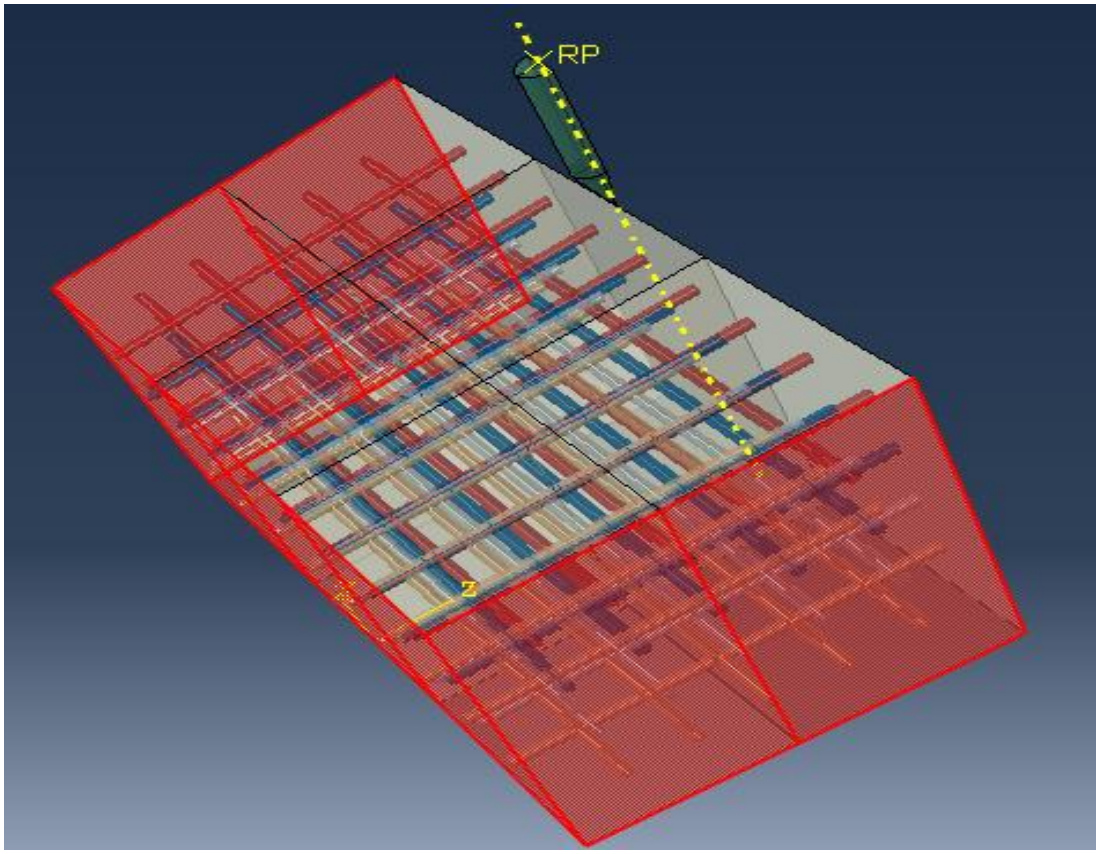


Fig.3.47. Boundary condition-1 concrete model

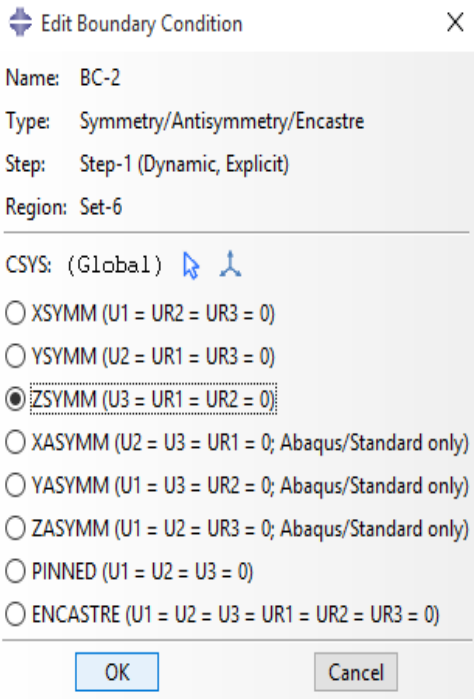


Fig.3.48. Boundary conditions-2 of concrete panel

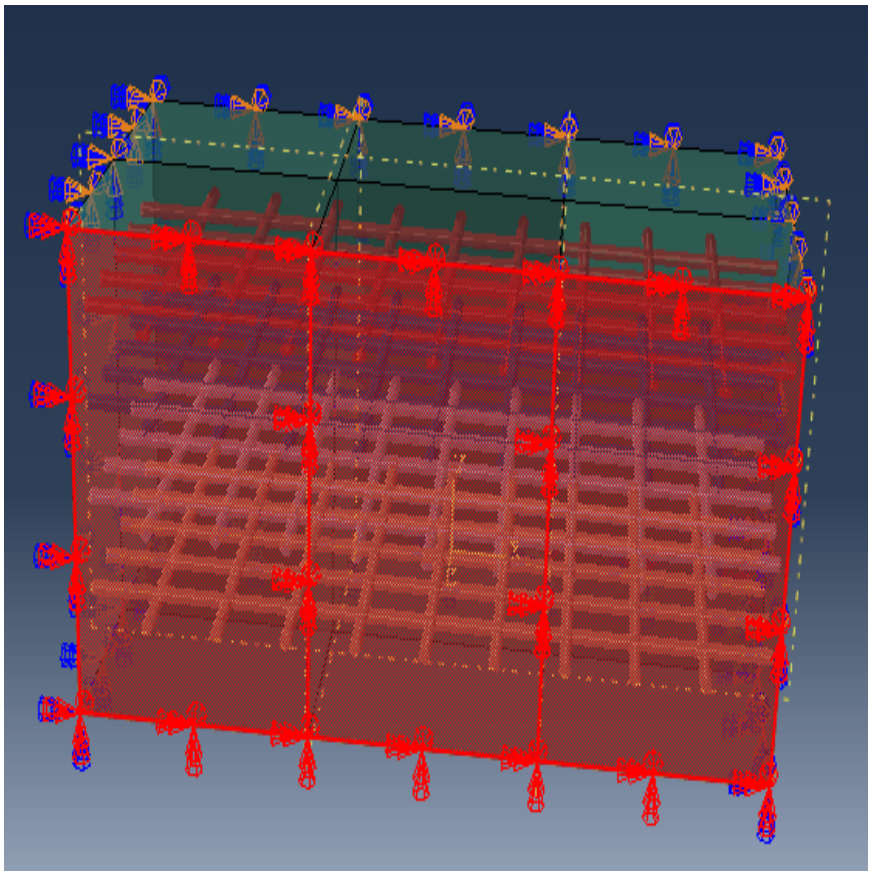


Fig.3.49. Boundary conditions-2 concrete model

For a projectile, the boundary condition-3 is created which is displacement and rotation type and step is dynamic/ explicit the distribution is uniform for projectile which is (U1=0, U3=0, UR1=0, UR2=0, UR3=0) where U2 is not 0, and amplitude is instantaneous.

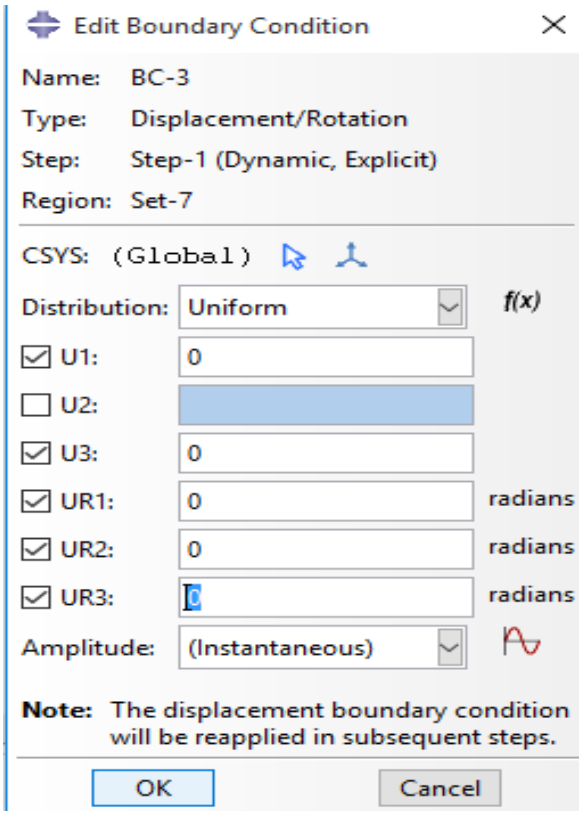


Fig.3.50. Boundary condition-3 for projectile-1

At the end of the load step, creating the predefined fields in which we can set the velocity of the projectile. In this simulation we can set the approximate velocity V2 which is 400m/s (400000 mm/s) and 600m/s (600000 mm/s) .In predefined filed the distribution is uniform and definition is translation only for the projectile. The velocity V1 and V3 is 0 in both cases.

3.9 Mesh

In the Abaqus/ CAE simulation there is a various use of the meshing techniques for mesh the model for the different geometry. In the various cases we can select the method for mesh a model or a model region. In a numerical simulation, a finite element model is run successful, it is mandatory that the meshing will done in the proper manner. In this section, the various element size is done for a material and meshing will done by parts.

3.9.1 Projectile

In the meshing part firstly creating a meshing for a projectile, the meshing will done by size method, the approximate element size should be 5mm, maximum deviation factor is 0 and minimum size factor is default (0, 1).

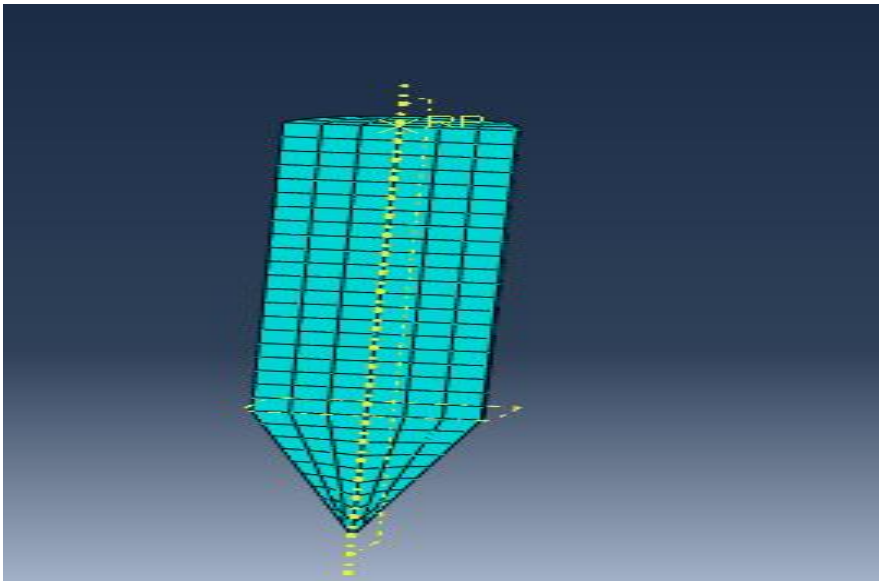


Fig.3.51. Meshing of projectile-1

3.9.2 Reinforcement

In the reinforcement, the approximate element size should be 10mm, maximum deviation factor is 0.1, minimum size factor is default and it will do with the help of size method.

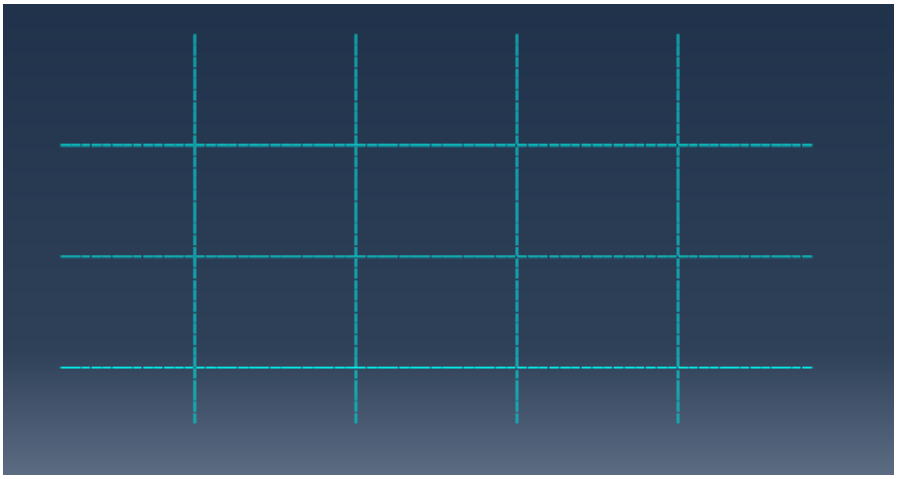


Fig.3.52. Mesh of reinforcement

3.9.3 Concrete

In the meshing of concrete panel it is divided into four parts: right part, middle part, left part and downward region, there are two downward region left and right region it can be done by parts. In a concrete panel, the meshing of left and right part ,the minimum size is 5mm and the maximum size is 15mm and it can done by size method having a single bias. For the middle the approximate element size is 5mm and in the downward region for left region the approximate element size is 5mm and the minimum element size is 5mm and maximum element size is 15mm for right region.

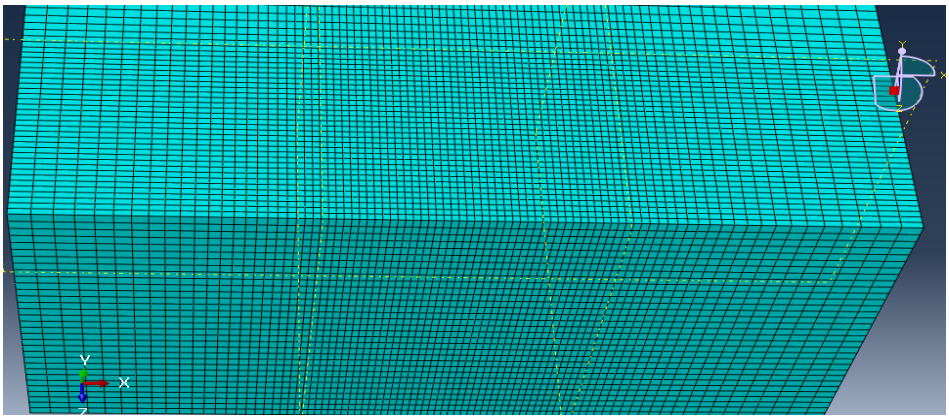


Fig.3.53. Concrete panel mesh model

3.10 Job

In the Abaqus /CAE simulation the job has been for analysis the results. The job is a complete analysis, recording in which the output file is associated to the model is write down and submit for monitor. The results are done for the ODB for visualization.

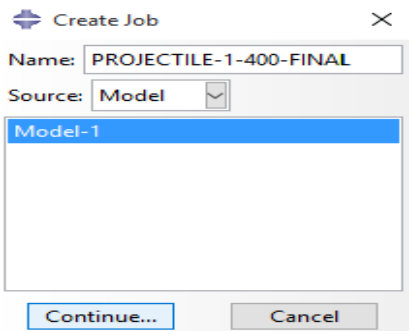


Fig.3.54. Create a Job-1

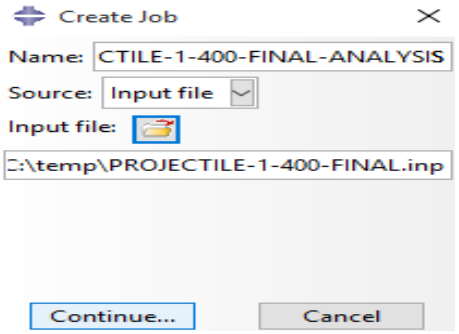
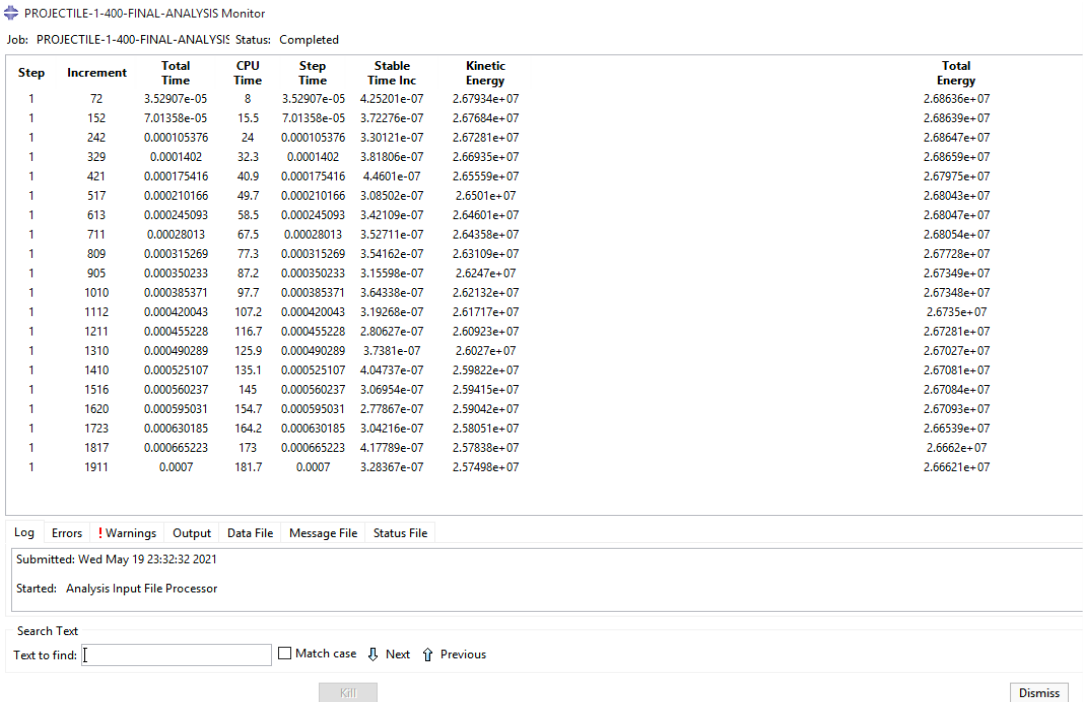


Fig.3.55. Create a job-2 for output results

The last part of the simulation is job part, in which we can submit the job for the analysis. In this simulation, creating two jobs the first job is projectile-1-final and the second job is projectile-1-400-analysis. The job-1 is creating for write the input file of the model. The job-2 is creating for submitted the input file of model for analysis. After the job-2 was submitted, we can monitor the model for analysis.


PROJECTILE-1-400-FINAL-ANALYSIS Monitor

Job: PROJECTILE-1-400-FINAL-ANALYSIS Status: Completed

Step	Increment	Total Time	CPU Time	Step Time	Stable Time Inc	Kinetic Energy	Total Energy
1	72	3.52907e-05	8	3.52907e-05	4.25201e-07	2.67934e+07	2.68636e+07
1	152	7.01358e-05	15.5	7.01358e-05	3.72276e-07	2.67684e+07	2.68639e+07
1	242	0.000105376	24	0.000105376	3.30121e-07	2.67281e+07	2.68647e+07
1	329	0.0001402	32.3	0.0001402	3.81806e-07	2.66935e+07	2.68659e+07
1	421	0.000175416	40.9	0.000175416	4.4601e-07	2.65559e+07	2.67975e+07
1	517	0.000210166	49.7	0.000210166	3.08502e-07	2.6501e+07	2.68043e+07
1	613	0.000245093	58.5	0.000245093	3.42109e-07	2.64601e+07	2.68047e+07
1	711	0.00028013	67.5	0.00028013	3.52711e-07	2.64358e+07	2.68054e+07
1	809	0.000315269	77.3	0.000315269	3.54162e-07	2.63109e+07	2.67728e+07
1	905	0.000350233	87.2	0.000350233	3.15598e-07	2.6247e+07	2.67349e+07
1	1010	0.000385371	97.7	0.000385371	3.64338e-07	2.62132e+07	2.67348e+07
1	1112	0.000420043	107.2	0.000420043	3.19268e-07	2.61717e+07	2.6735e+07
1	1211	0.000455228	116.7	0.000455228	2.80627e-07	2.60923e+07	2.67281e+07
1	1310	0.000490289	125.9	0.000490289	3.7381e-07	2.6027e+07	2.67027e+07
1	1410	0.000525107	135.1	0.000525107	4.04737e-07	2.59822e+07	2.67081e+07
1	1516	0.000560237	145	0.000560237	3.06954e-07	2.59415e+07	2.67084e+07
1	1620	0.000595031	154.7	0.000595031	2.77867e-07	2.59042e+07	2.67093e+07
1	1723	0.000630185	164.2	0.000630185	3.04216e-07	2.58051e+07	2.66539e+07
1	1817	0.000665223	173	0.000665223	4.17789e-07	2.57838e+07	2.6662e+07
1	1911	0.0007	181.7	0.0007	3.28367e-07	2.57498e+07	2.66621e+07

Log Errors ! Warnings Output Data File Message File Status File

Submitted: Wed May 19 23:32:32 2021

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Fig.3.56. Analysis of projectile-1 at velocity 400m/s

3.11 Penetration of Projectile -1 at Velocity (600m/s)

3.11.1 General

In a Abaqus/ Cae simulation the penetration of projectile-1 at velocity 600m/s on concrete panel are also done for monitoring the analysis. In the first step of Abaqus simulation the geometry of the concrete panel, reinforcement and projectile-1 is same as shown in fig 3.6, fig 3.11, fig 3.14. In the next step we can assign the properties of concrete panel, reinforcement and projectile-1 which is also same shown in table-1, table-2 and table-3. After assigning the properties now we can do the assembly. In the assembly, firstly we can done the assembly of concrete panel and

reinforcement, then providing the reinforcement in the outer region of the concrete panel at a distance 60mm between them with the help of translate instances, rotate instance and linear pattern. Then we can do the assembly of projectile on a concrete panel. In the numerical simulation the next part is step in this part the time period and the filed output request has been applied for the better analysis of the model. After the step the interaction has been taken place for the model, the first interaction is between the embedded and second interaction is done for the region shown in fig 3.41, and the third interaction is done for the projectile which is rigid body and the point is selected as reference point. In the load part, the boundary conditions are applied for the model in which it can express the collection of geometric faces and collection of the edges and faces. There are three boundary conditions are created for this model boundary conditions-1 which is in all direction, the boundary condition-2 is for the front face of concrete panel which is in global –Z directions, and the boundary conditions-3 is applied for a projectile-1 in which the velocity was taken for the analysis by using the create predefined field in this simulation the velocity is 600m/s for the projectile-1 shown in fig- 3.68

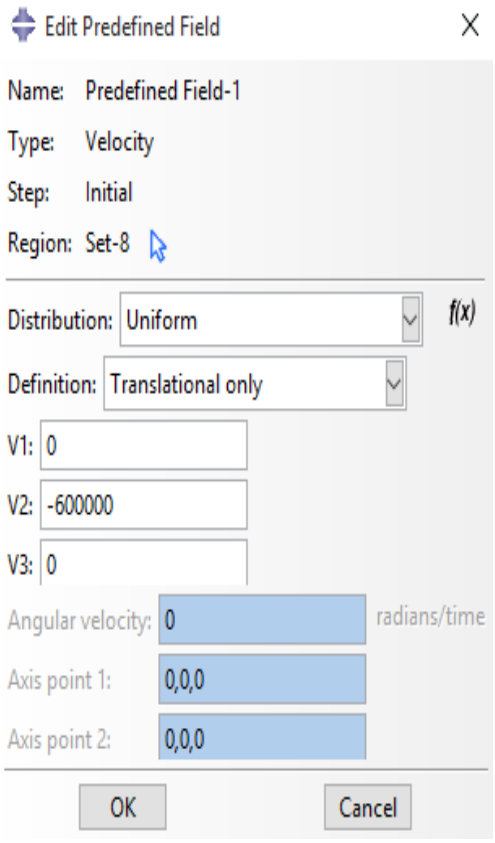


Fig.3.57. Create velocity for projectile-1 (600m/ s)

In the mesh part we can do the meshing for each part simultaneously. In this model the meshing for concrete panel, reinforcement and concrete panel has been done by size method. In projectile, the meshing is done by size method; the accurate element size for the projectile is 5mm shown in figure-3.49, for reinforcement it is also done by the size method in which the sizing control is 10mm shown in fig- 3.53 and the model mesh of reinforcement shown in fig-3.54. For the concrete there is finer mesh in the center region and coarse mesh in the outer region. In the outer region the maximum approximate element size is 15mm and minimum element size is 5mm, for center region the approximate element size is 5mm. Fig-3.61 shows the mesh model of concrete panel.

3.11.2 Job

Create a two job-1 and job-2 for the analysis, Job-1 for write the input file of the analysis. The name of job-1 is projectile-1-final-analysis shown in fig 3.69. The job-2 is create for the analysis of the model, the name of job-2 is projectile-1-final-analysis, this job is for the output analysis of model. The job-2 is submitted by submit option and also submitting for monitoring the model.

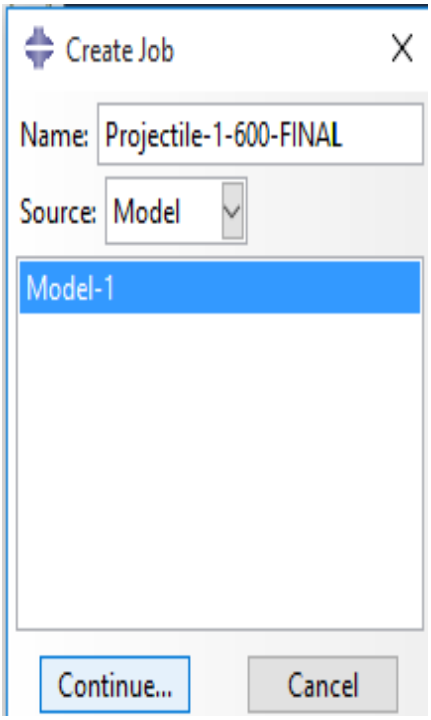


Fig.3.58. Create a job-1(v= 600m/s)

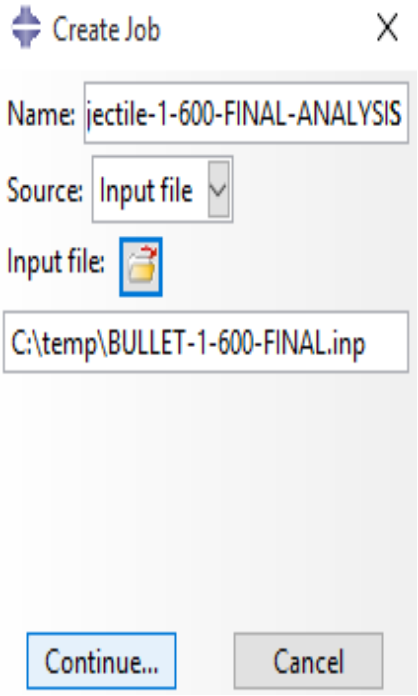


Fig.3.59. Job for analysis (v= 600m/s**)**

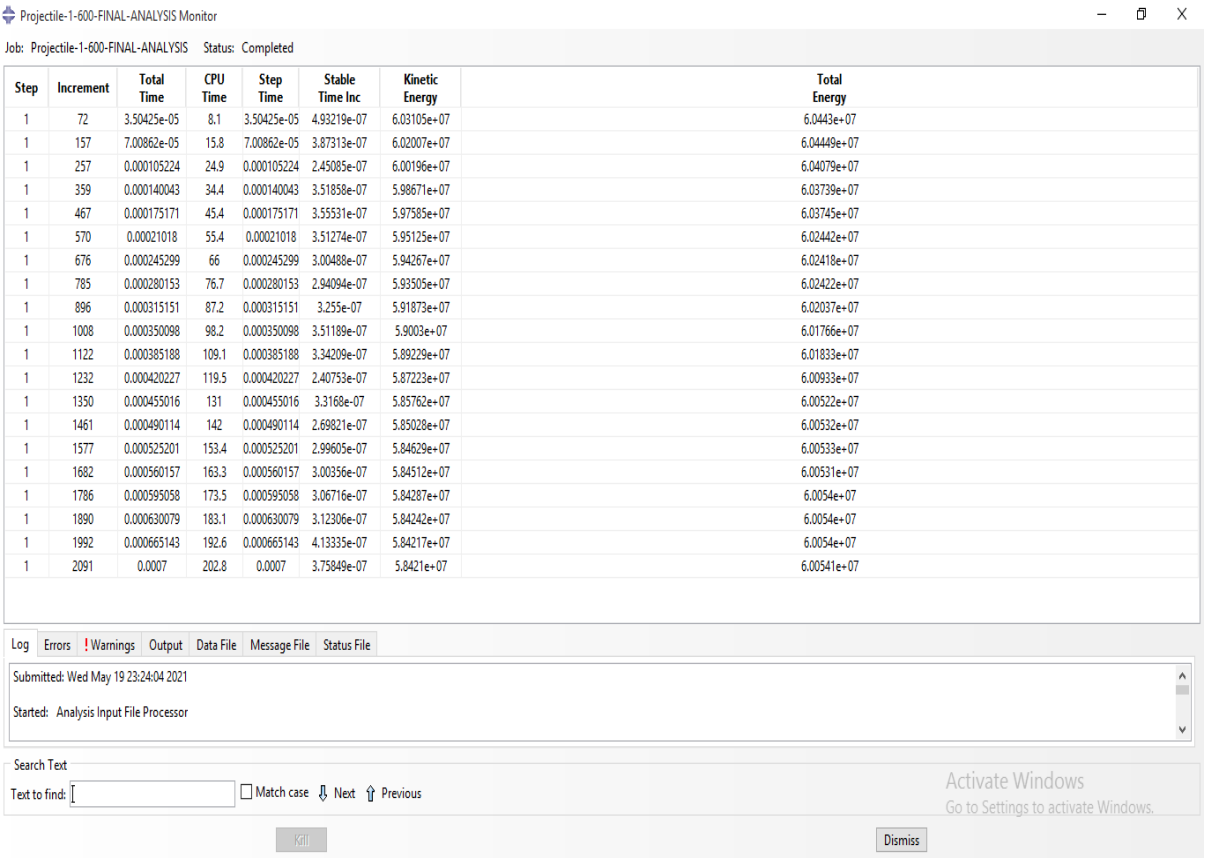


Fig.3.60. Analysis of projectile-1 at velocity 600m/s

3.12 Numerical Simulation of Projectile-2 at Velocity (400m/s)

The length of the projectile is 180mm and having a circular shape.

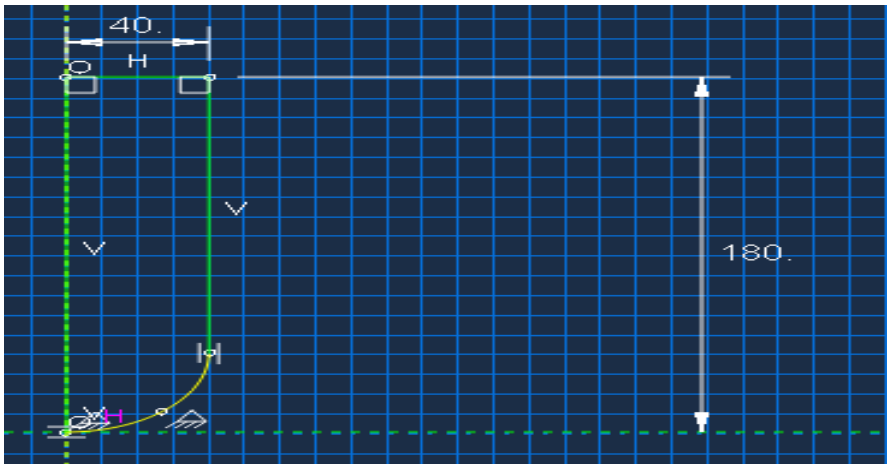


Fig.3.61. Geometry of projectile-2

3.13 Part

In the numerical simulation modeling the part-1 is created as projectile-2, which have 3D modeling space and it is deformable type. The base features of projectile-2 are solid and type is revolution. The approximate size of creating a projectile-2 is 2000.And the projectile-2 is circular/ arc in shape from penetrated end.

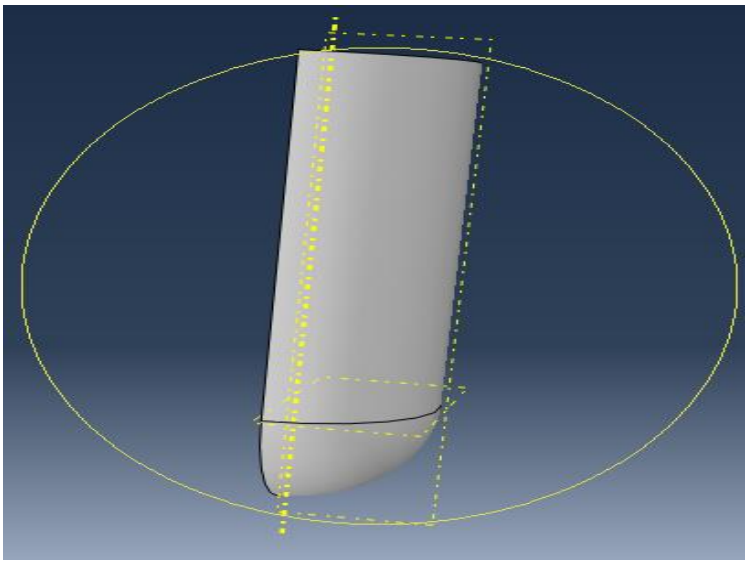


Fig.3.62. Model of projectile-2

The geometry of the concrete panel and reinforcement is same for projectile -2. The dimensions of concrete panel and reinforcement are same for the projectile-2 penetration. The geometry of concrete panel and reinforcement are shown in fig. 3.6 and fig.3.11.

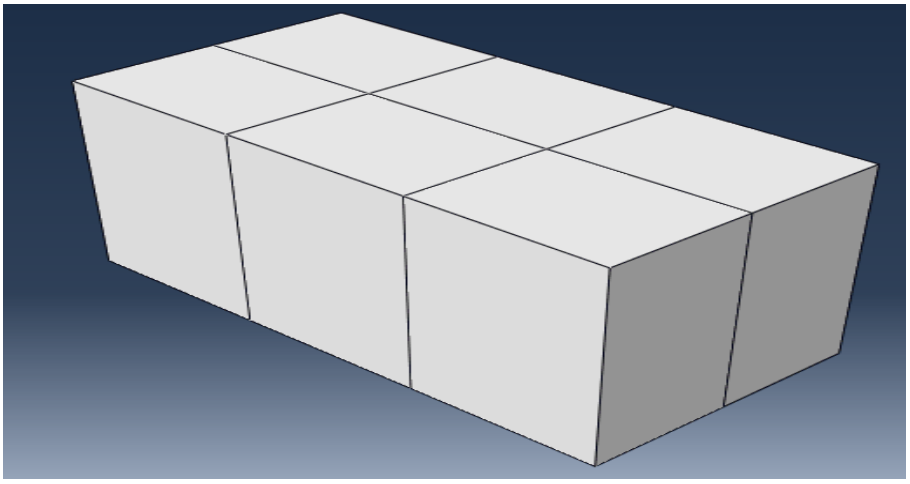


Fig.3.63. Model of concrete panel for projectile-2

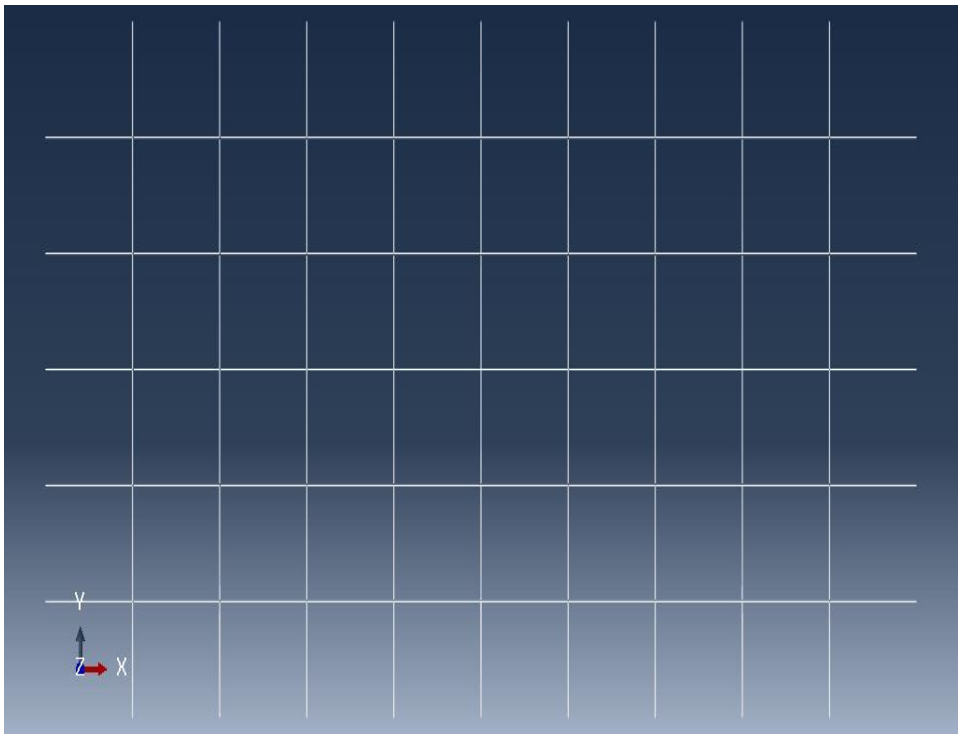


Fig.3.64. Model of reinforcement

3.14 Property

In the property section, the property of concrete panel and reinforcement is same in this modeling, and for the projectile-2. In the property of projectile-2 the elastic and plastic properties are same for the projectile also. The density of projectile is 8.05e-009. Where in the create section the category of projectile-2 is steel and it is homogeneous type and material the material for projectile-2 is steel. For a concrete panel the parameters are same as shown in table.1, and have 32 mechanical constants. The number of solution- dependent state variable is 8.

Density	Elastic Properties	
Mass Density	Young Modulus	Poisson Ratio
8.05e-009	210000	0.3

Table.4 Density and Elastic properties of steel for projectile-2

Yield Stress	Plastic Strain
251	0
264	0.024
295	0.049
316	0.074
326	0.099
334	0.124
336	0.149
339	0.174

Table.5. Plastic properties of steel for projectile-2

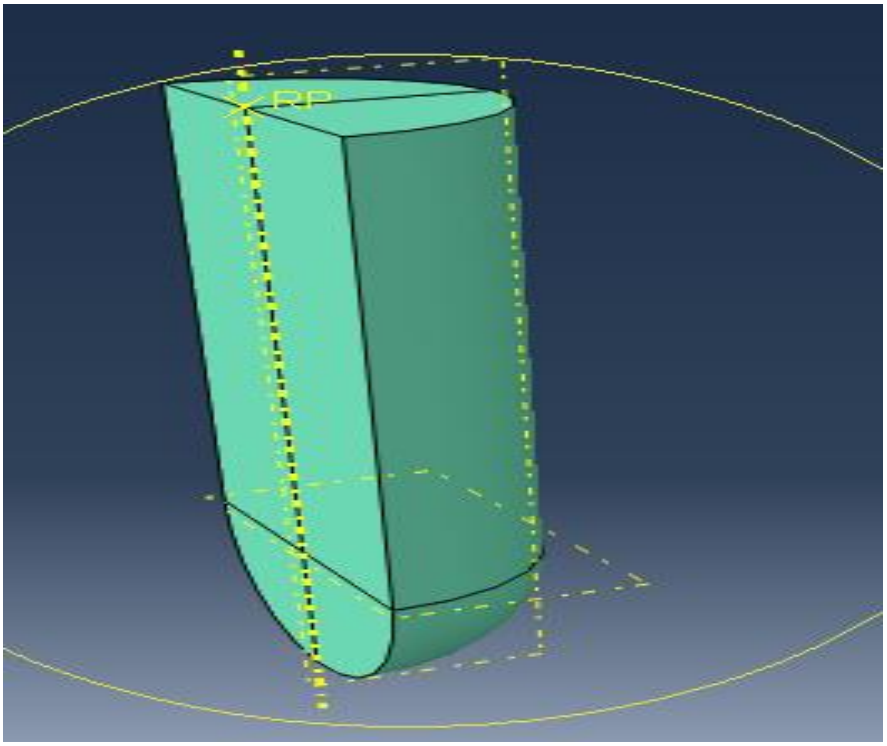


Fig.3.65. Projectile-2 assigning properties model

3.15 Assembly

Firstly we can assemble the concrete panel and providing the reinforcement in the outer region of concrete panel. There is 4 reinforcement in the outer region of concrete panel and the distance 60mm between them. With the help of linear pattern providing reinforcement in the concrete panel. For the assembly of the projectile-2 , the start point for the axis of rotation is (X,Y,Z) is (0,0,0) and the end point for axis of rotation (X,Y,Z) IS (0,1,0), the angle of rotation for the projectile-2 is 180 degree. After the rotation of projectile now, assemble the projectile over a concrete panel by using coincident point option.

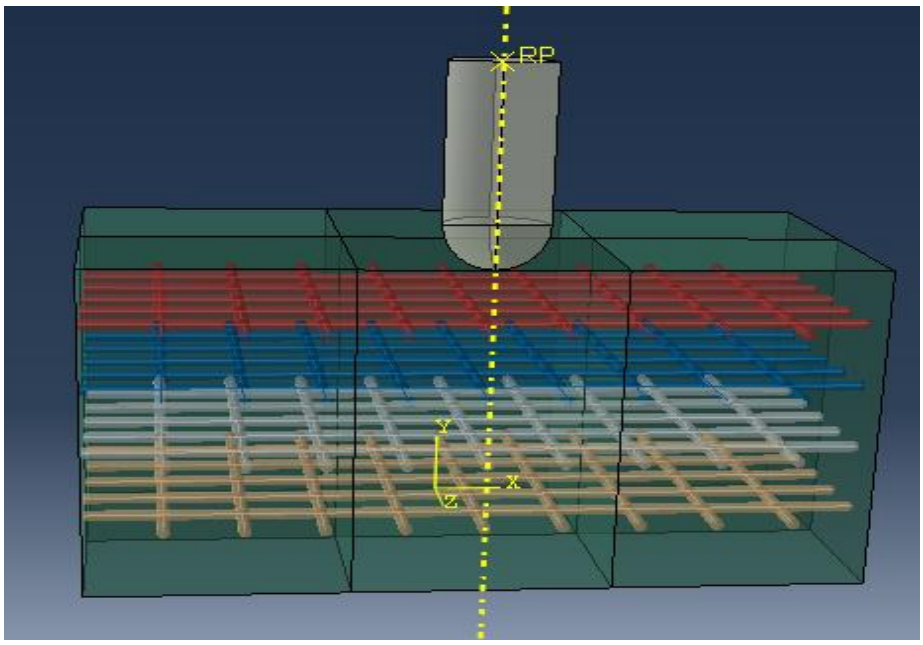


Fig.3.66. Assembly of projectile-2 on concrete panel

3.16 Step

After the assembly, the step part is created for simulation of this model. In the step part creating is step-1 which is dynamic, explicit and time period is 0.0007s. For this simulation of projectile-2 impact in concrete panel there are 8 output parameters.

3.17 Interaction

In this model, firstly the interaction of embedded and region has been taken place. The weight factor round off tolerance is 1E-006, absolute exterior tolerance is 0 where the fractional exterior tolerance is 0.005. In the edit constraint the host region is region and embedded region is

embedded. For the interaction of projectile-2, creating a create constraint where the body is rigid type, the region is b_set_3 and point is reference point.

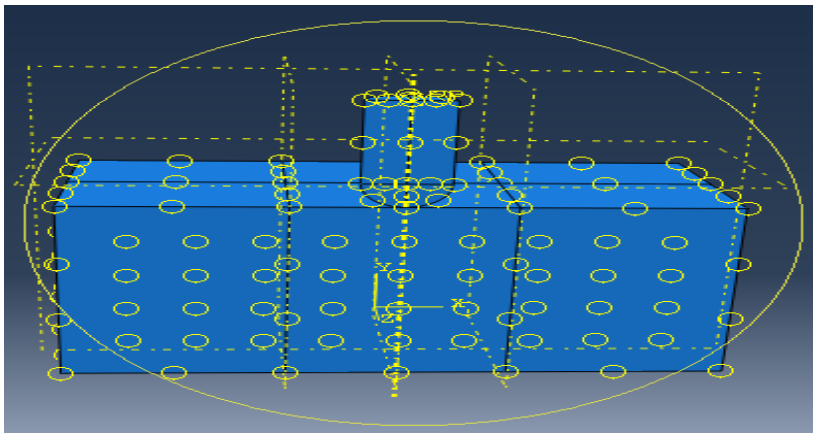


Fig.3.67. Interaction of projectile-2 on concrete panel

3.18 Load

In the load section, the boundary conditions are created for the simulation. For the right, left and the back face of concrete panel the boundary conditions are in global all directions and named as boundary condition-1, which is symmetry, antisymmetry and encastre and this boundary conditions are of mechanical category. For the front face of concrete panel the boundary conditions-2 is created which are mechanical categories and it is also of symmetry/ antisymmetry/ encastre type and it is in global z directions. The boundary condition for projectile-2 is displacement and rotation type, there distribution is uniform and the amplitude is instantaneous. For projectile-2 the boundary condition named as boundary conditions-3.

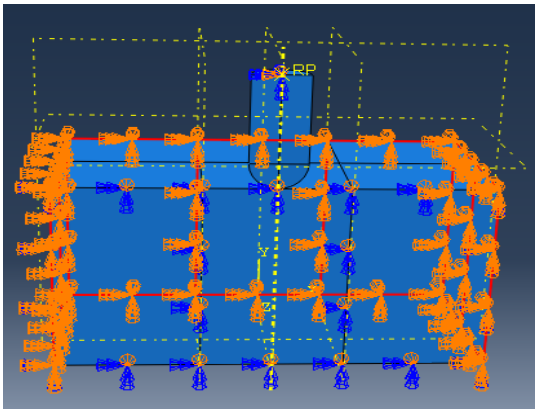


Fig.3.68. Boundary conition-1 on concrete panel

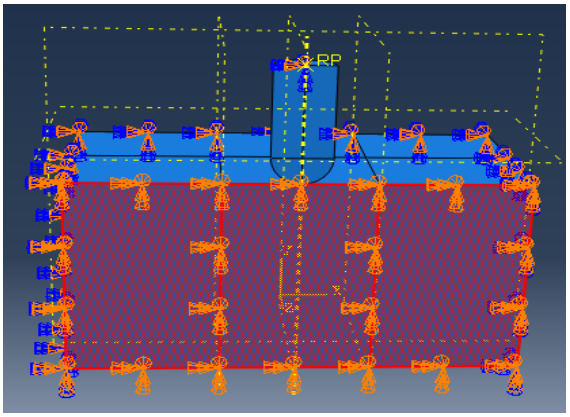


Fig.3.69. Boundary condition- 2

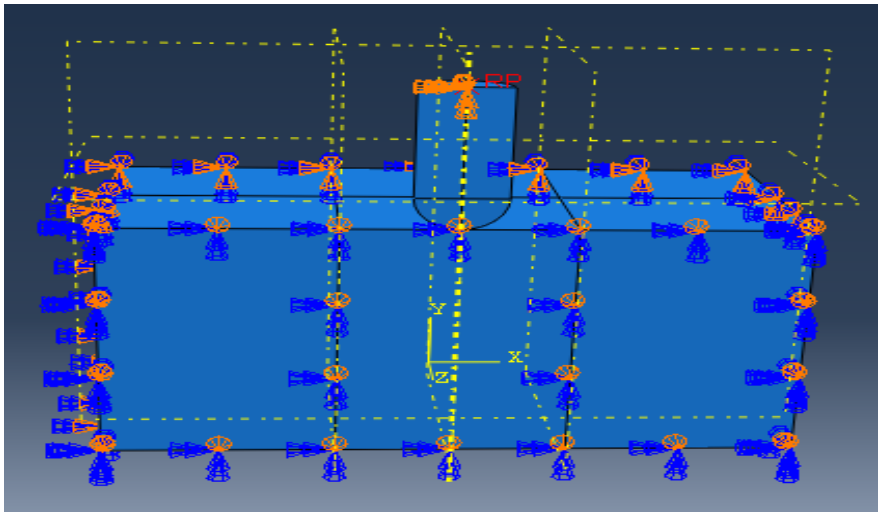


Fig.3.70. Boundary conditions-3 of projectile-2

The velocity of projectile-2 for this simulation is 400m/s (-400000 mm/s).

3.19 Mesh

The meshing of projectile -2 is done by size method and the element size is 4mm for projectile-2. For the concrete panel the element size is 5mm in the center of panel, where the minimum size 5mm and maximum size 15 mm in the outer region of concrete panel. For the reinforcement the element size is 10mm.

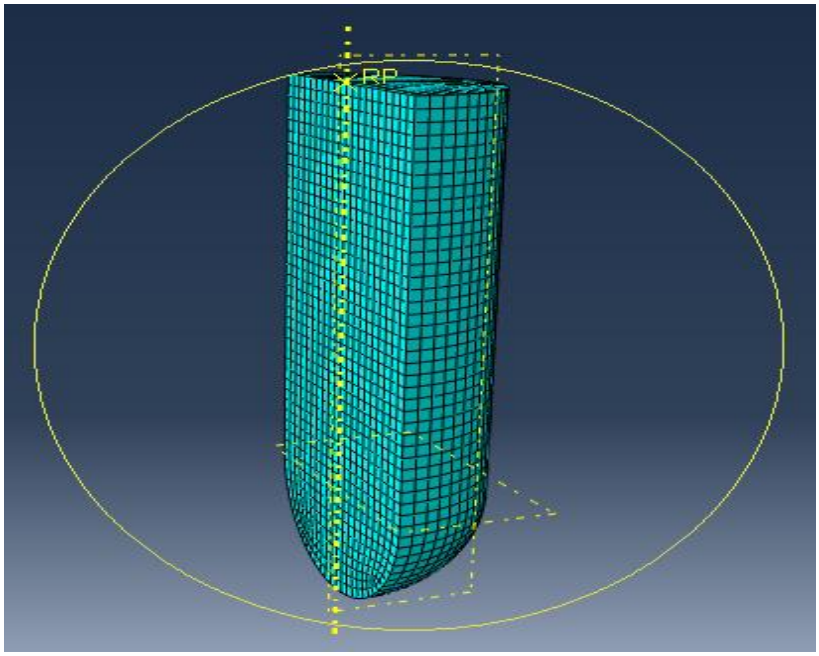


Fig.3.71. Mesh model of projectile-2

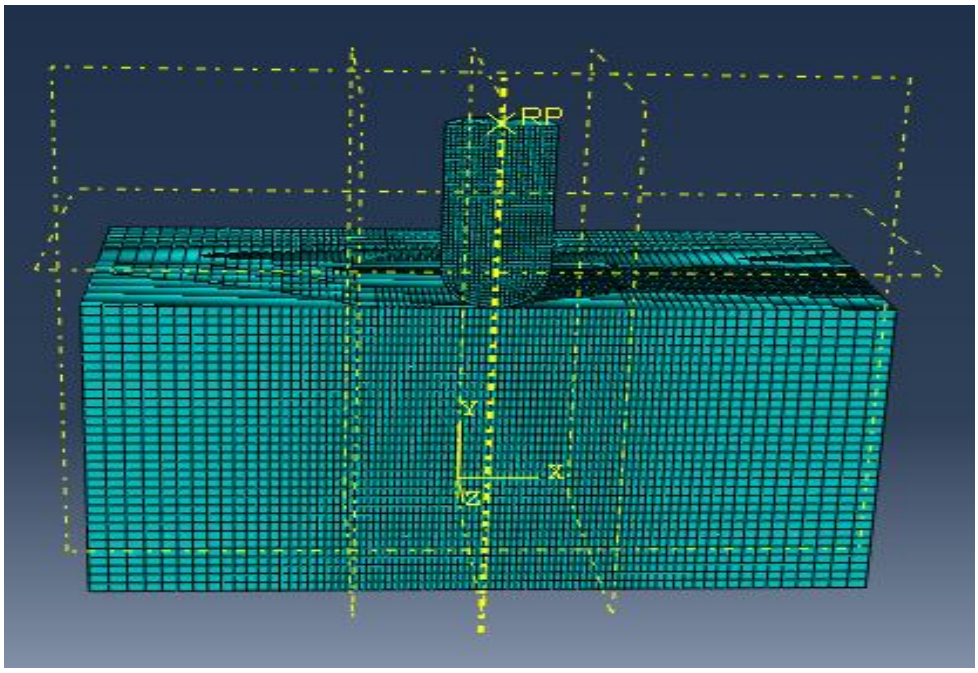


Fig.3.72. Whole model mesh model

3.20 Job

For this model there are two jobs are creating for this model the job-1 and job-2 for the ODB visualization**.** The job-1 is creating for the write the input of the model and the job-2 is submitted for the analysis and monitoring of the model.

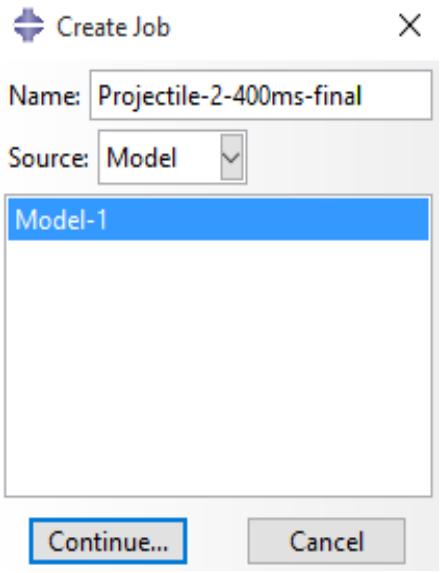


Fig.3.73. Create job-1 for p-2

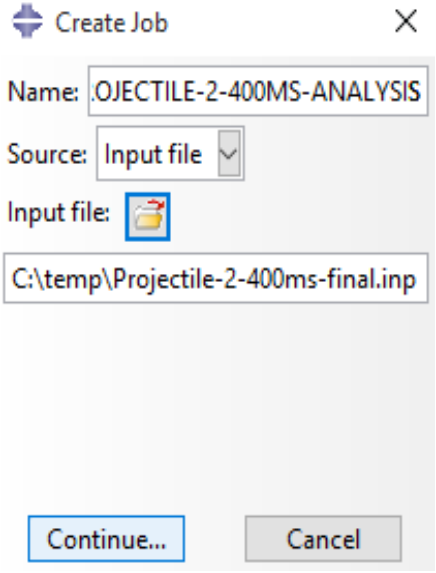
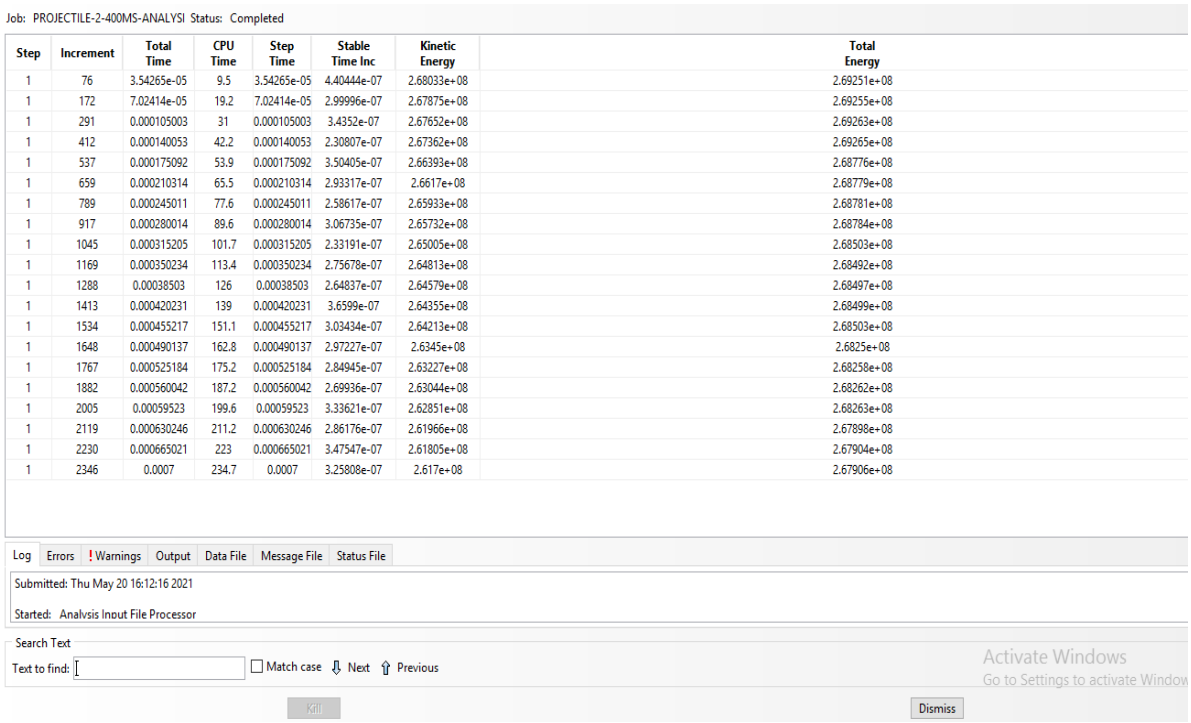


Fig.3.74. Create job-2 for output analysis



Job: PROJECTILE-2-400MS-ANALYSI Status: Completed

Step	Increment	Total Time	CPU Time	Step Time	Stable Time Inc	Kinetic Energy	Total Energy
1	76	3.54265e-05	9.5	3.54265e-05	4.40444e-07	2.68033e+08	2.69251e+08
1	172	7.02414e-05	19.2	7.02414e-05	2.99996e-07	2.67875e+08	2.69255e+08
1	291	0.000105003	31	0.000105003	3.4352e-07	2.67652e+08	2.69263e+08
1	412	0.000140053	42.2	0.000140053	2.30807e-07	2.67362e+08	2.69265e+08
1	537	0.000175092	53.9	0.000175092	3.50405e-07	2.66393e+08	2.68776e+08
1	659	0.000210314	65.5	0.000210314	2.93317e-07	2.6617e+08	2.68779e+08
1	789	0.000245011	77.6	0.000245011	2.58617e-07	2.65933e+08	2.68781e+08
1	917	0.000280014	89.6	0.000280014	3.06735e-07	2.65732e+08	2.68784e+08
1	1045	0.000315205	101.7	0.000315205	2.33191e-07	2.65005e+08	2.68503e+08
1	1169	0.000350234	113.4	0.000350234	2.75678e-07	2.64813e+08	2.68492e+08
1	1288	0.00038503	126	0.00038503	2.64837e-07	2.64579e+08	2.68497e+08
1	1413	0.000420231	139	0.000420231	3.6599e-07	2.64355e+08	2.68499e+08
1	1534	0.000455217	151.1	0.000455217	3.03434e-07	2.64213e+08	2.68503e+08
1	1648	0.000490137	162.8	0.000490137	2.97227e-07	2.6345e+08	2.6825e+08
1	1767	0.000525184	175.2	0.000525184	2.84945e-07	2.63227e+08	2.68258e+08
1	1882	0.000560042	187.2	0.000560042	2.69936e-07	2.63044e+08	2.68262e+08
1	2005	0.00059523	199.6	0.00059523	3.33621e-07	2.62851e+08	2.68263e+08
1	2119	0.000630246	211.2	0.000630246	2.86176e-07	2.61966e+08	2.67898e+08
1	2230	0.000665021	223	0.000665021	3.47547e-07	2.61805e+08	2.67904e+08
1	2346	0.0007	234.7	0.0007	3.25808e-07	2.617e+08	2.67906e+08

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Fig.3.75. Analysis of projectile-2 at velocity 400m/s

3.21 Penetration of Projectile-2 at velocity 600m/s

In numerical simulation, modeling the penetration projectile-2 at velocity 600m/s. The dimensions of the projectile-2, concrete pane and reinforcement is same for this simulation. In the property section the properties of concrete panel is named as abq-jh2_concrete and there are also a 32 mechanical constants and 8solution dependent variables. In the create section of concrete panel the category is solid and it is homogeneous type where the material is abq_jh2_concrete. For the reinforcement the elastic and plastic are same, which are used for the projectile-1 simulation, section are also same. For projectile the material is of solid category and homogeneous type, where the material is steel. After the property part has been done we can assemble the reinforcement in the inner region of the concrete panel and at the center edge point assemble the projectile-2 having a velocity 600m/s. In the step part we can adjust the time period for projectile-2 to be penetrated shown in fig. 3.89. Output parameters are also applied in the step section for the better simulation results. Then the interaction of the each part has been done. In this simulation the interaction between concrete panel and reinforcement is firstly done then projectile and concrete panel has done. In the load part, firstly create the boundary conditions for the each part in the simulation. After creating the boundary conditions in model, set the velocity

of projectile-2 for the penetration in this model the velocity of the projectile-2 is 600m/s. Before submitting the job the mesh has been done for the each part. For the better results the meshing will done in the proper manner, better the meshing better the modeling is done.

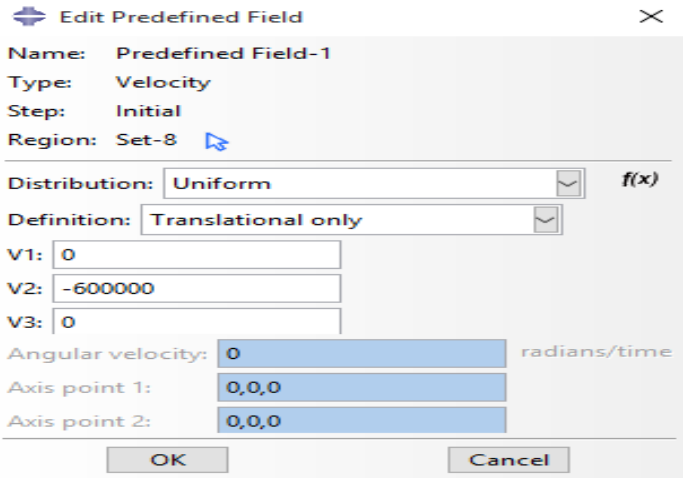


Fig.3.76. Velocity for projectile-2 600m/s

3.21.1 Job (V=600m/s)

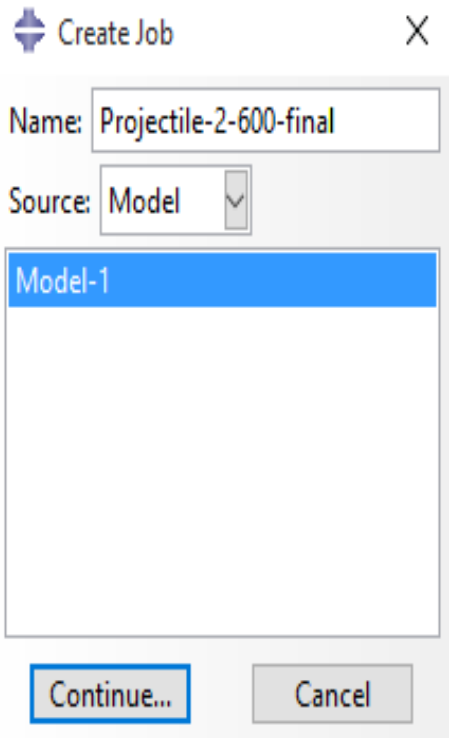


Fig.3.77.(b). Create job1 for projectile-2

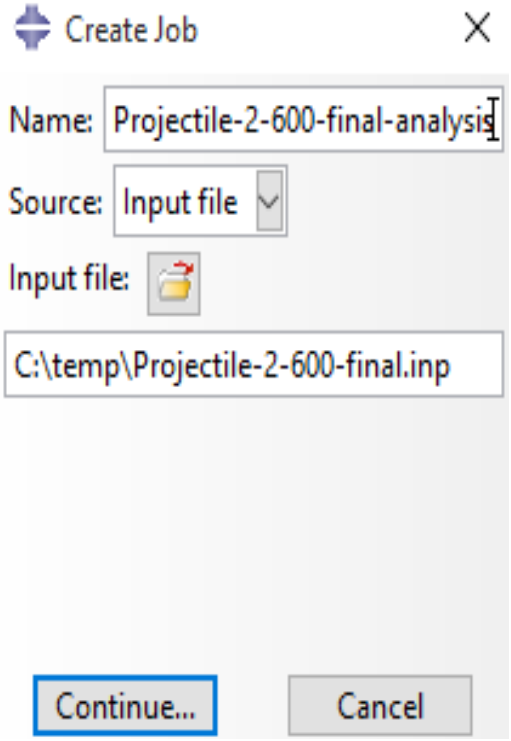
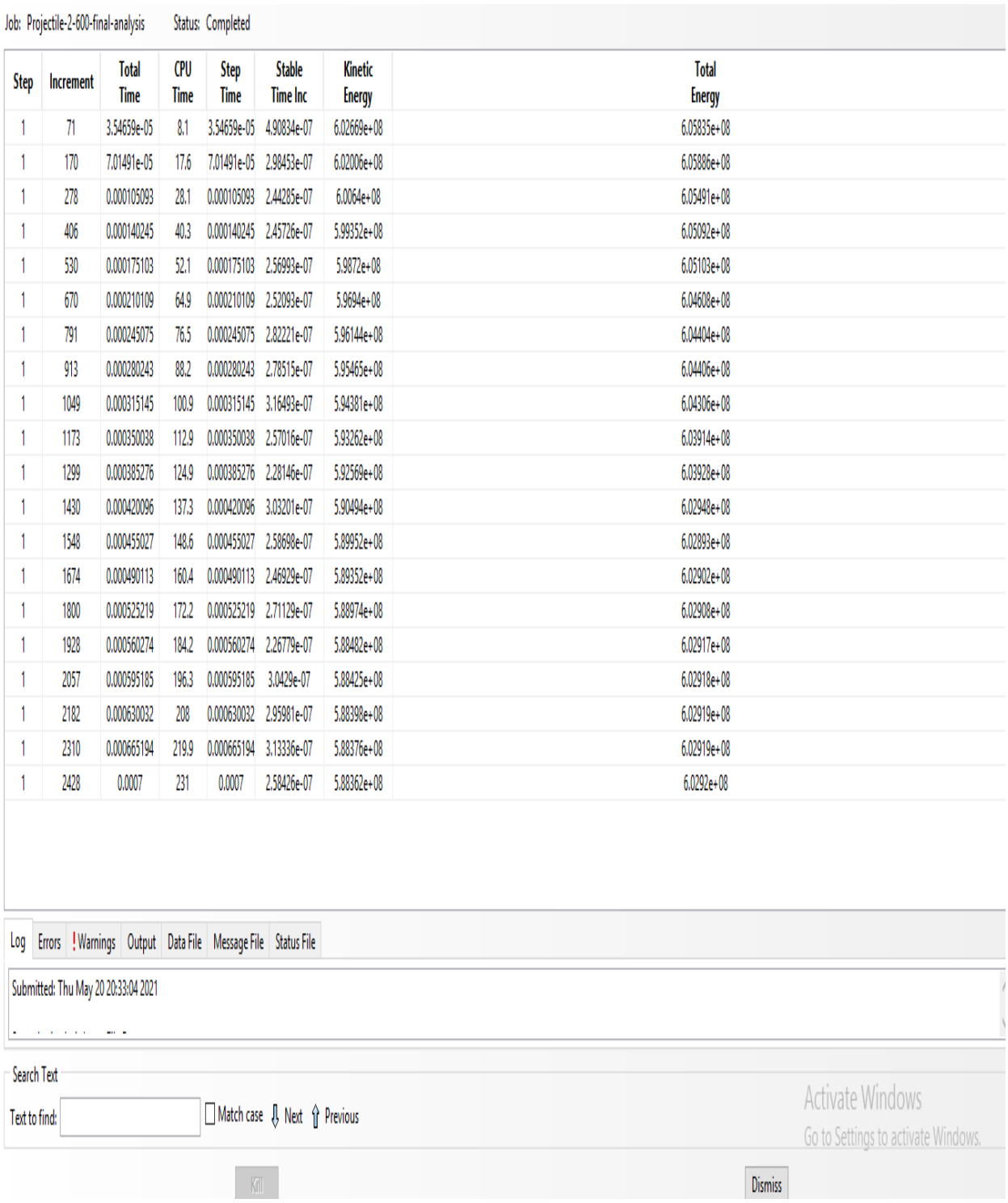


Fig.3.77(b). Create job-2 for monitoring



Job: Projectile-2-600-final-analysis Status: Completed

Step	Increment	Total Time	CPU Time	Step Time	Stable Time Inc	Kinetic Energy	Total Energy
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1	170	7.01491e-05	17.6	7.01491e-05	2.98453e-07	6.02006e+08	6.05886e+08
1	278	0.000105093	28.1	0.000105093	2.44285e-07	6.0064e+08	6.05491e+08
1	406	0.000140245	40.3	0.000140245	2.45726e-07	5.99352e+08	6.05092e+08
1	530	0.000175103	52.1	0.000175103	2.56993e-07	5.9872e+08	6.05103e+08
1	670	0.000210109	64.9	0.000210109	2.52093e-07	5.9694e+08	6.04608e+08
1	791	0.000245075	76.5	0.000245075	2.82221e-07	5.96144e+08	6.04404e+08
1	913	0.000280243	88.2	0.000280243	2.78515e-07	5.95465e+08	6.04406e+08
1	1049	0.000315145	100.9	0.000315145	3.16493e-07	5.94381e+08	6.04306e+08
1	1173	0.000350038	112.9	0.000350038	2.57016e-07	5.93262e+08	6.03914e+08
1	1299	0.000385276	124.9	0.000385276	2.28146e-07	5.92569e+08	6.03928e+08
1	1430	0.000420096	137.3	0.000420096	3.03201e-07	5.90494e+08	6.02948e+08
1	1548	0.000455027	148.6	0.000455027	2.58698e-07	5.89952e+08	6.02893e+08
1	1674	0.000490113	160.4	0.000490113	2.46929e-07	5.89352e+08	6.02902e+08
1	1800	0.000525219	172.2	0.000525219	2.71129e-07	5.88974e+08	6.02908e+08
1	1928	0.000560274	184.2	0.000560274	2.26779e-07	5.88482e+08	6.02917e+08
1	2057	0.000595185	196.3	0.000595185	3.0429e-07	5.88425e+08	6.02918e+08
1	2182	0.000630032	208	0.000630032	2.95981e-07	5.88398e+08	6.02919e+08
1	2310	0.000665194	219.9	0.000665194	3.13336e-07	5.88376e+08	6.02919e+08
1	2428	0.0007	231	0.0007	2.58426e-07	5.88362e+08	6.0292e+08

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Fig.3.78. Analysis of projectile-2 at velocity 600m/s

CHAPTER 4

RESULTS AND DISCUSSION

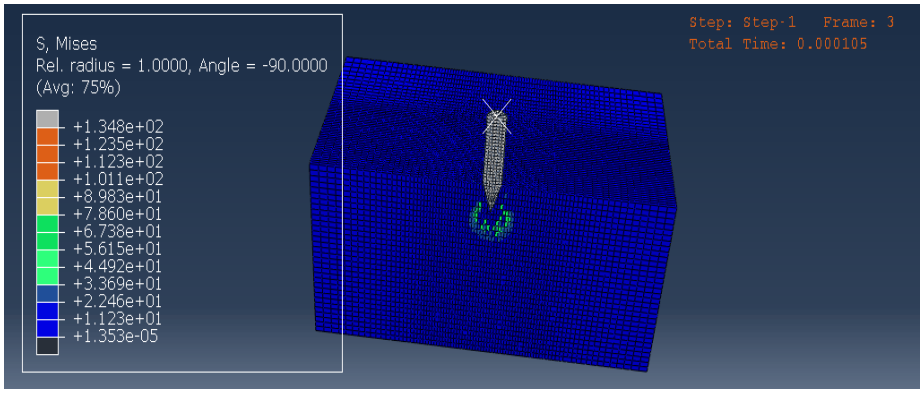
4.1 General

This part shows the results and observations of the simulation which are done in the chapter-3. In the first stage, the penetration of projectile-1 is done with the velocity 400 m/s and 600 m/s. In the second stage, the penetration of projectile-2 has simulate having a velocity of 400 m/s and 600 m/s. The effect of the projectile-1 and projectile on a concrete panel and in a reinforcement are discussed below.

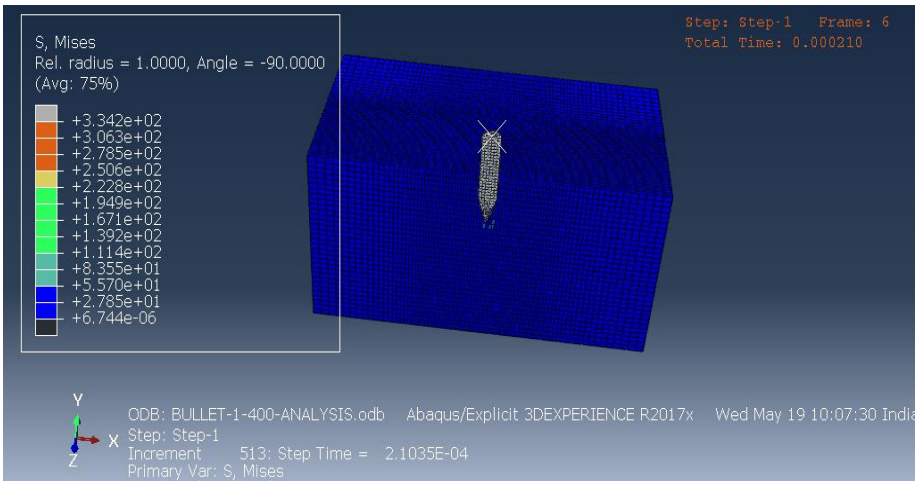
4.2 Penetration of Projectile-1 on concrete panel, damage in concrete panel and damage in reinforcement at velocity 400m/s

4.2.1 Penetration of projectile-1 on concrete panel

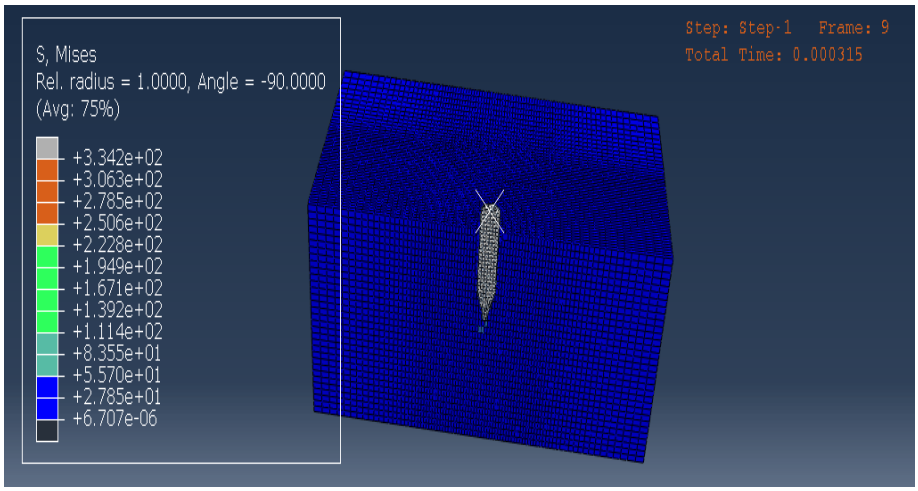
Fig 4.1 (a) to (g), shows the penetration of a projectile at time t =0s to t =0.0007s in a concrete panel, the velocity of projectile-1 is 400m/s. At a time t= 0.0001s the projectile is starts to penetrate and at time t = 0.007s the projectile is fully penetrated in a concrete panel. When the projectile is starts to penetrate the value of penetration is starts to decreasing and then suddenly increasing with time. The initial value and final value of projectile-1 at the time (t= 0.001s) of penetration is 1.348 and 1.353, and when the projectile is fully penetrated at time t= 0.0007s the value is 3.3 and 6.6 .The angle is -90 degree at the time of the penetration. The projectile is not fully penetrated at velocity 400 m/s.



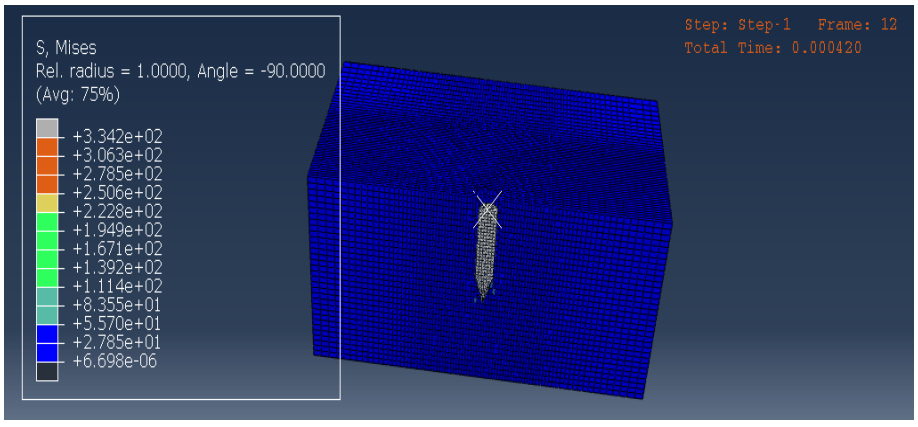
(a) t= 0.0001s



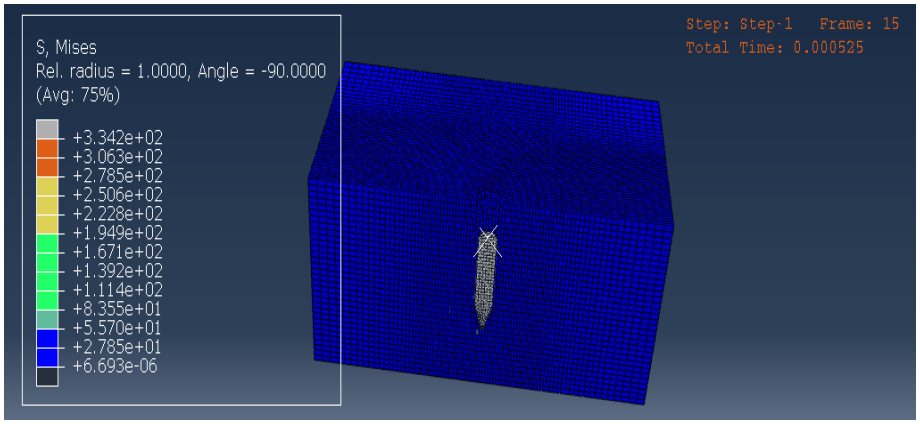
(b) t= 0.0002s



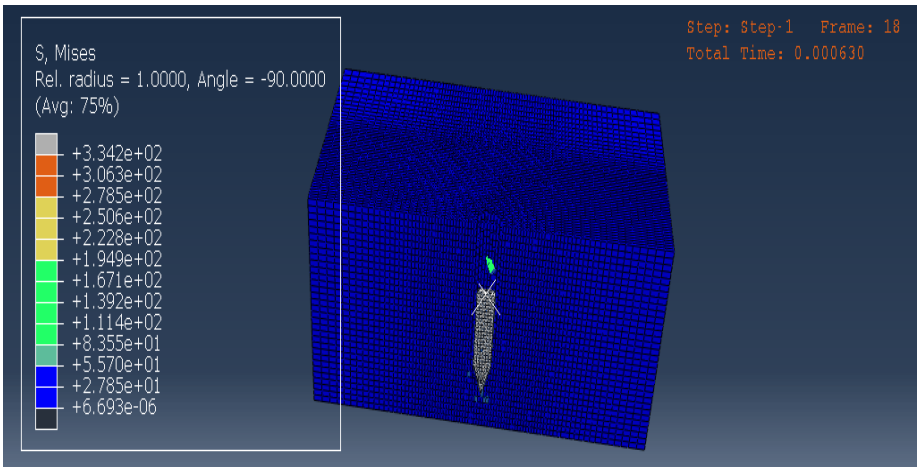
(c) t= 0.0003s



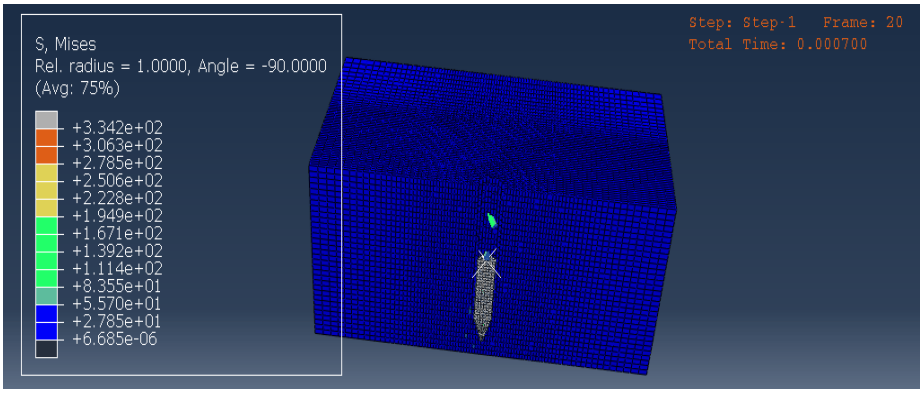
(d) t= 0.0004s



(e) t= 0.0005s



(f) t= 0.0006s

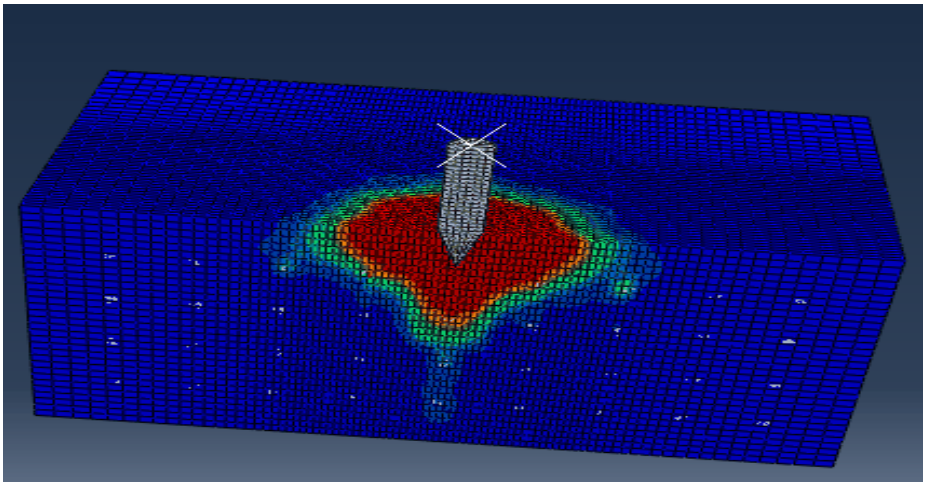


(g) t= 0.0007

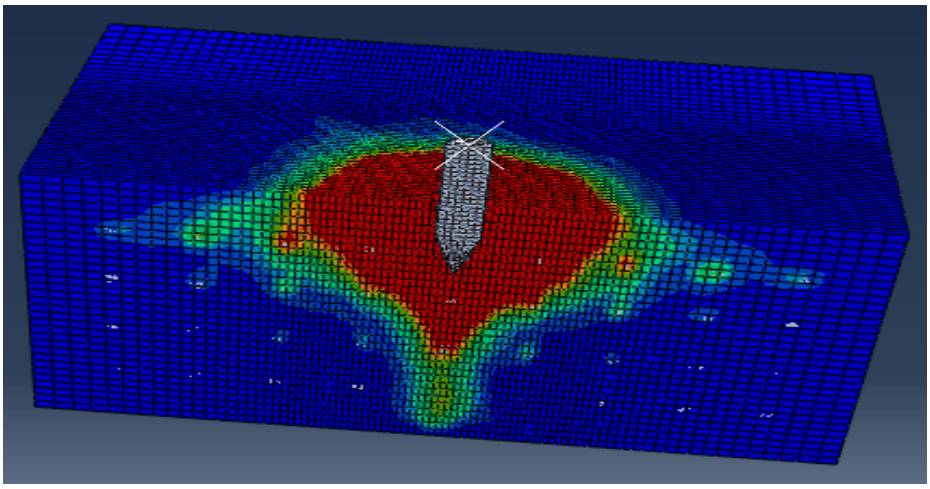
Fig.4.1.(a) to (g). Penetration of projectile-1 in concrete panel at time 0.0001 to 0.0007s

4.2.2 Damage in concrete panel

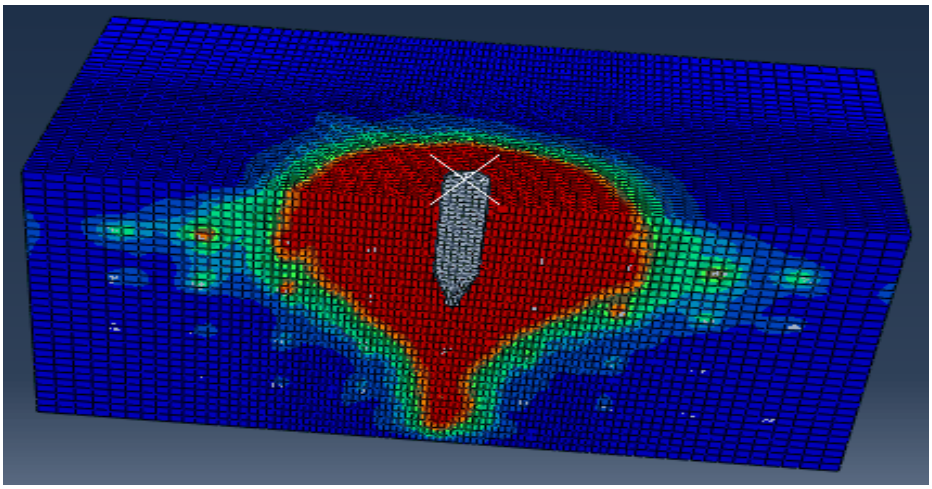
In this simulation of projectile-1 penetration the damage can occur in the concrete panel. At time t= 0s there is no damage in a concrete panel. The damage is creating when the projectile is starts to penetrated at a velocity of 400m/s . In the damage of concrete panel the concrete panel accept the values 0.0 and 1.0, when projectile is undamaged and fully damaged. There is large damage can occurred in a concrete panel at time t=0.0007s . Fig 4.2 ((a) – (g)) ,shows the damage in concrete panel due to the projectile.



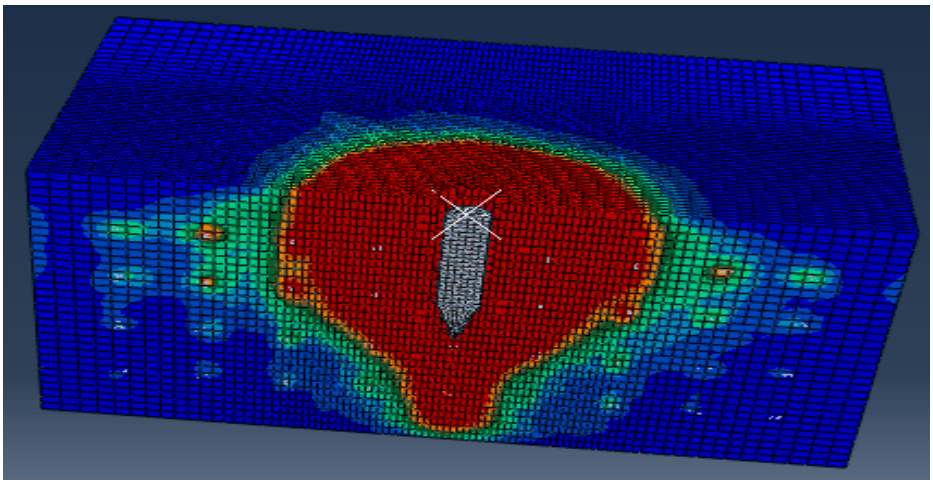
(a) t= 0.0001s



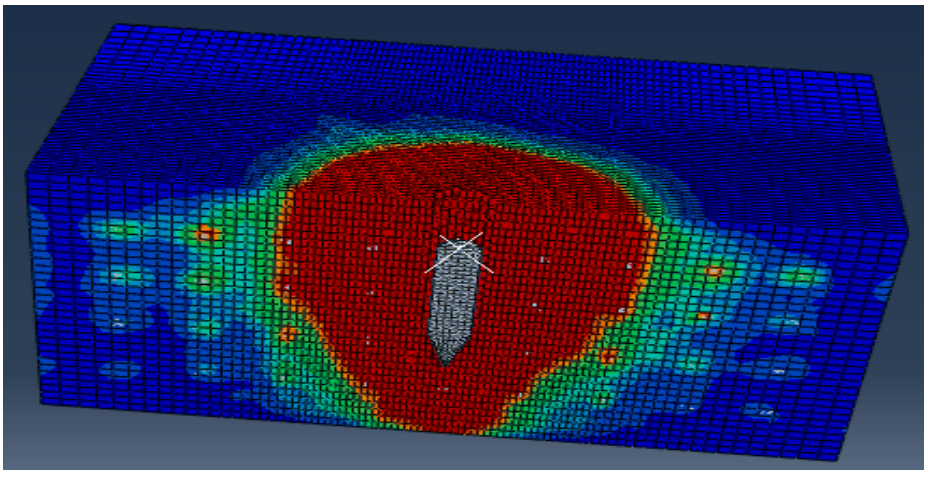
(b) t= 0.0002s



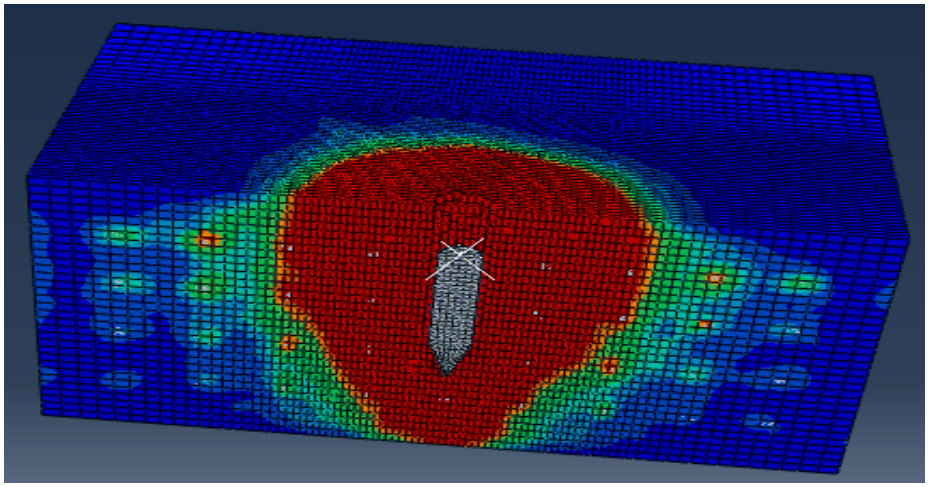
(c) t= 0.0003s



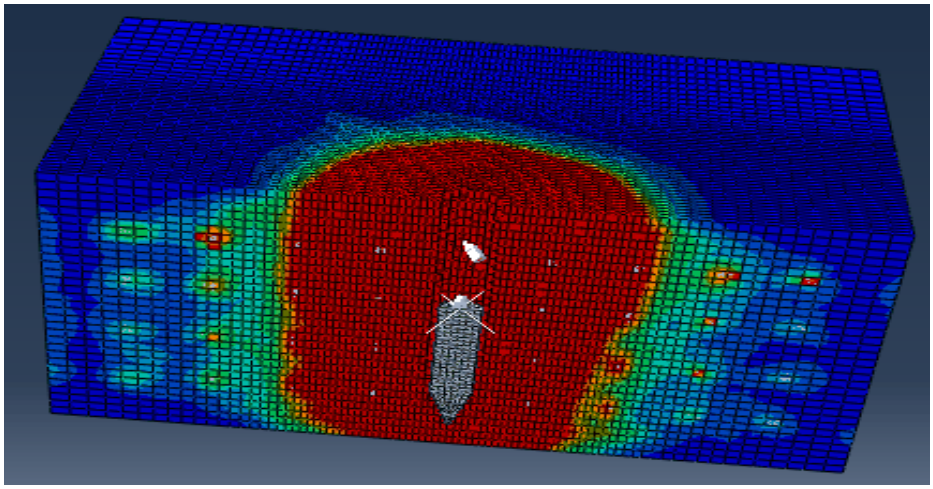
(d) t= 0.0004s



(e) t= 0.0005s



(f) t= 0.0006s

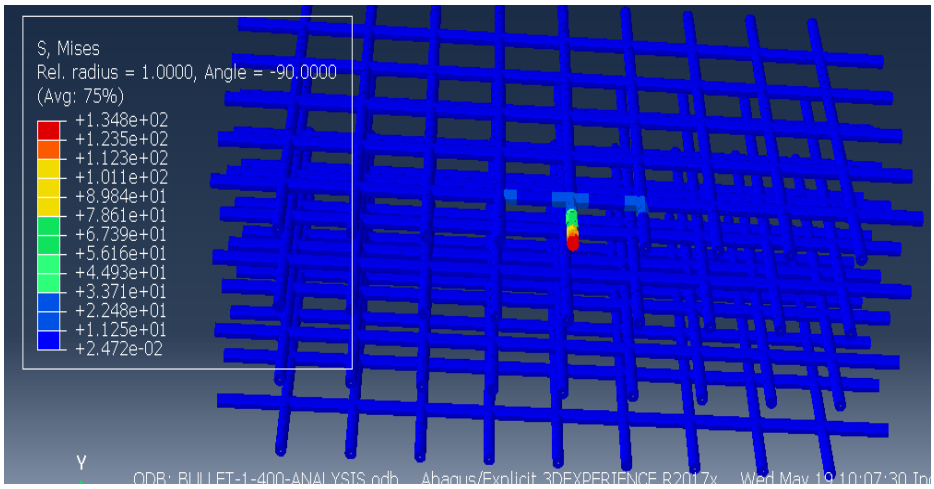


(g) t= 0.0007s

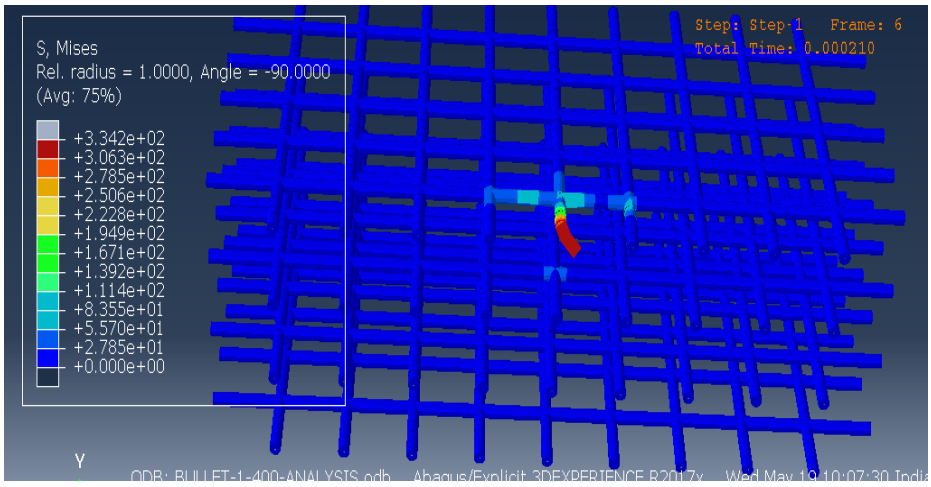
Fig.4.2. (a) to(g). Damage in concrete panel at velocity 400m/s

4.2.3 Damage in reinforcement

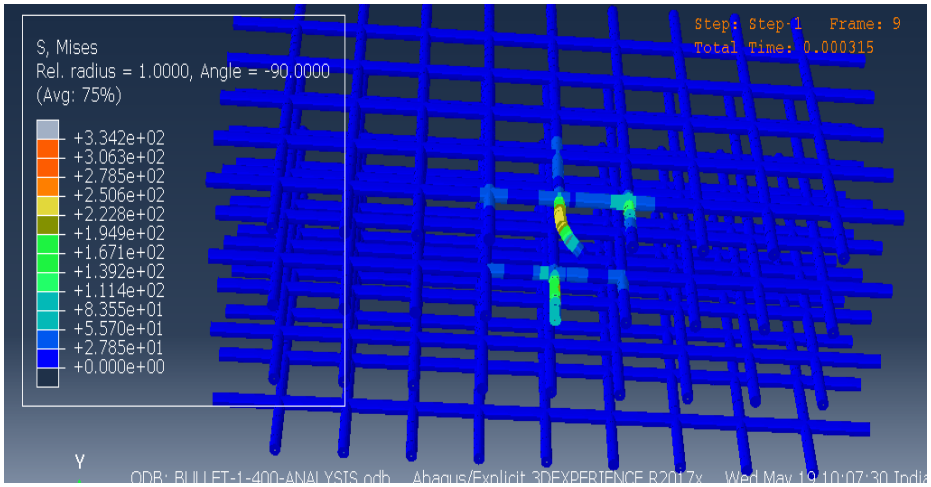
In this simulation, the damage in reinforcement is also analzed by the penetration of a projectile-1. The damage in reinforcement is taken place from t= 0.0001 to t= 0.0007s. There are the stresses can created in the reinforcement when the projectile-1 is starts to penetrate at velocity 400m/s. The initial value and final for stresses in reinforcement is 0 and 3.42 at time t= 0.0007s. Fig 4.3.(a) to (g) shows the damage in reinforcement due to the projectile-1 shown below:



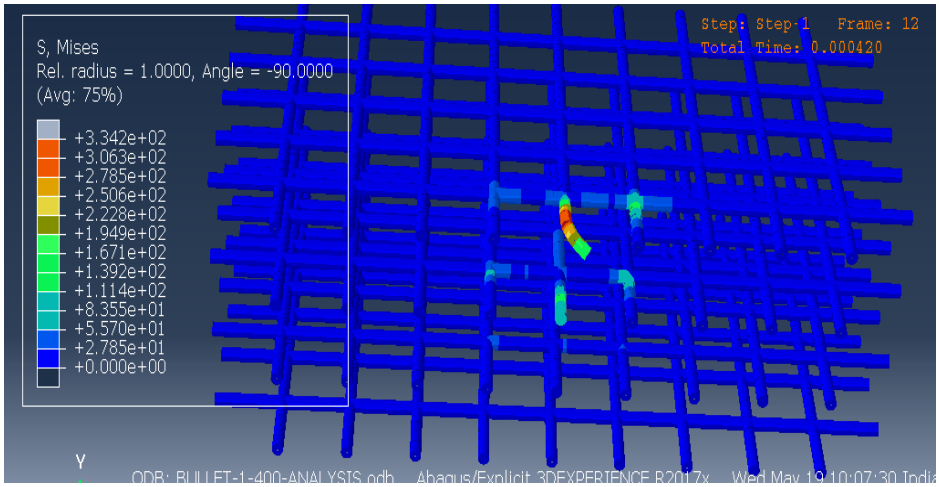
(a) t= 0.0001s



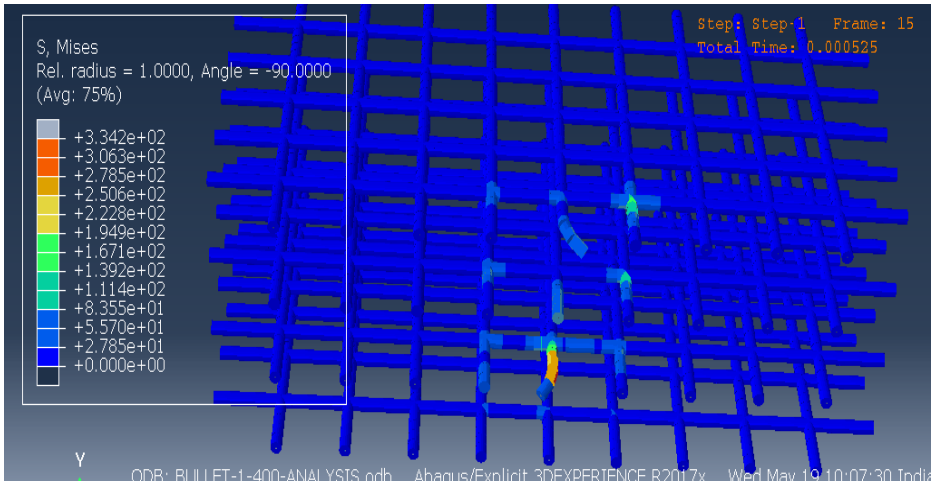
(b) t= 0.0002s



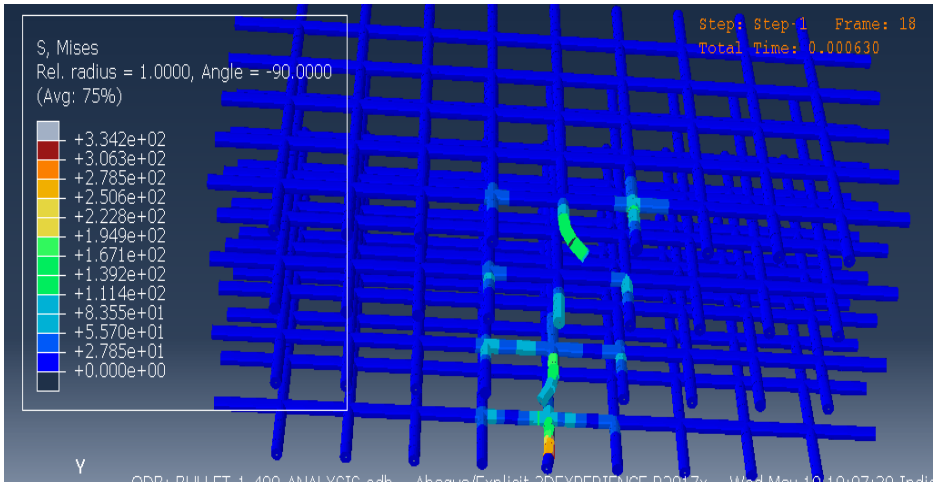
(c) t= 0.0003s



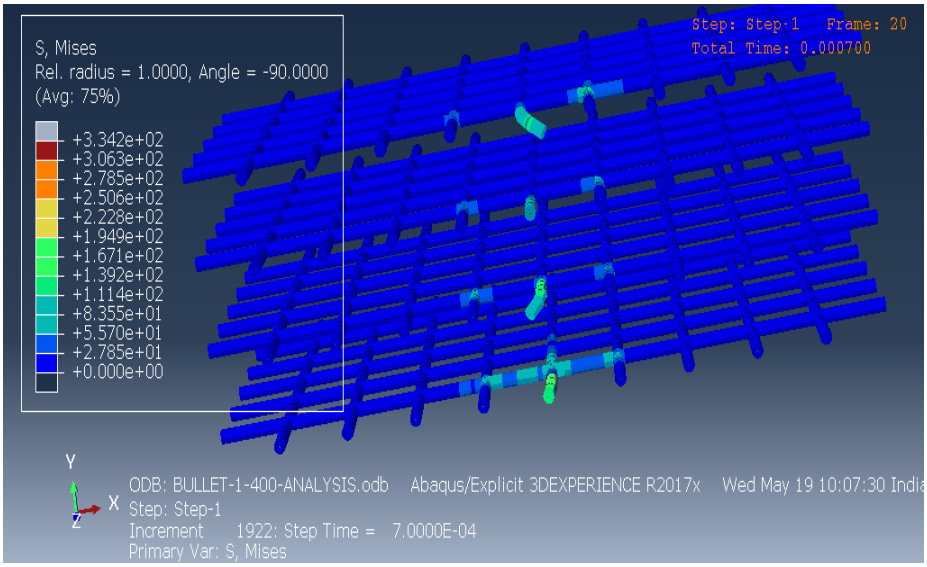
(d) t= 0.0004s



(e) t= 0.0005s



(f) t= 0.0006s



(a) t= 0.0007s

Fig.4.3. (a) to(g). Damage in reinforcement at velocity 400m/s

4.3 Internal energy, kinetic energy, strain energy and total energy analysis

4.3.1 General

In this section, the internal energy of concrete slab, the kinetic energy of projectile-1, strain energy of whole model and total energy of model is analyzed under the impact of projectile at a velocity 600m/s.

4.3.2 Internal energy of concrete panel

When a projectile is penetrated in a concrete panel the internal energy of a concrete panel is gradually increasing with the time.

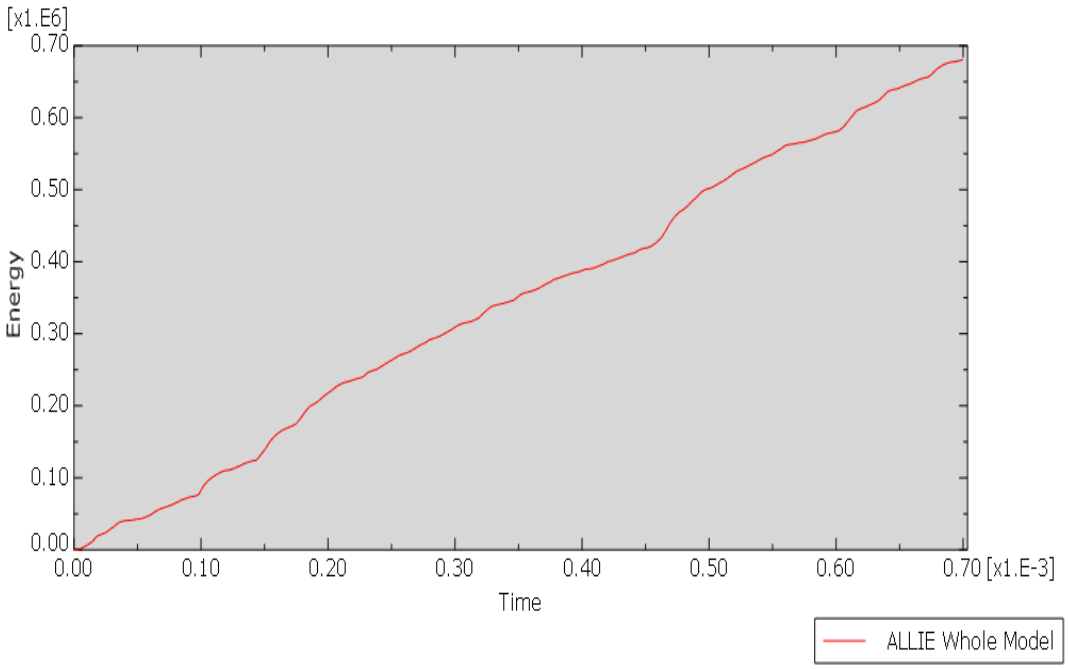


Fig.4.4. Internal energy of concrete panel (V=400m/s)

4.3.3 Kinetic energy of projectile-1

The energetic absorption of projectile is decreasing, when it starts to penetrate in a concrete panel at a velocity 400m/s. The kinetic energy of the projectile-1 is 2.57 at time t= 0.0007s.

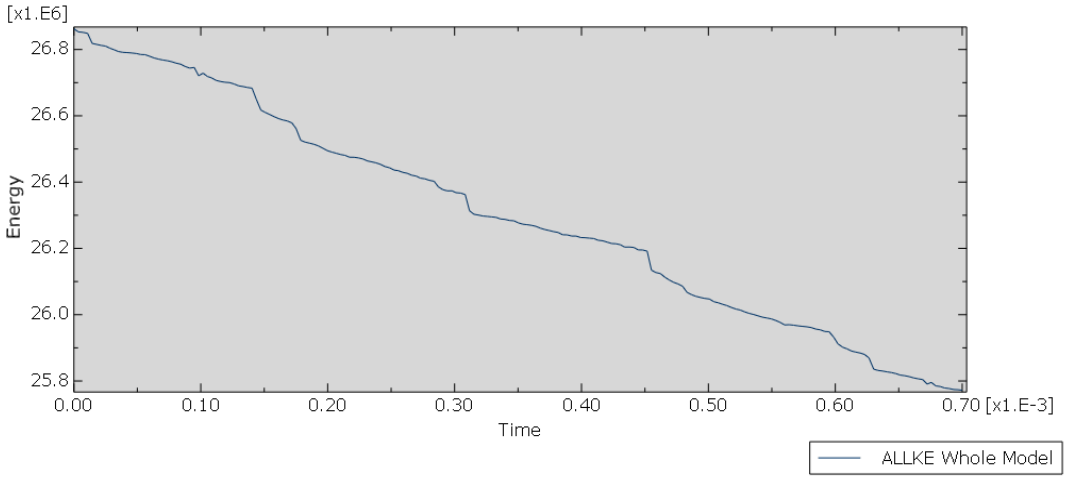


Fig.4.5. Kinetic energy of projectile-1

4.3.4 Strain energy and total energy of model

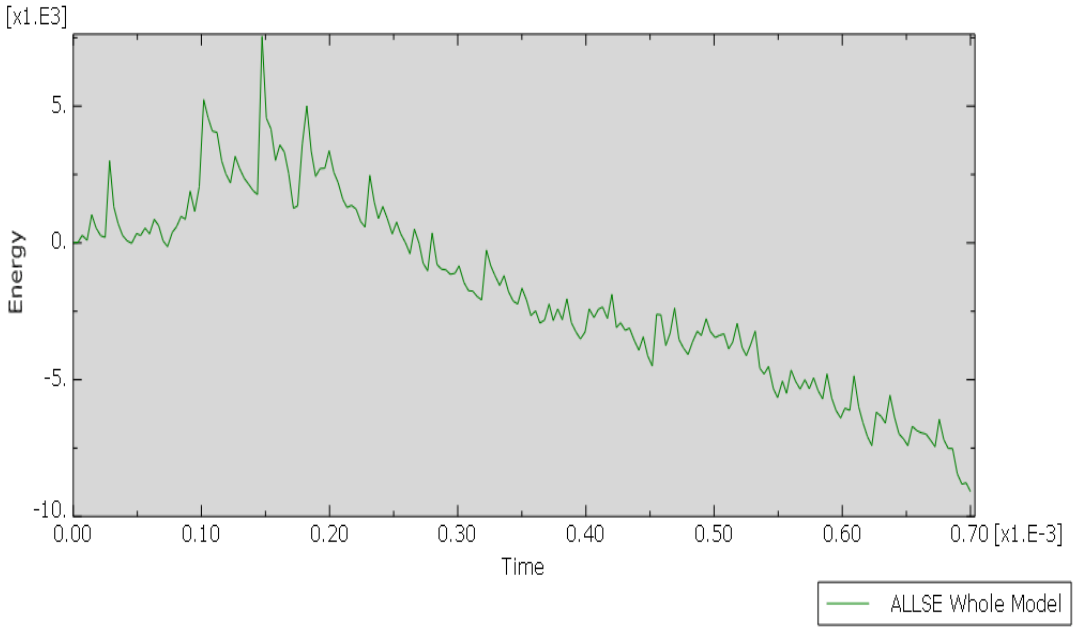


Fig.4.6. Strain energy of whole model

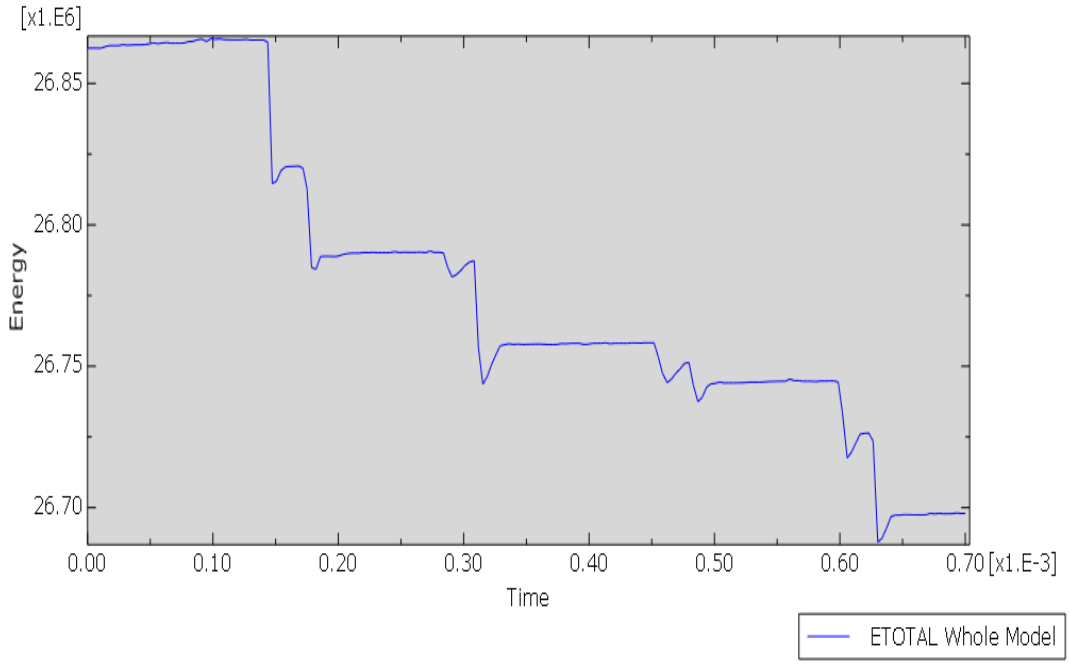


Fig.4.7. Total energy of whole model

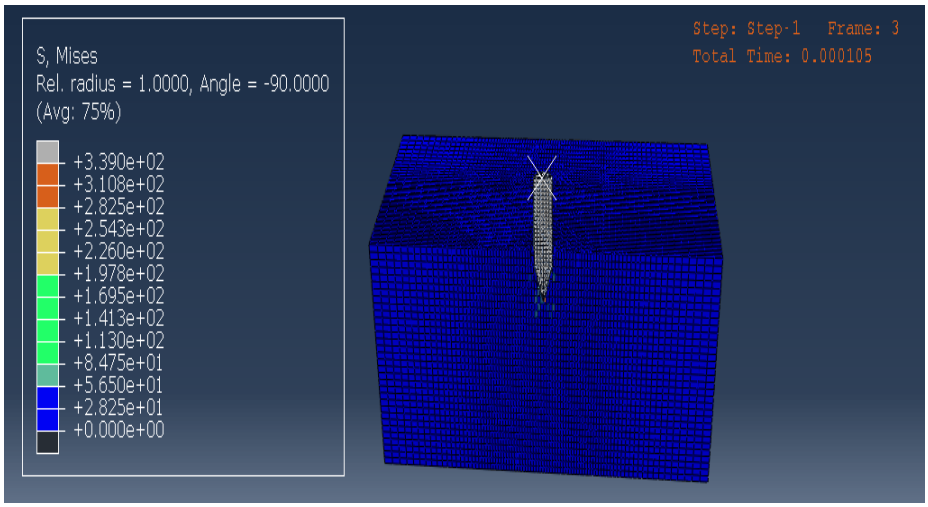
4.4 Projectile-1 impact in concrete panel at velocity 600m/s.

4.4.1 Projectile-1 penetration, damage in concrete panel and damage in reinforcement

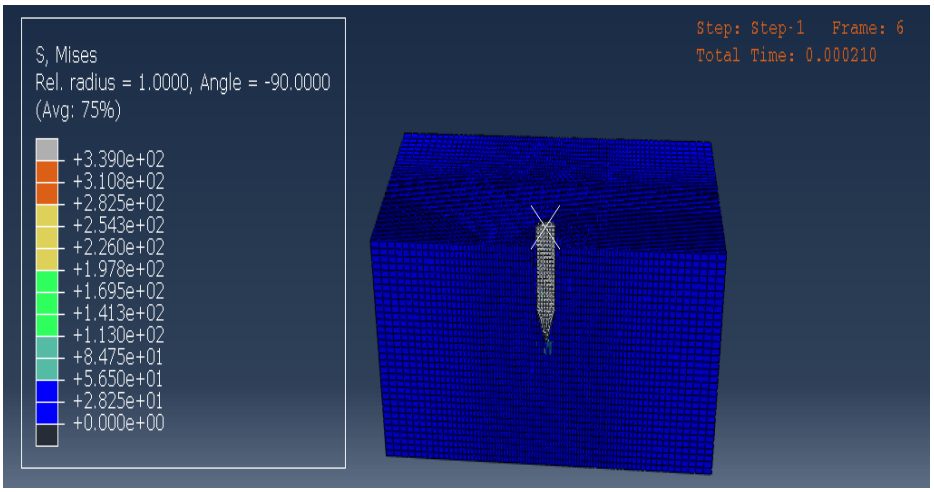
4.4.2 General

The projectile-1 is penetrated at a velocity of 600m/s in concrete panel. At time t= 0.0s and time t= 0.0007s the projectile-1 is not penetrated and fully penetrated. At time t= 0.0007s the initial and final value is 3.3 and 6.6. There is damage are also created in a concrete panel due to the projectile-1 impact. There is no damage in a concrete panel at time t= 0.000s. When a projectile starts to penetrate the damage variables takes a initial and final value, which is 0.0 and 1.0, undamaged and fully damaged. There is maximum damage at time t= 0.0007s. The projectile-1 takes a time of 0.0007s to be fully penetrated in a concrete panel. In reinforcement there is a maximum damage in the reinforcement where projectile is penetrated. The stresses are also created by the projectile. The projectile take 0.0007s to passes the all reinforcement in a inner region of concrete panel.

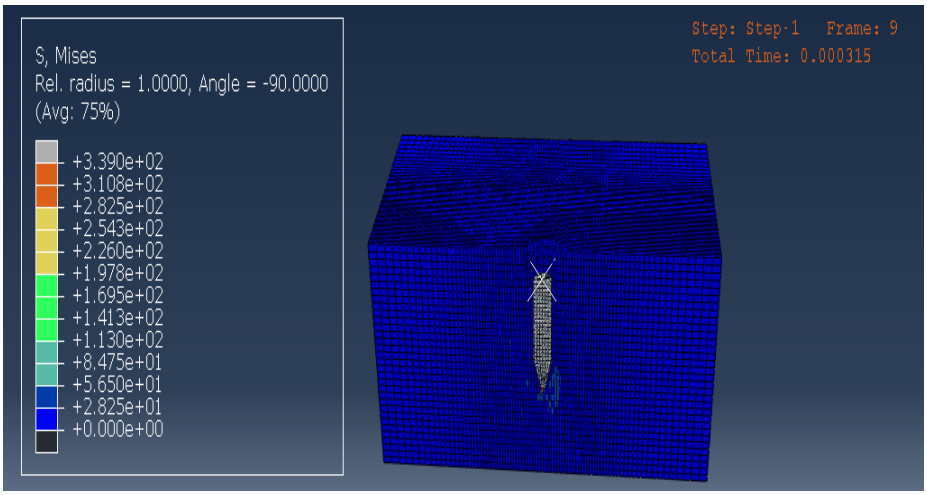
4.4.3 Penetration of projectile-1 in concrete panel



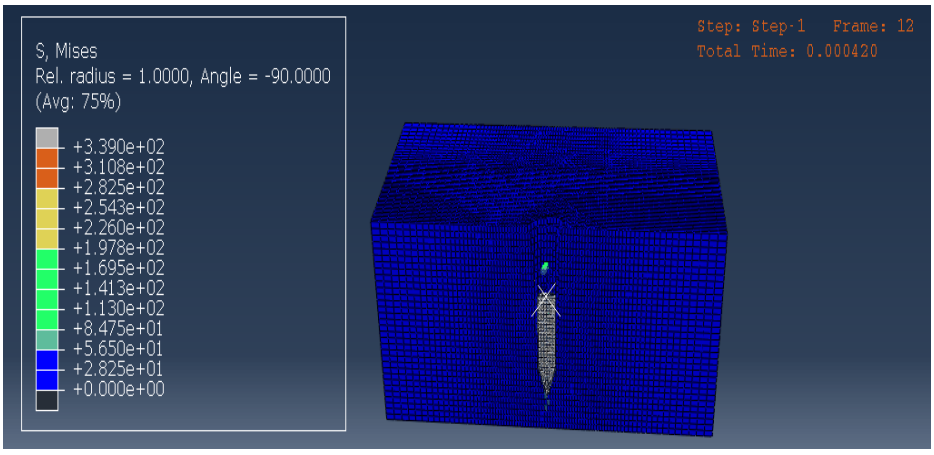
(a) Period = 0.0001s



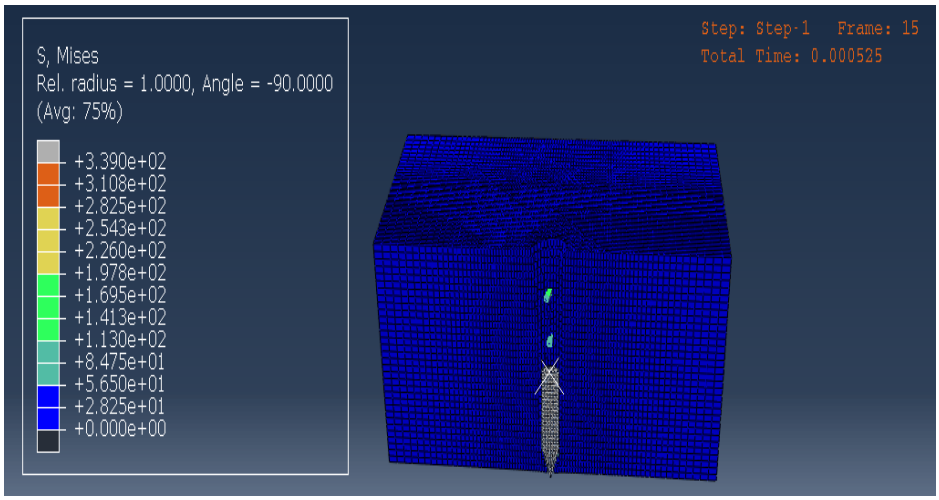
(b) Period = 0.0002s



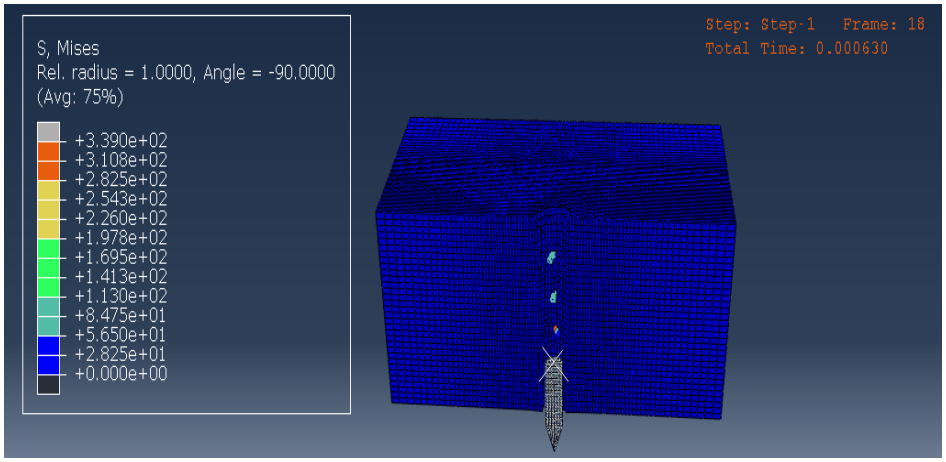
(c) Period = 0.0003s



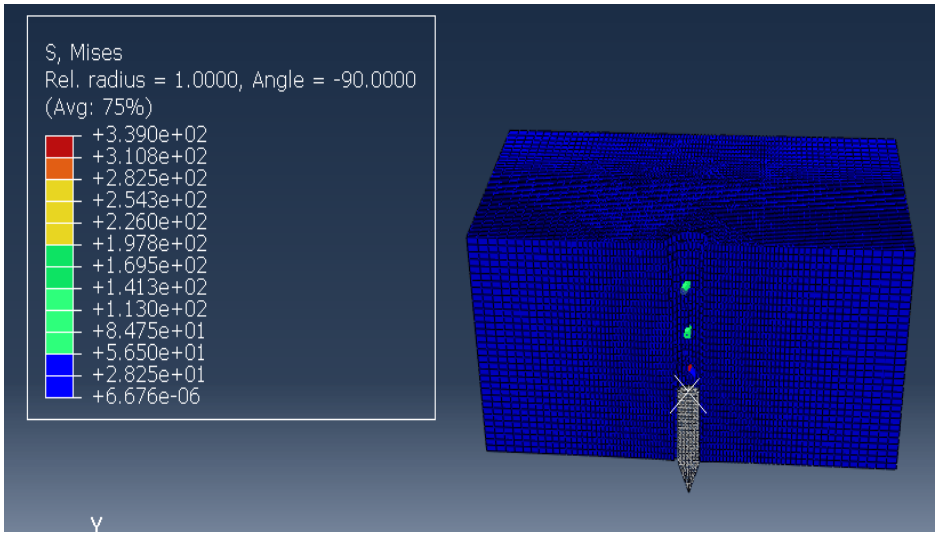
(d) Period= 0.0004s



(e) Period= 0.0005s



(f) Period= 0.0006s

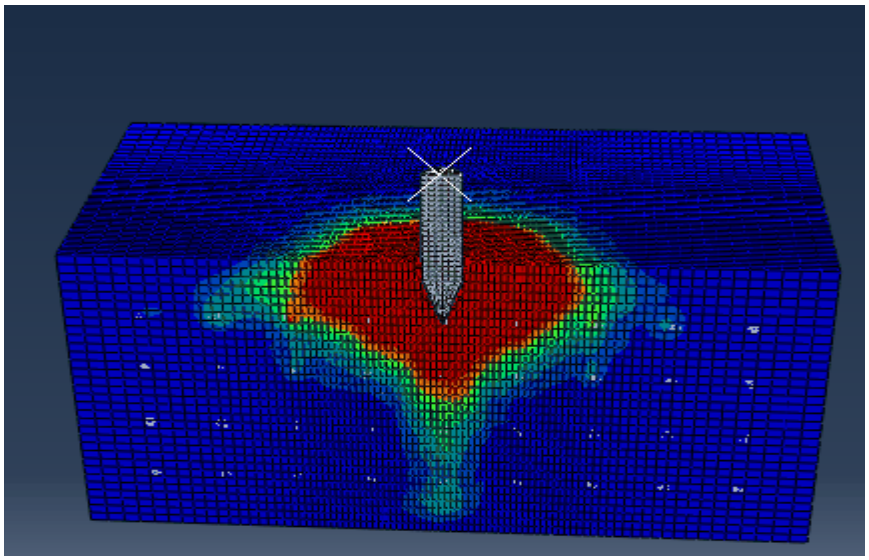


(g) Period= 0.0006s

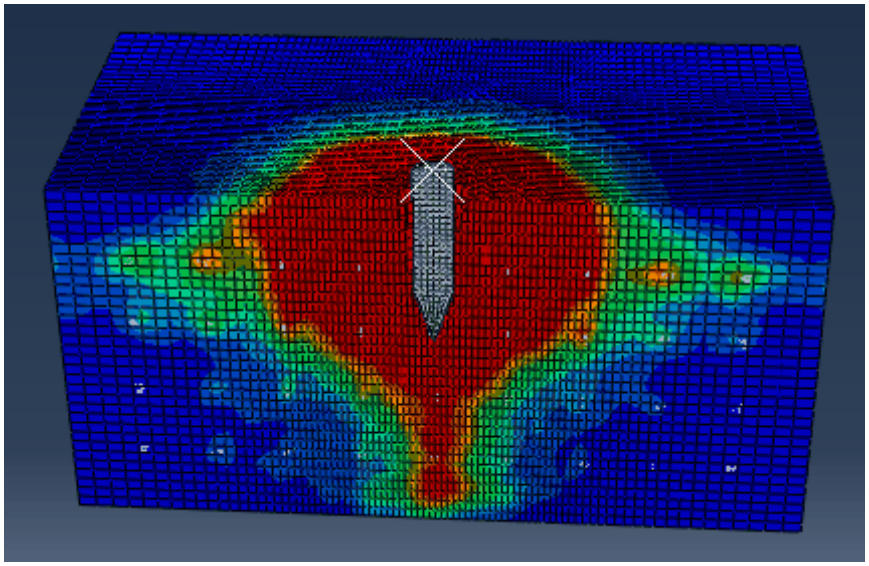
Fig.4.8.(a) to (g). Penetration of projectile-1 in concrete panel at time 0.0001 to 0.0007s (V=600m/s)

4.4.4 Damage in concrete panel

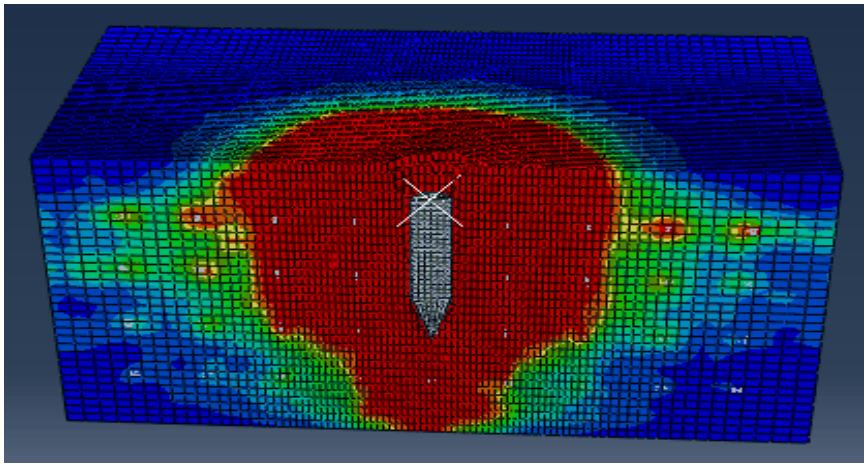
The figure 4.5(a) to (g) shows the damage in concrete panel by projectile-1 at velocity 600m/s shown below :



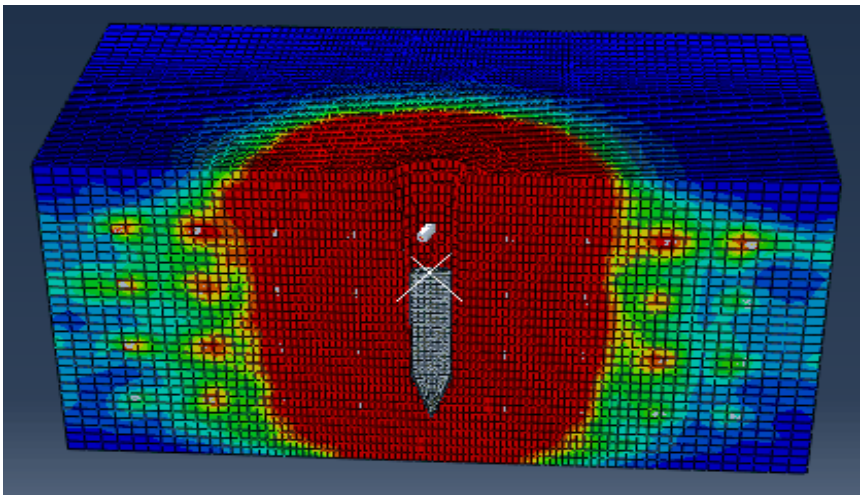
(a) t= 0.0001s



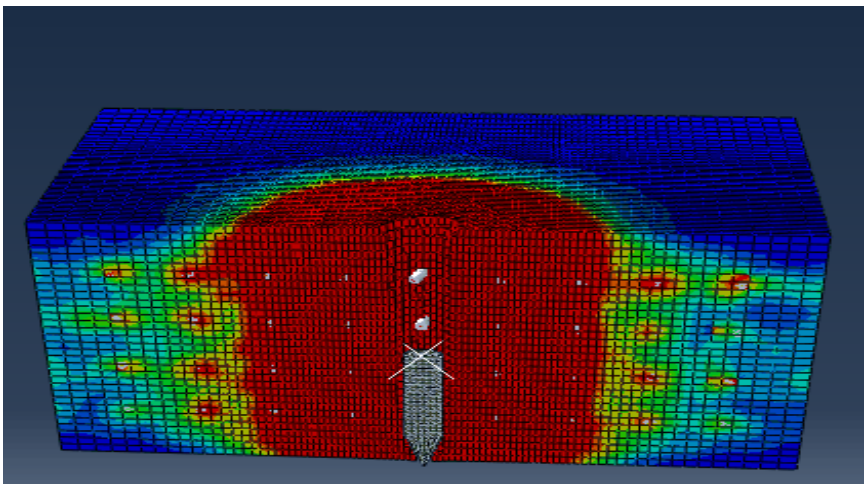
(b) t= 0.0002s



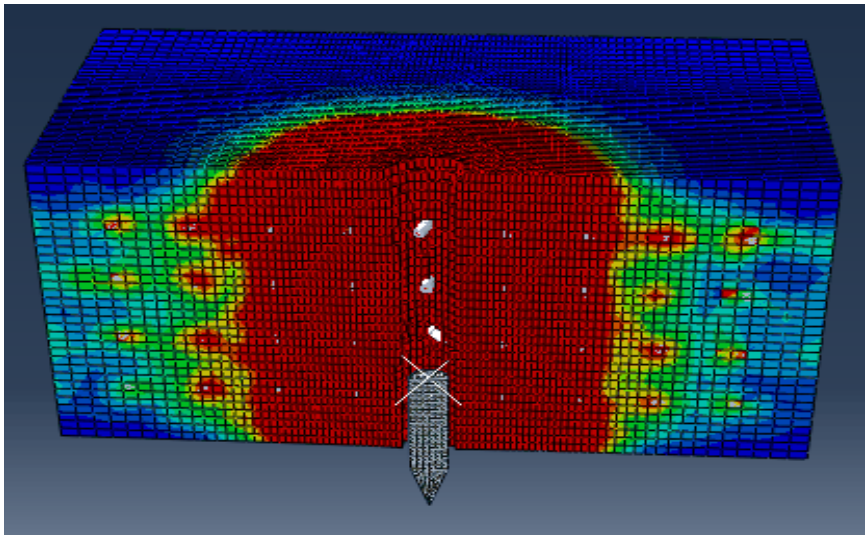
(c) t= 0.0003s



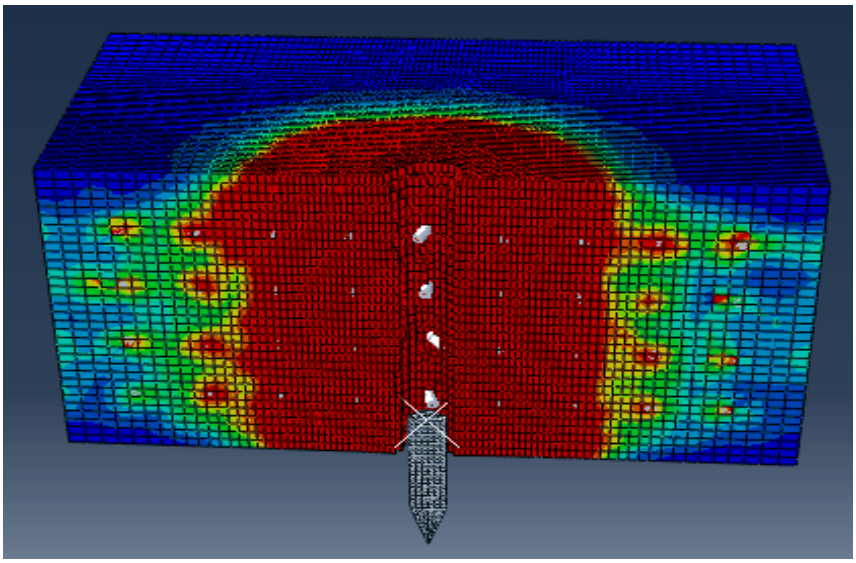
(d) t= 0.0004s



(e) t= 0.0005s



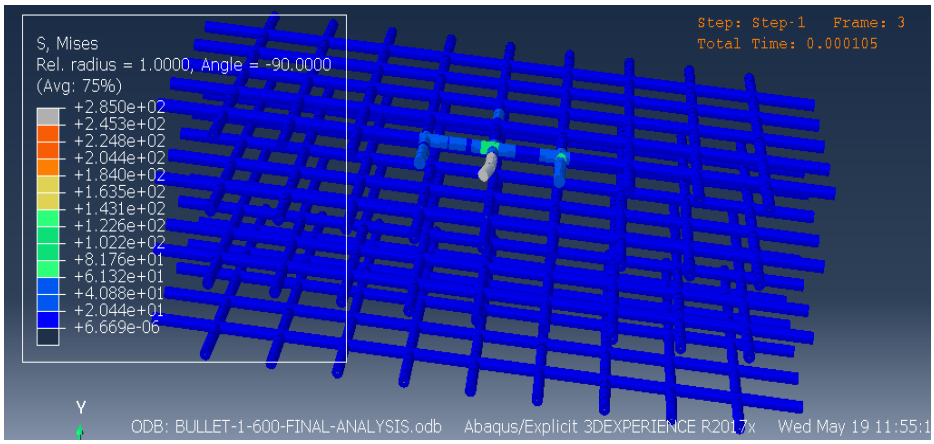
(f) t= 0.0006s



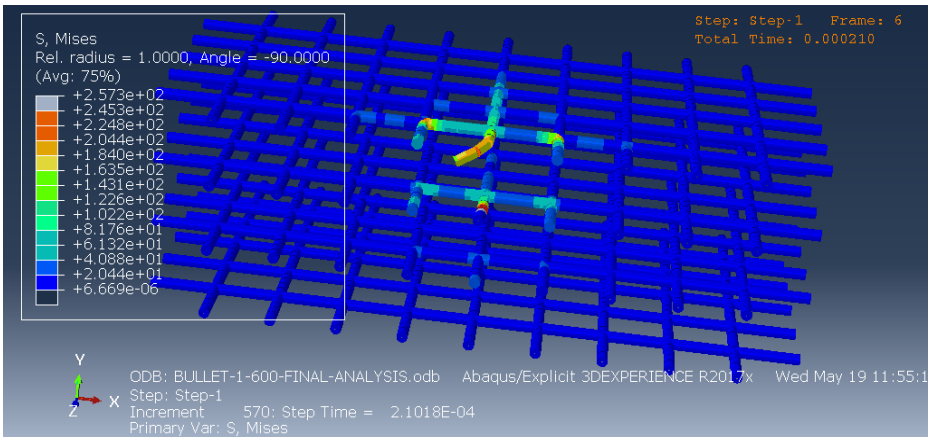
(g) t= 0.0007s

Fig.4.9. (a) to(g). Damage in concrete panel at velocity 600m/s

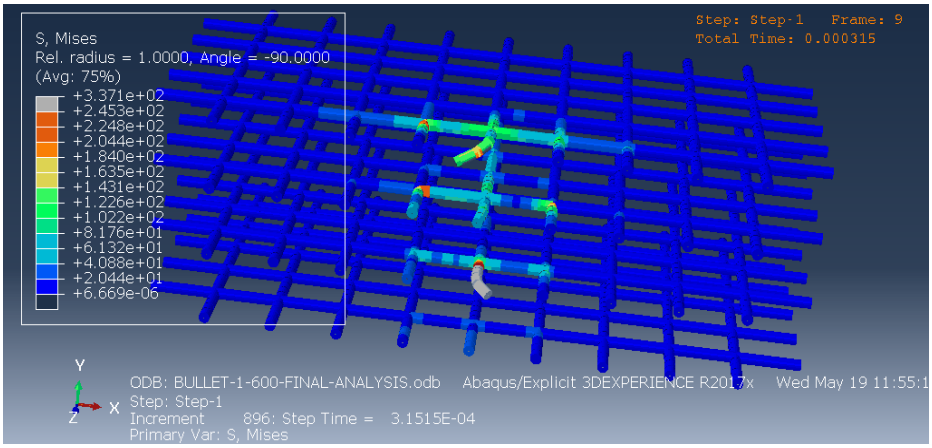
4.4.5 Damage in reinforcement due to projectile-1 at velocity (V= 600m/s)



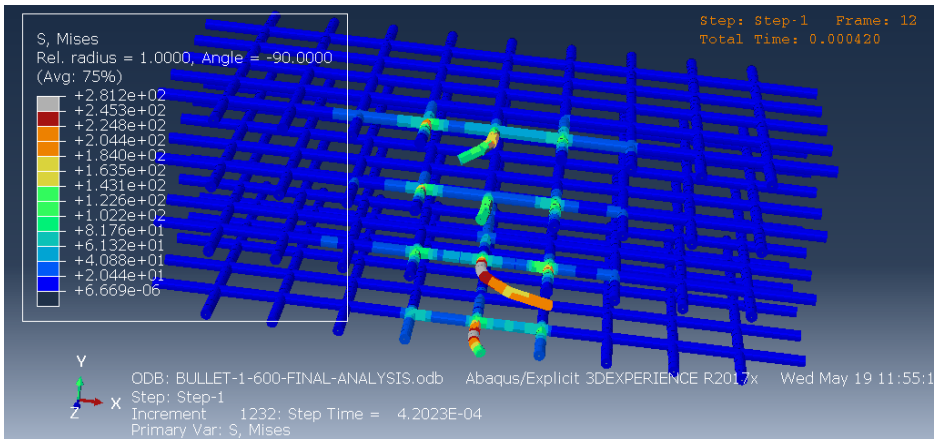
(a) Duration = 0.0001s



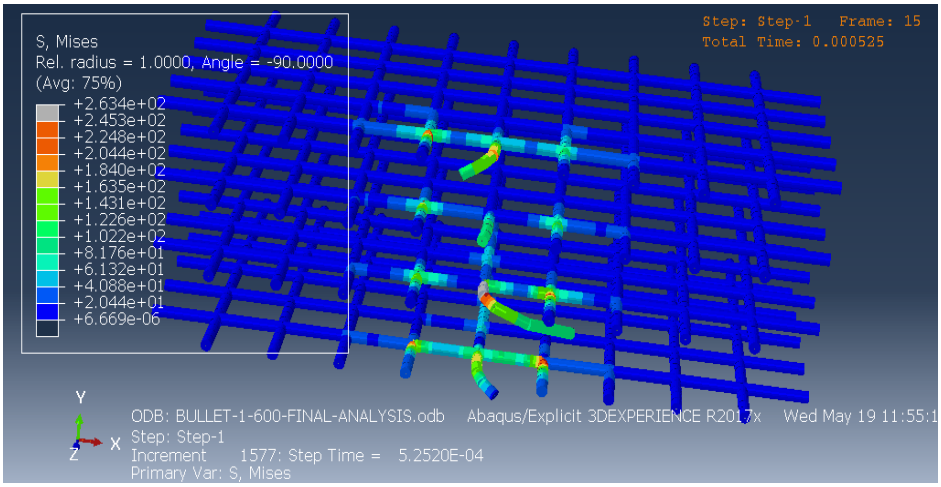
(b) Duration= 0.0002s



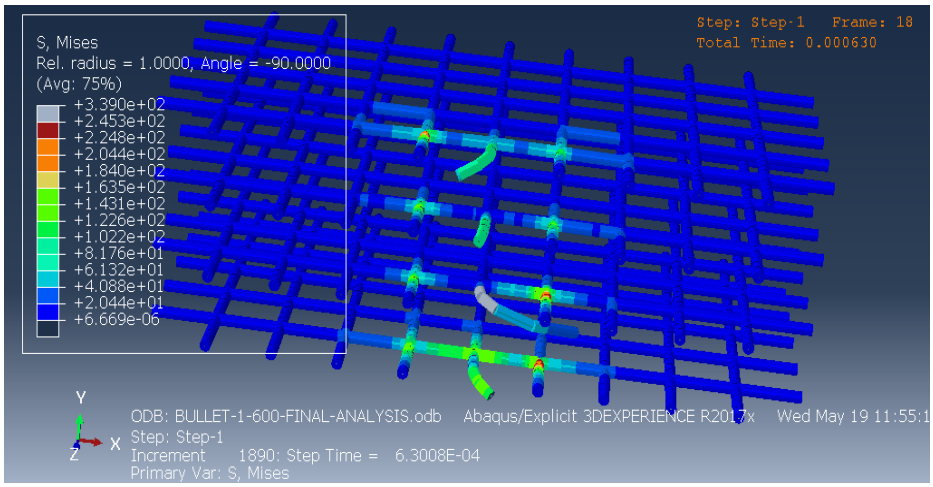
(c) Duration= 0.0003s



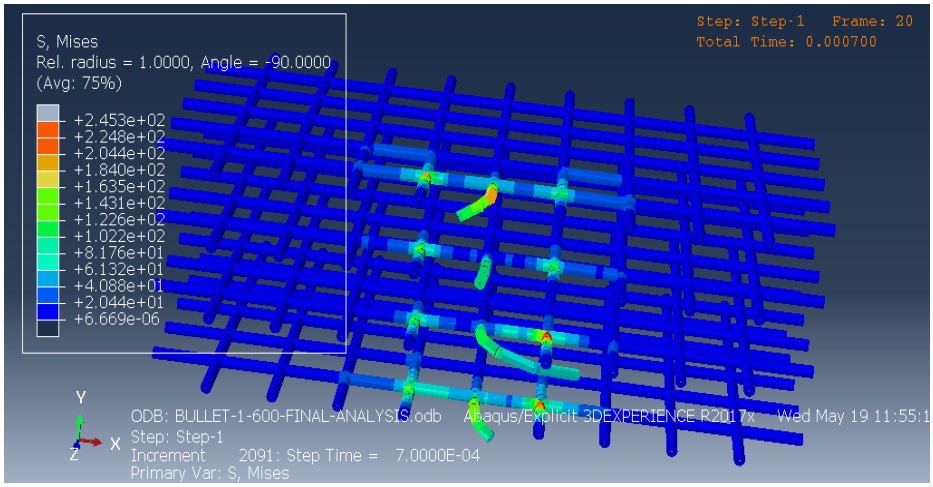
(d) Duration= 0.0004s



(e) Duration= 0.0005s



(f) Duration= 0.0006s



(g) Duration= 0.0007s

Fig.4.10. (a) to(g). Damage in reinforcement due to projectile-1 (600m/s)

4.5 Internal energy, Kinetic energy, strain energy and total energy analysis (V =600 m/s)

4.5.1 General

In this phase the internal energy of concrete panel, Kinetic energy of projectile-1, strain energy of model, and total energy is analyzed. The projectile-1 is penetrated in a concrete panel at velocity 600m/s. The internal energy of concrete panel is increased with time, when projectile starts to impact in concrete panel. The kinetic energy of the projectile is reduce with time. The kinetic energy of projectile-1 is minimum at a time t =0.0007s. When a projectile-1 is starts to penetrated in panel the kinetic energy at time t= 0.0001s is 6.00 and at the time of fully penetration the kinetic energy is 5.8421 (t= 0.0007s). The total energy of the model is gradually decreasing with time and at the end it goes constant. The maximum total energy is 60.45 and minimum is 60.05. The strain energy of the model is firstly increasing at starting then goes to negative at time t= 0.0007s. The maximum positive strain energy is 10.

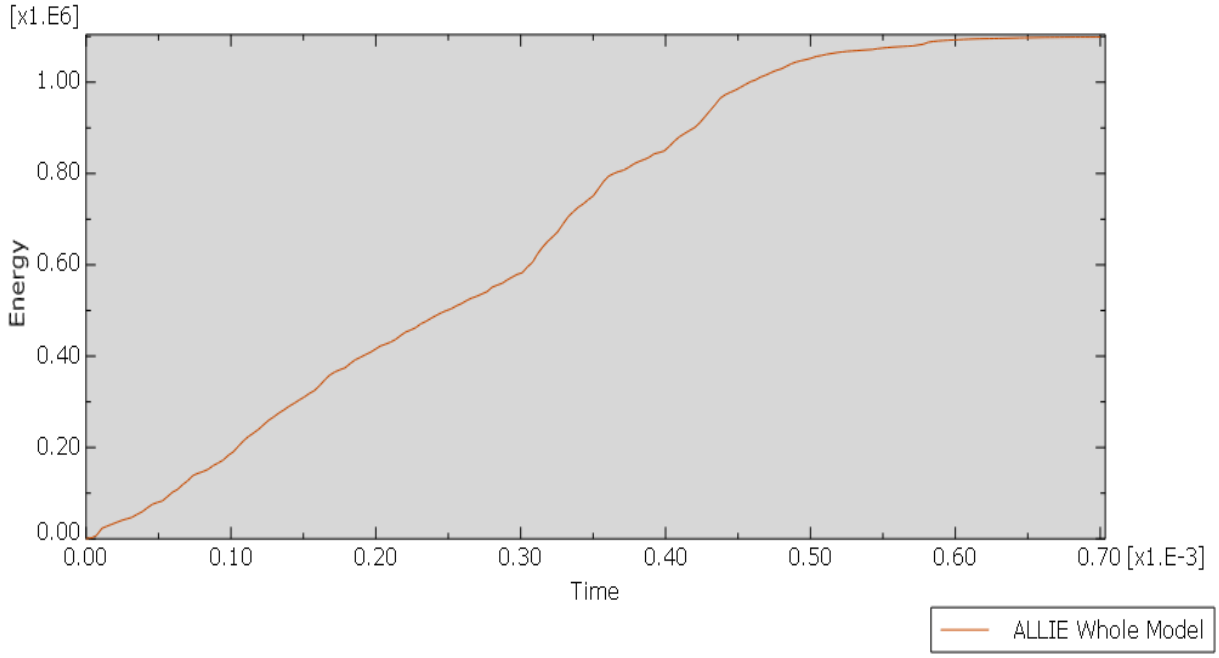


Fig4.11. Internal energy of concrete panel at (v= 600m/s)of projectile-1

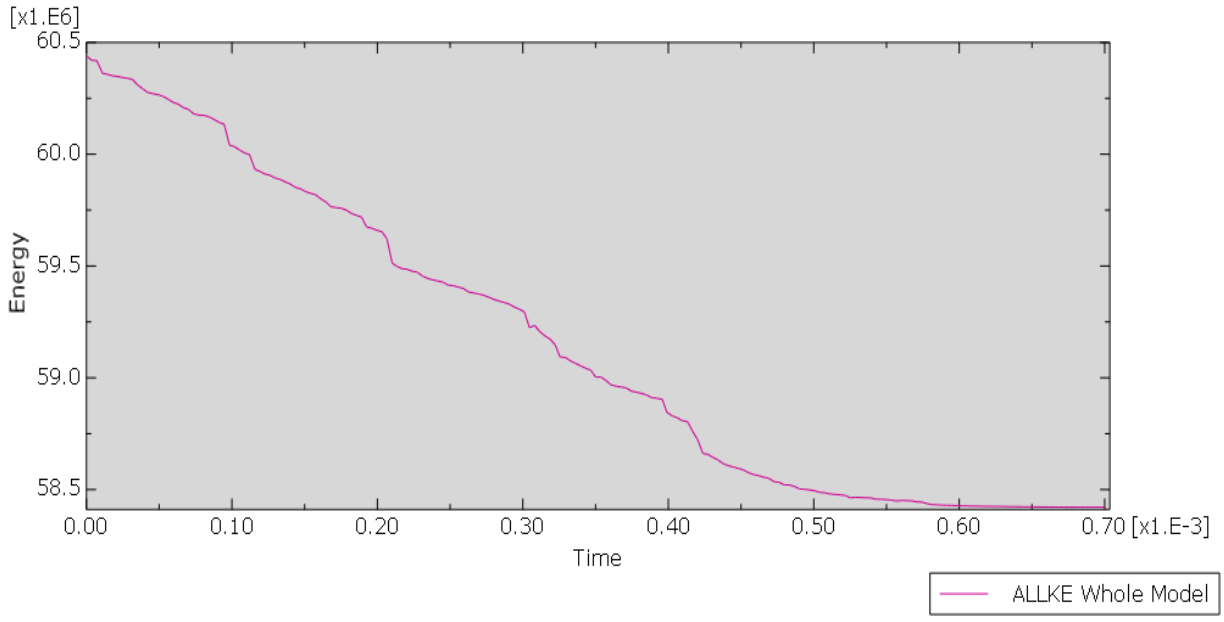


Fig.4.12. Kinetic energy of projectile-1

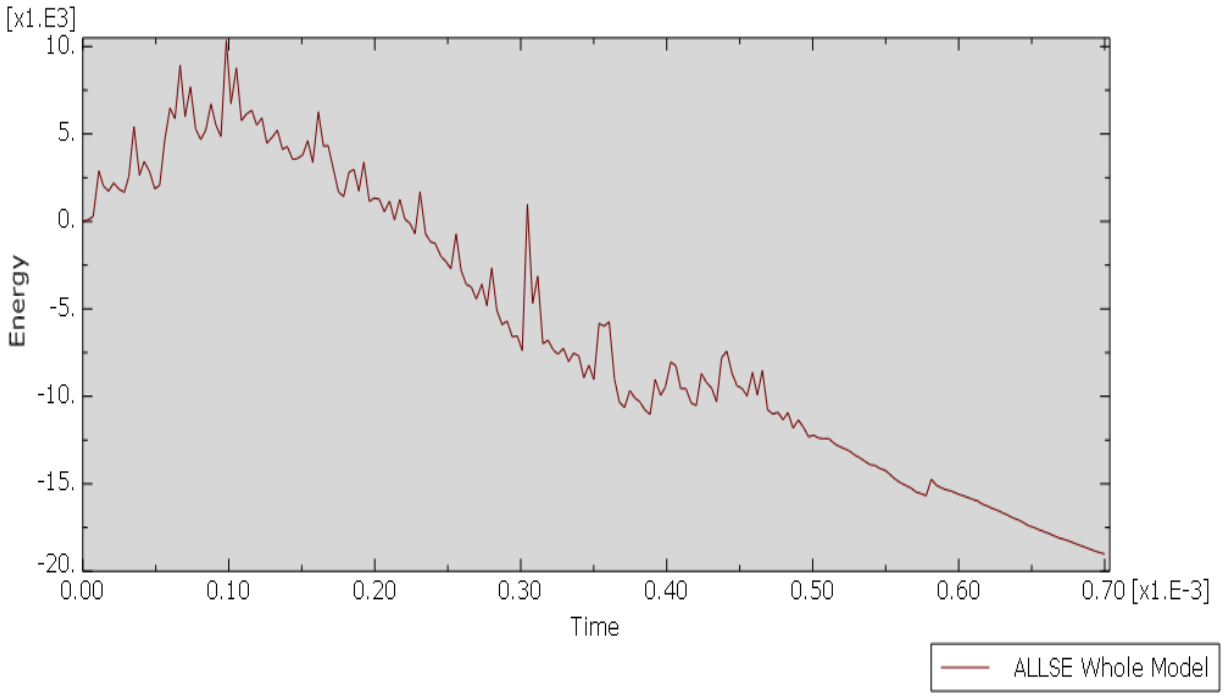


Fig.4.13. Strain energy of whole model

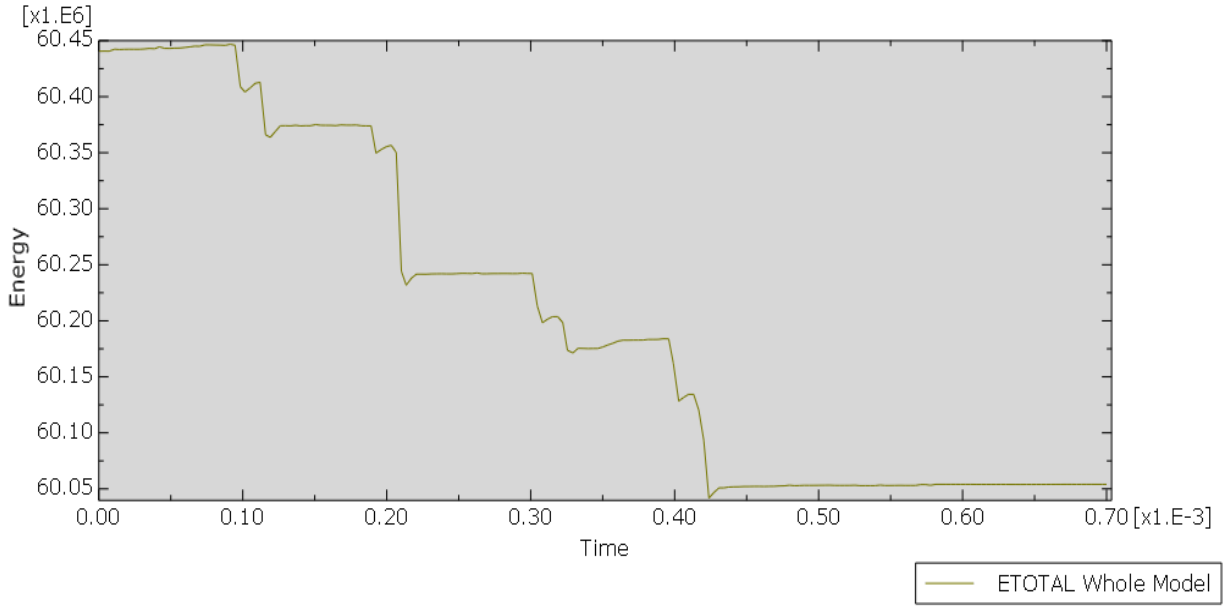


Fig.4.14. Total energy of model

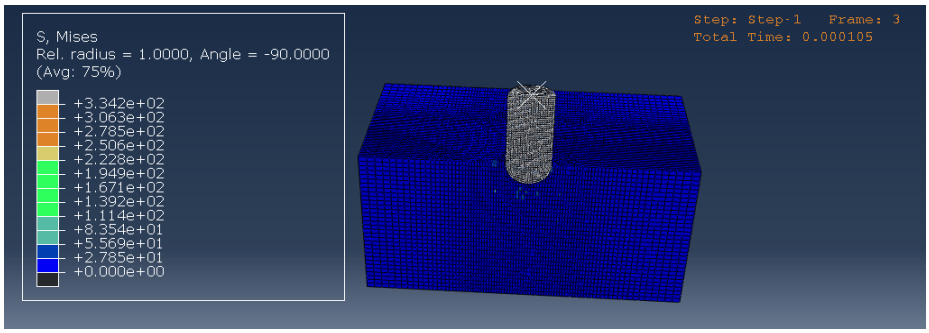
4.6 Penetration of Projectile-2 on concrete panel, damage in concrete panel and damage in reinforcement at velocity 400m/s

4.6.1 General

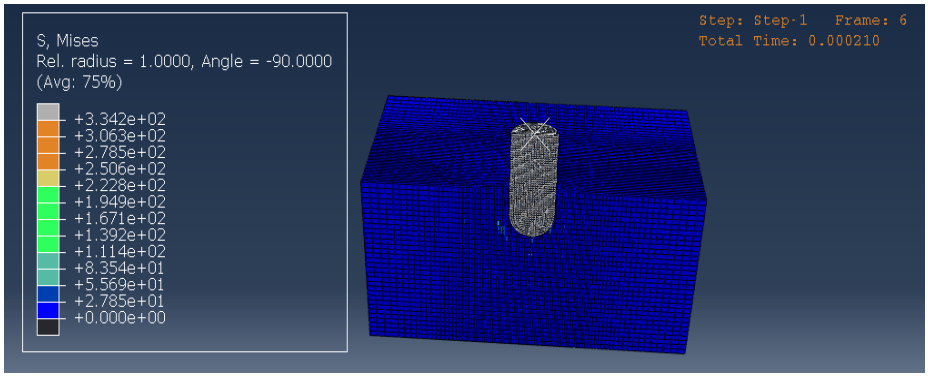
The projectile-2 is penetrated at a velocity of 400m/s on a concrete panel. The concrete panel has a dimensions of 600mm x 300mm x300mm. In the concrete panel there is 4 reinforcement provided, the distance between the each reinforcement is 60mm . The damage in concrete panel, penetration of the projectile-2 in panel and damage in reinforcement is analyzed.

4.6.2 Penetration of projectile-2 in concrete panel at velocity (V=400m/s)

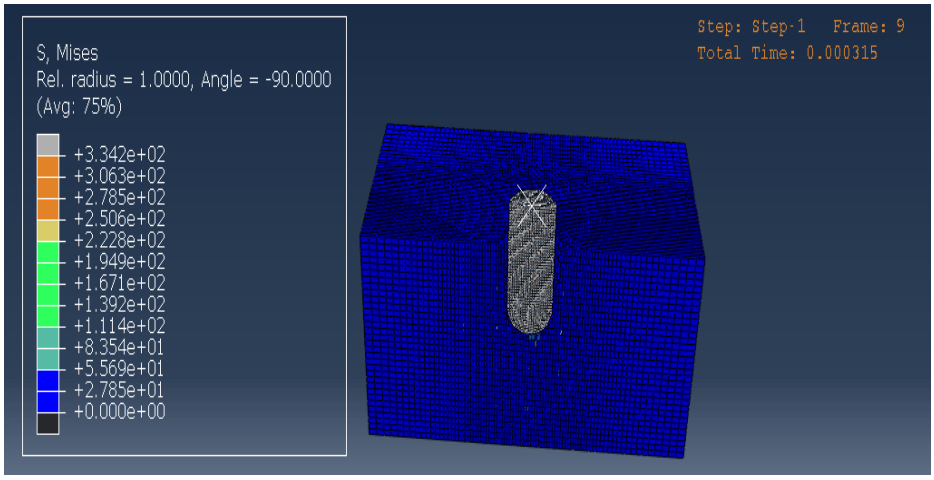
The projectile -2 is penetrated at a speed of 400m/s in concrete panel in first phase. At time t= 0s there is no penetration is seen in a concrete panel. At time t= 0.001s the projectile starts to penetrate and at time t= 0.0007s the projectile is penetrated more than one forth in a concrete panel. The projectile-2 is not fully penetrated in a concrete panel due to the minimum velocity. The figure below shown the penetration of projectile-2 in concrete panel.



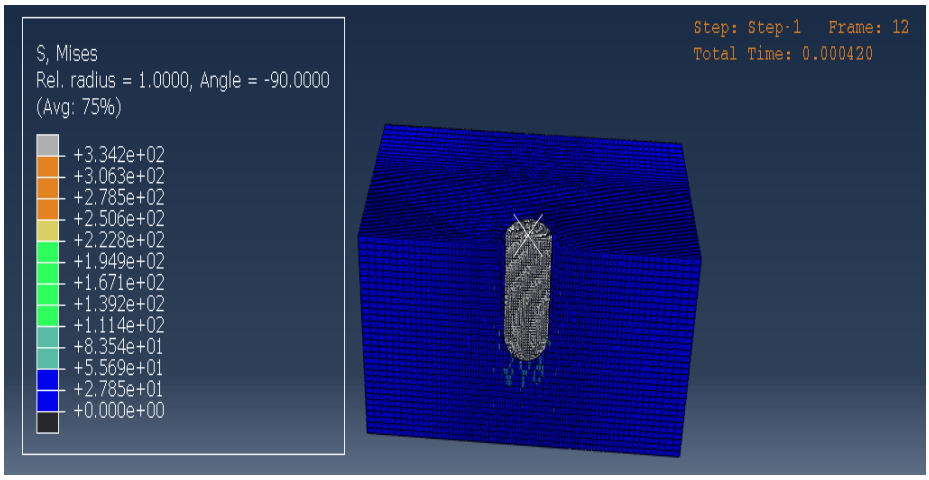
(a) Period= 0.0001s



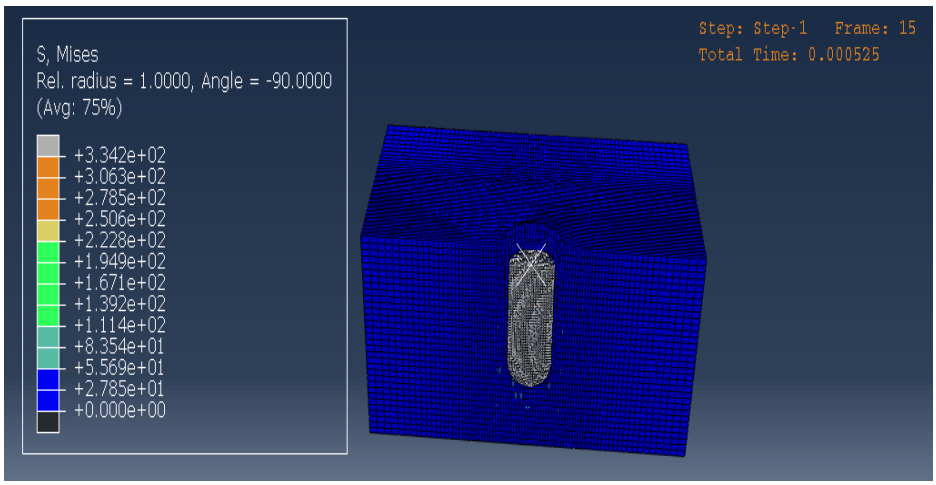
(b) Period= 0.0002s



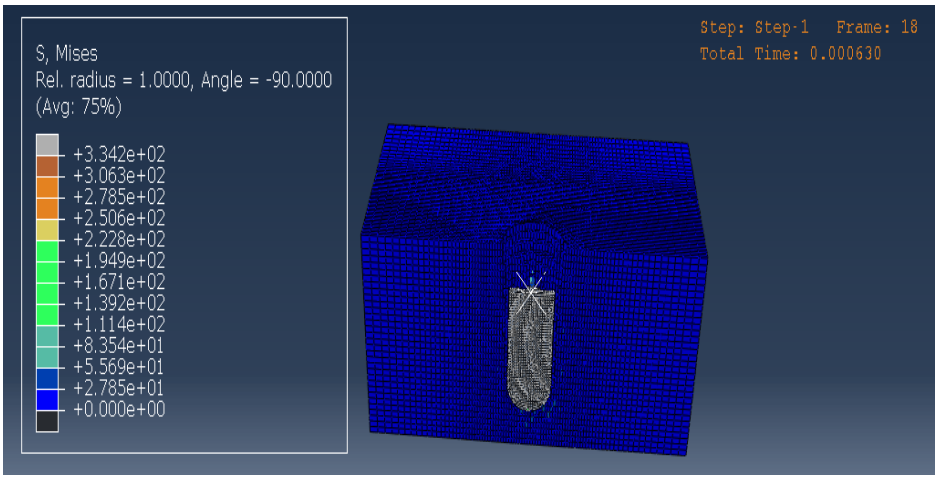
(c) Period= 0.0003s



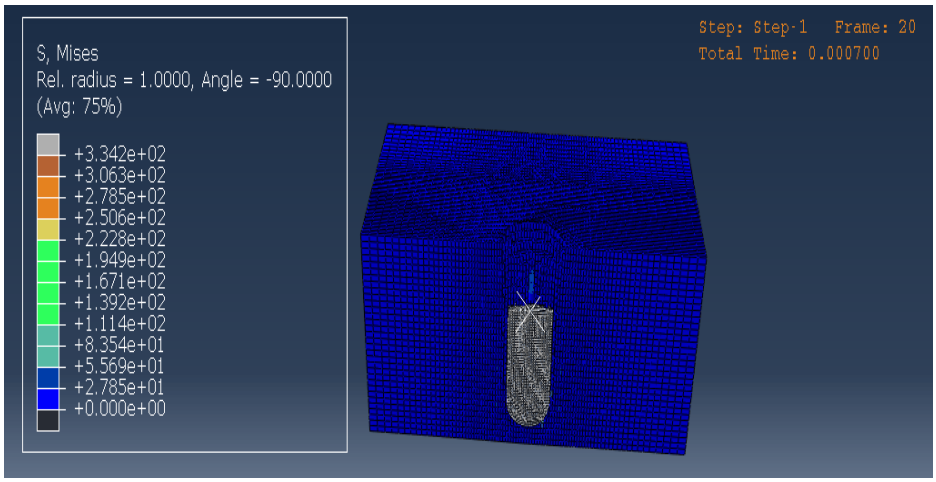
(d) Period= 0.0004s



(e) Period= 0.0005s



(f) Period= 0.0006s



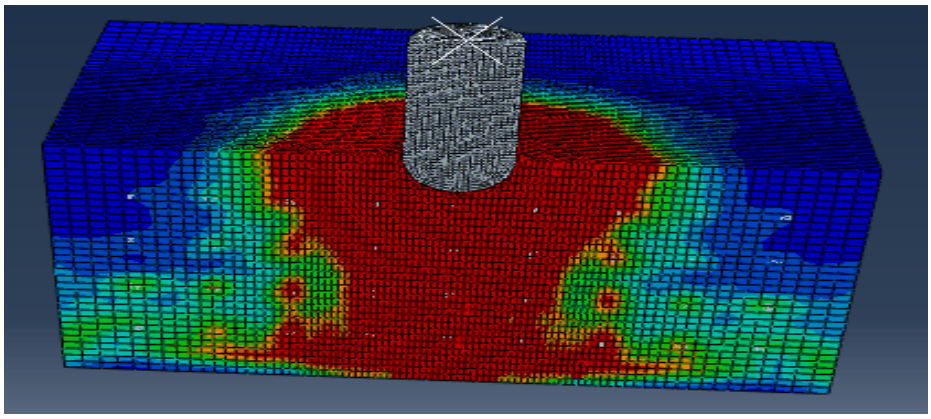
(g) Period= 0.0007s

Fig.4.15.(a) to (g). Penetration of projectile-2 in concrete panel at time 0.0001 to 0.0007s (V=400m/s)

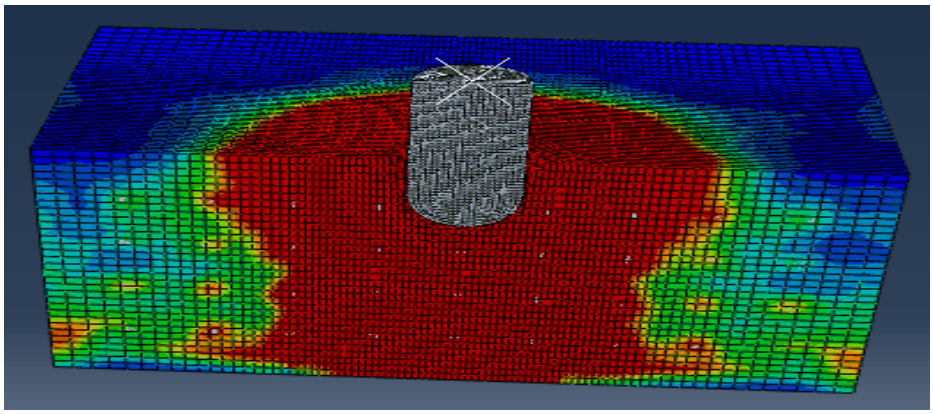
4.6.3 Damage in concrete panel

In a concrete panel the damage is created at time t= 0.0001s, at this time the projectile-2 is starts to penetrate in concrete panel at a velocity 400 m/s. The projectile-2 is penetrated one fourth region in concrete panel. The damage in concrete panel takes a value of 0.0 and 1.0, 0.0 at a

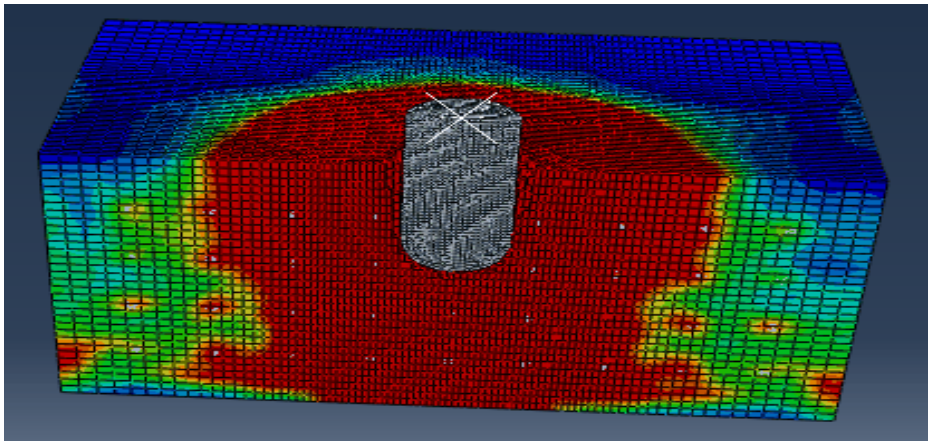
time of undamaged and 1.0 at a time (0.0007s). There is small damage in concrete panel at 0.0001s and maximum damage at time t=0.0007s. The figure shown below shows the damage in concrete panel due to projectile at a velocity 400m/s.



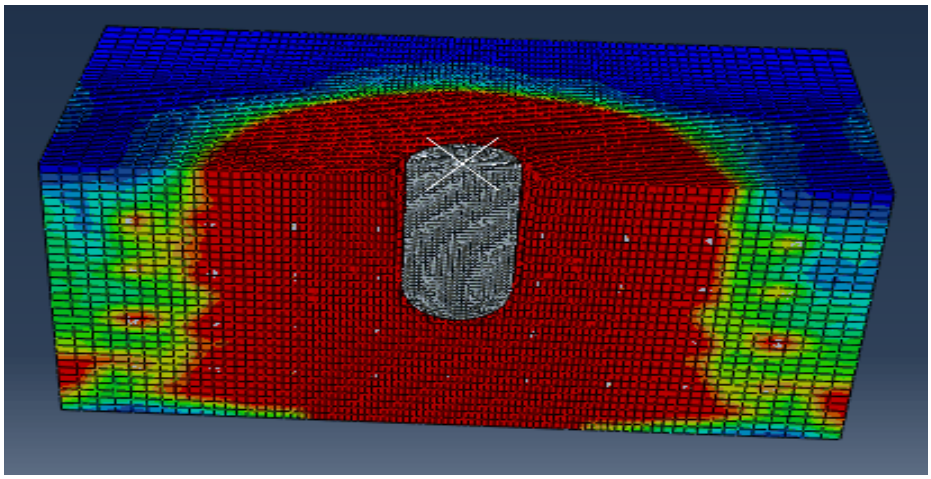
(a) t= 0.0001s



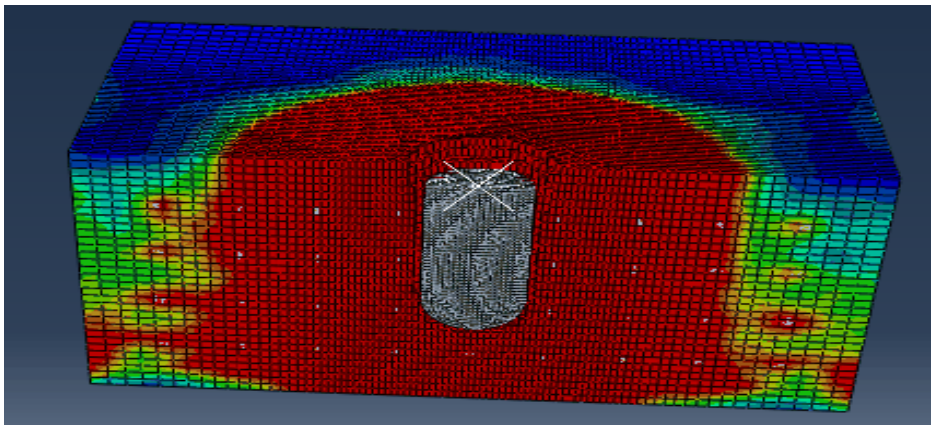
(b) t= 0.0002s



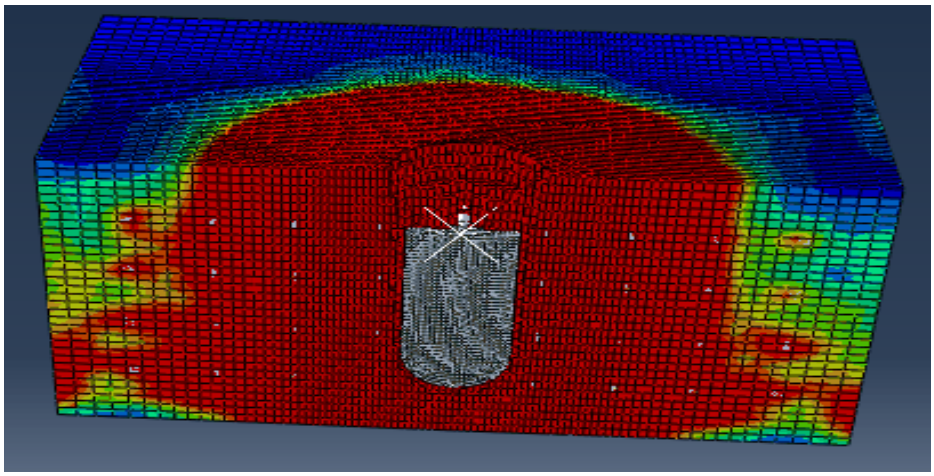
(c) t= 0.0003s



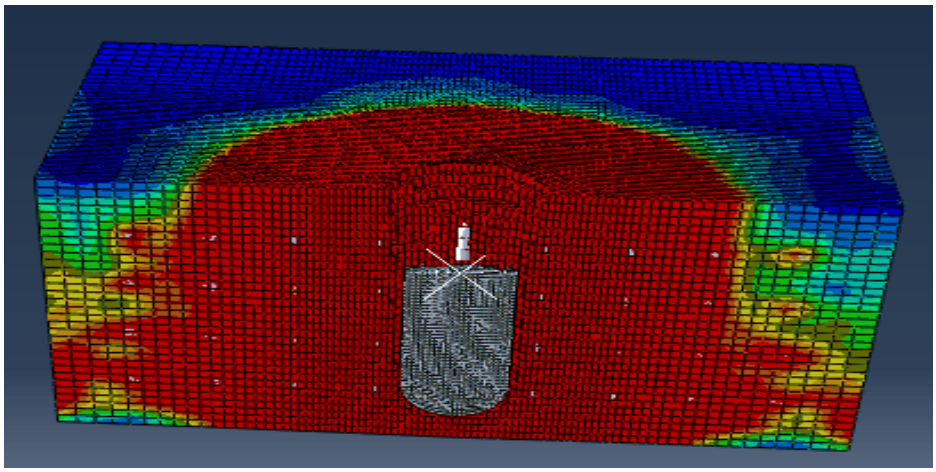
(d) t= 0.0004s



(e) t= 0.0005s



(f) t= 0.0006s

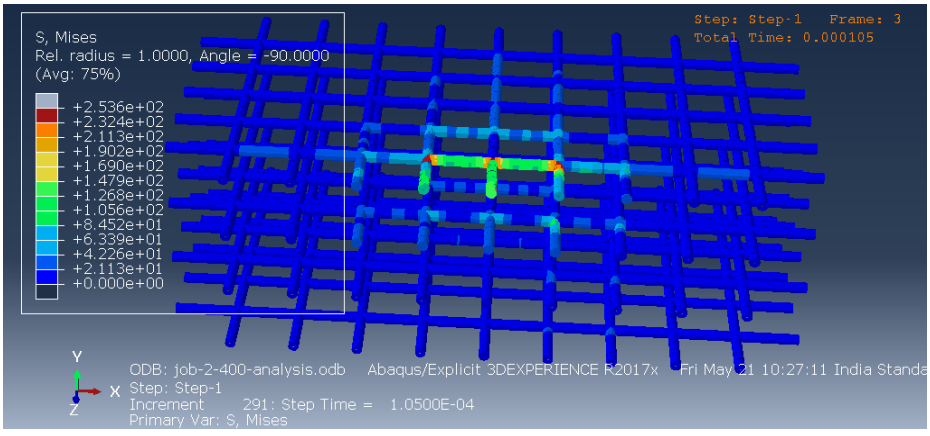


(g) t= 0.0007s

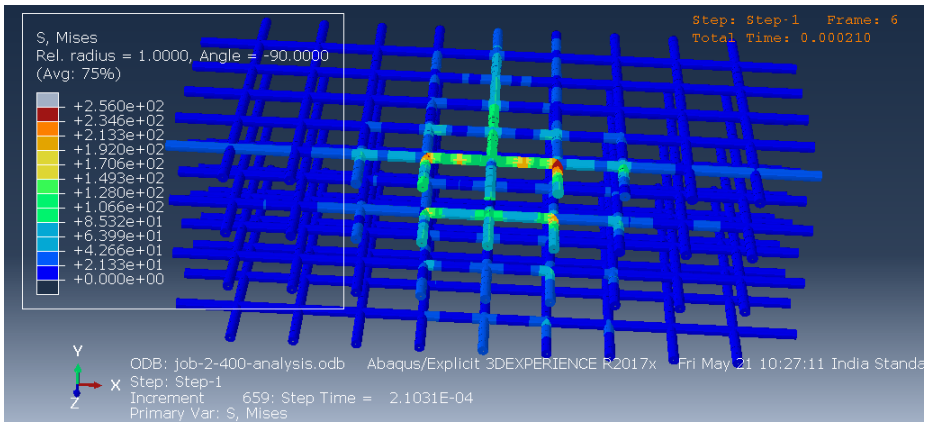
Fig.4.16. (a) to(g). Damage in concrete panel by projectile-2 (V= 400m/s)

4.6.4 Damage in reinforcement

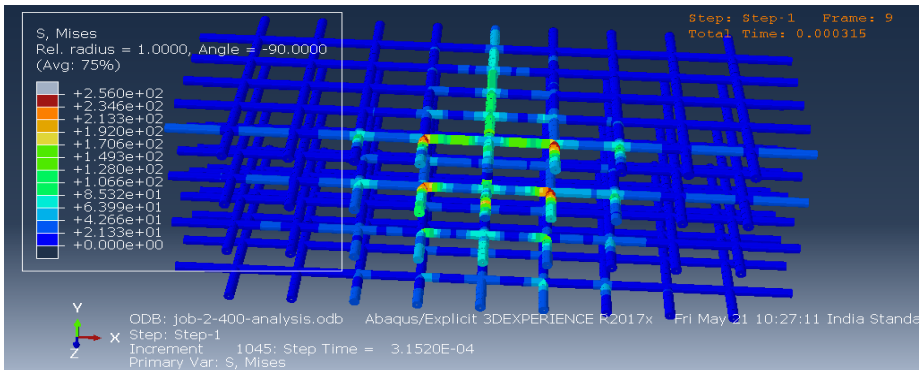
In the fig 4.9.(a) to (g) shown below shows the damage in the reinforcement by deformable projectile-2. When a projectile is starts to peneterated in a concrete panel, there is damage can also created in the reinforcement which is provided in the inner region of the projectile. There is small damage in the last region in concrete panel, because the projectile not fully reach that part of concrete panel. There is maximum damage in the first three reinforcement in concrete panel. The initial and final value is 0.0 and 2.53.



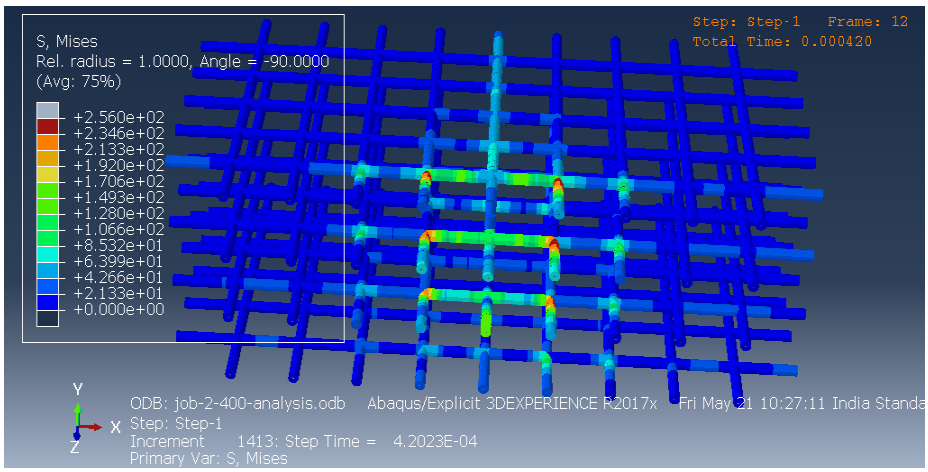
(a) Duration= 0.0001s



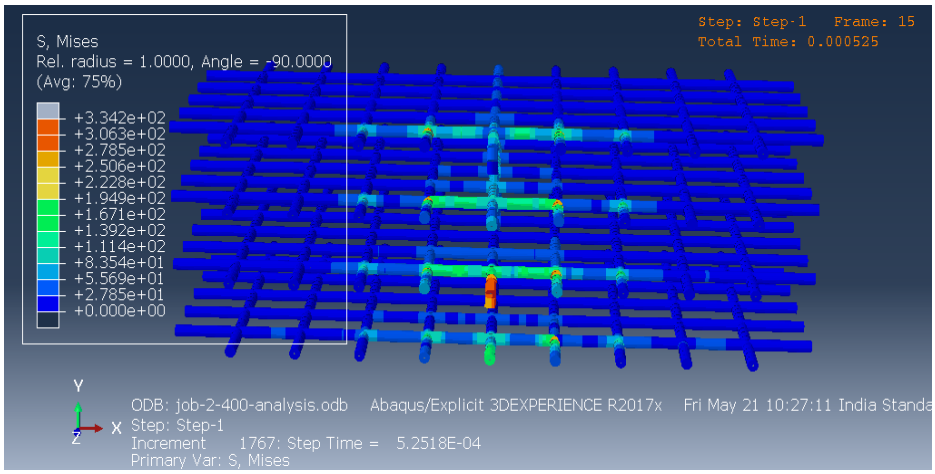
(b) Duration = 0.0002s



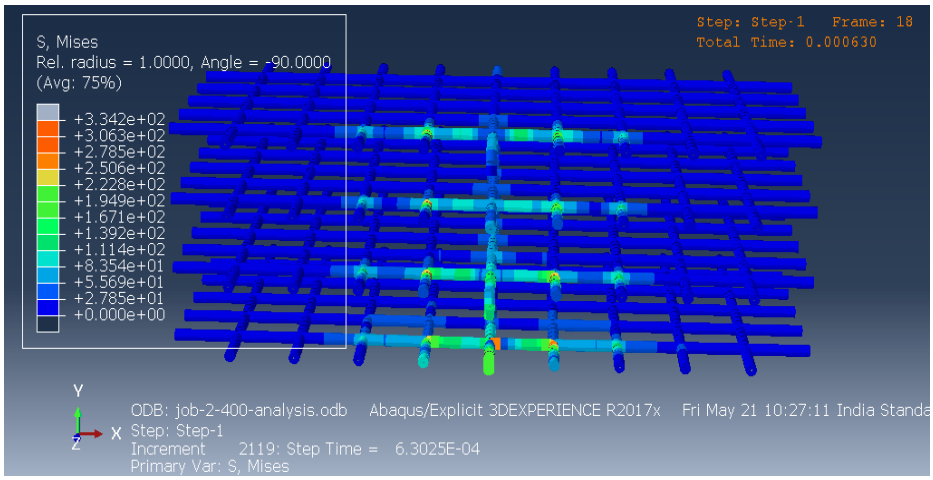
(c) Duration = 0.0003s



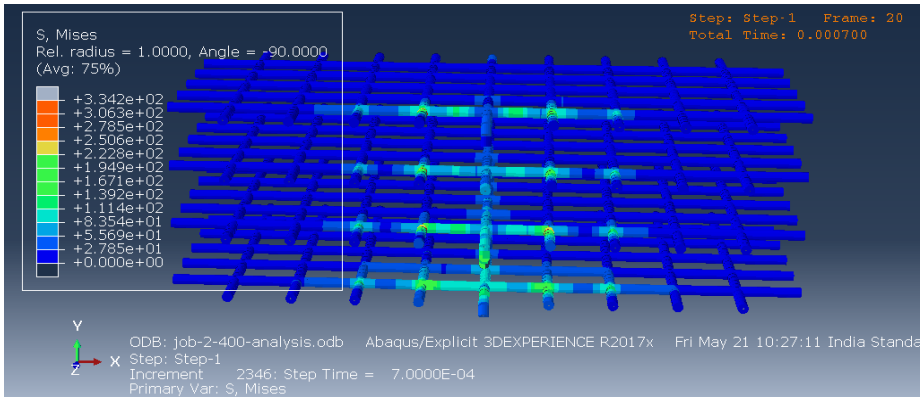
(d) Duration = 0.0004s



(e) Duration = 0.0005s



(f) Duration = 0.0006s



(g) Duration = 0.0007s

Fig.4.17. (a) to(g). Damage in reinforcement due to projectile-2 (400m/s)

4.7 Internal energy, Kinetic energy, strain energy and total energy analysis (V =400 m/s)

4.7.1 General

In this model the analysis takes place in which the projectile-2 is penetrated on panel, where the velocity of projectile is 400m/s. The internal energy in the concrete panel, kinetic energy of the bullet, strain energy of the model and total energy of whole model is analyzed. The interanl energy of concrete panel is increased at the time of penetration. The value of internal energy is 3.0 at time t= 0.0007s. The kinetic energy of projectile is decreasing when the penettration was happened in a panel. The strain energy of model is also increase with time . The total energy at time t= 0.0001s is 2.692, and at the end (t=0.0007s) the total energy is 2.67.

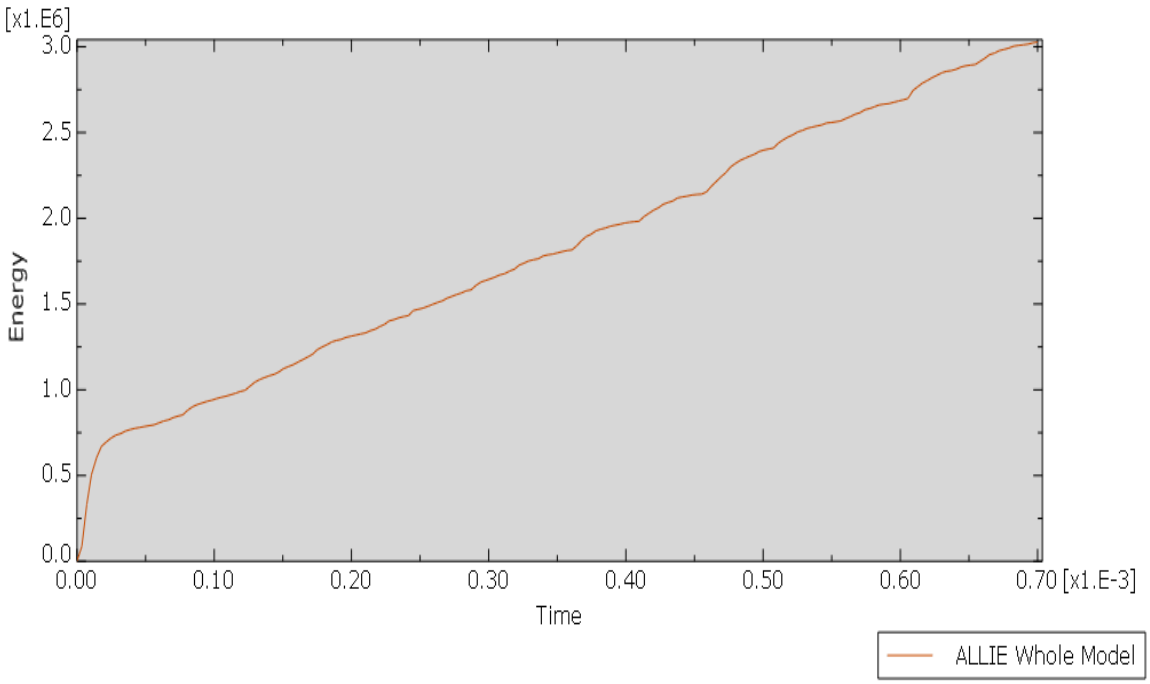


Fig.4.18. Internal energy of concrete panel

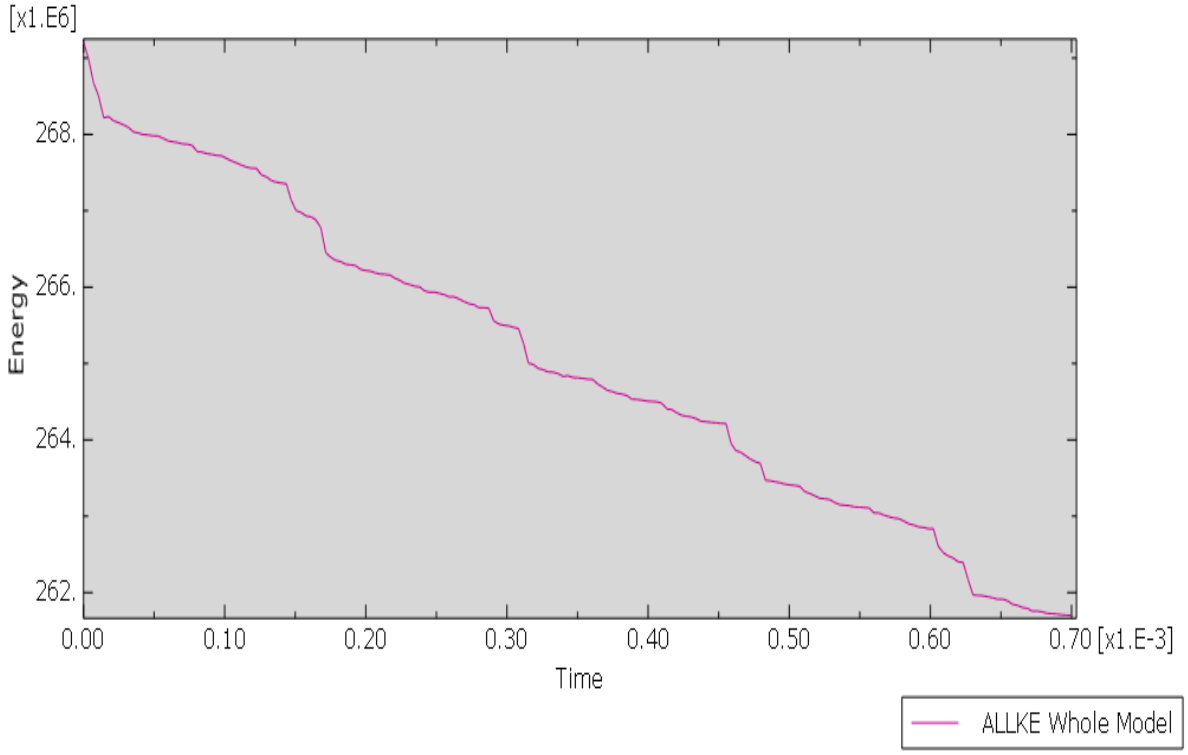


Fig.4.19. Kinetic energy of projectile-2 (v=400m/s)

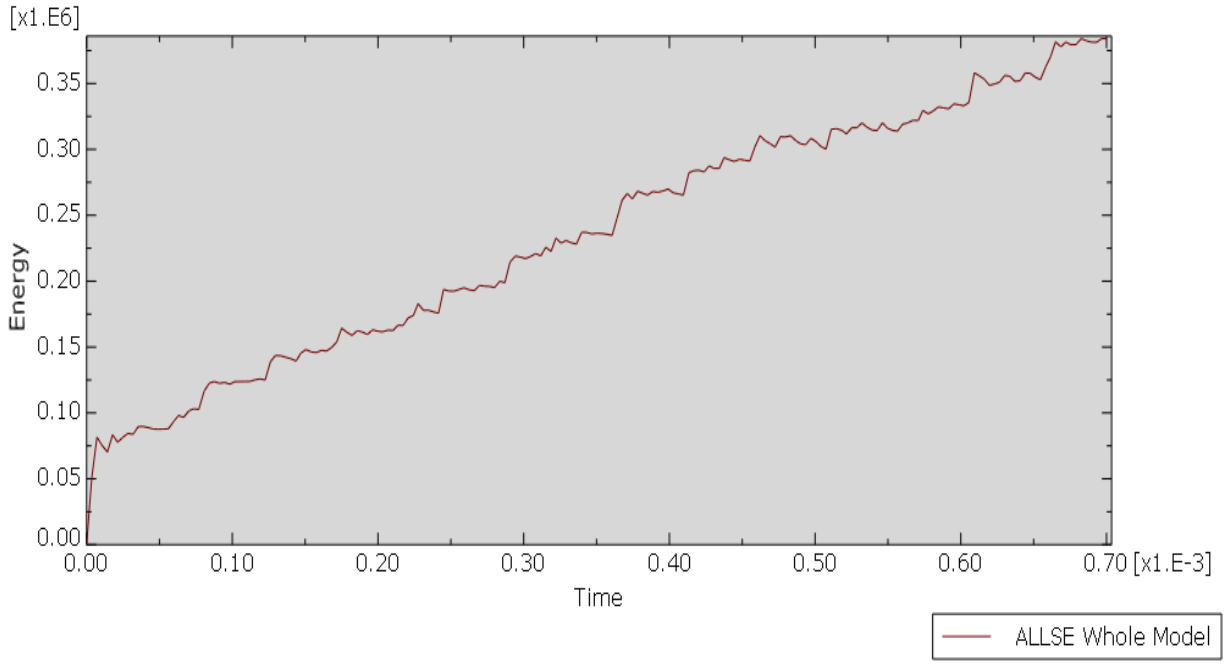


Fig.4.20. Strain energy of model

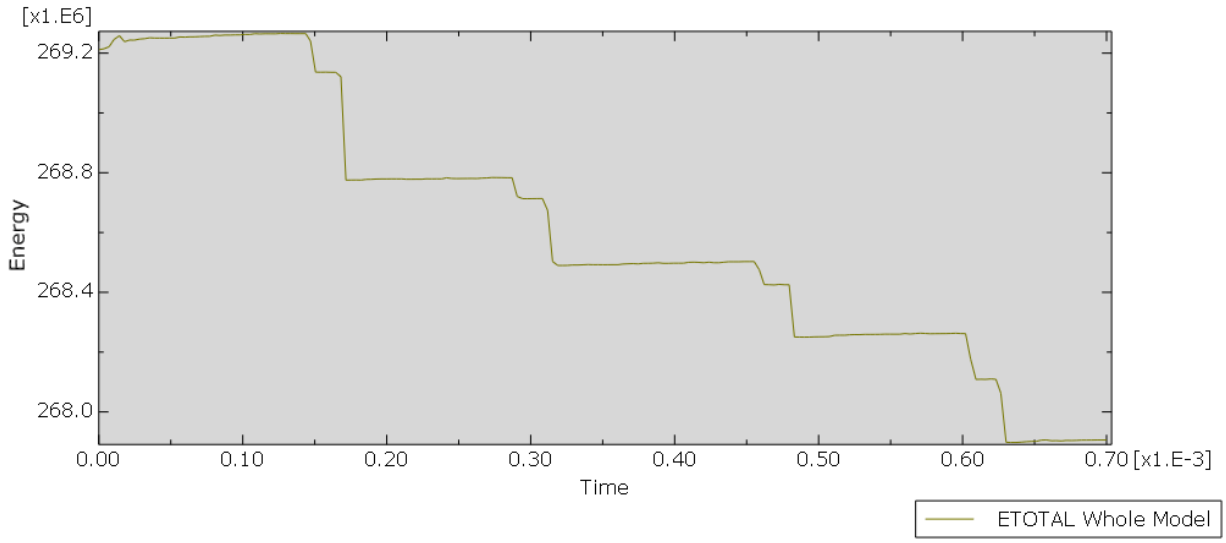


Fig.4.21. Total energy of whole model

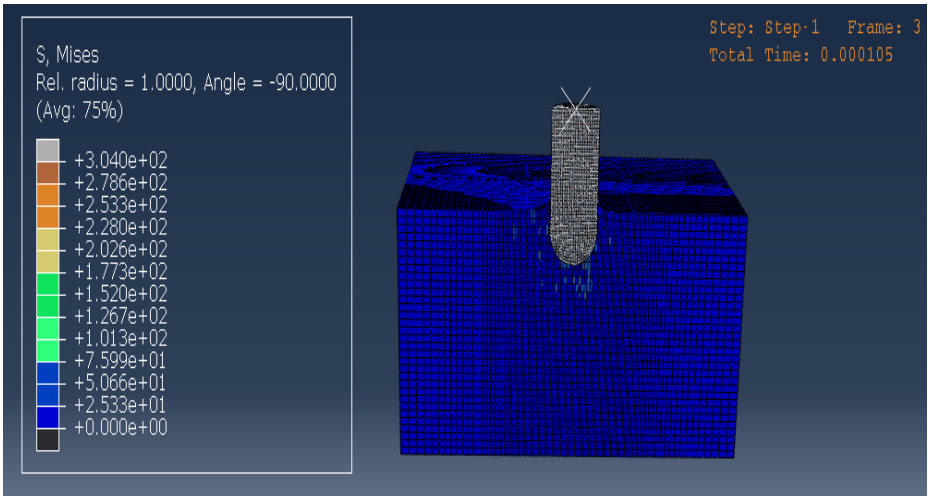
4.8 Penetration of Projectile-2 on concrete panel, damage in concrete panel and damage in reinforcement at velocity 600m/s

4.8.1 General

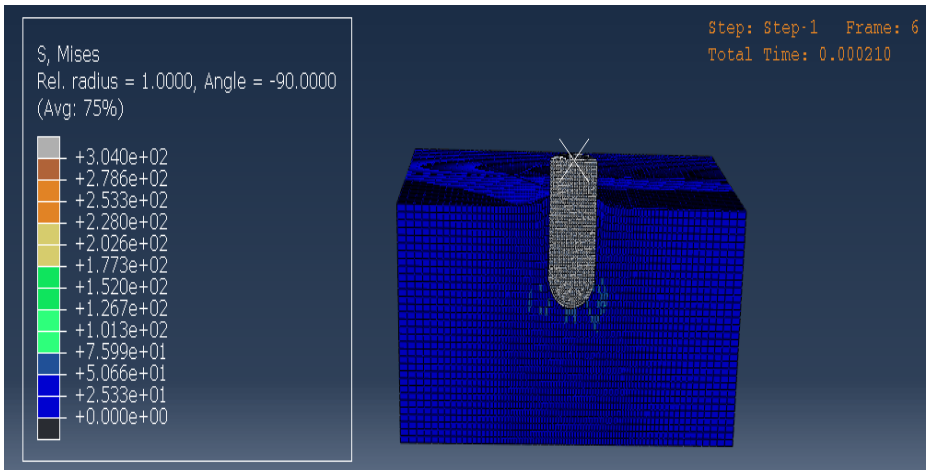
In this simulation modeling the penetration of projectile-2 at velocity 600m/s are also analysed. In this section the penetration of projectile, concrete panel damage and damage in reinforcement are observing.

4.8.2 Projectile-2 penetration (Velocity= 600m/s)

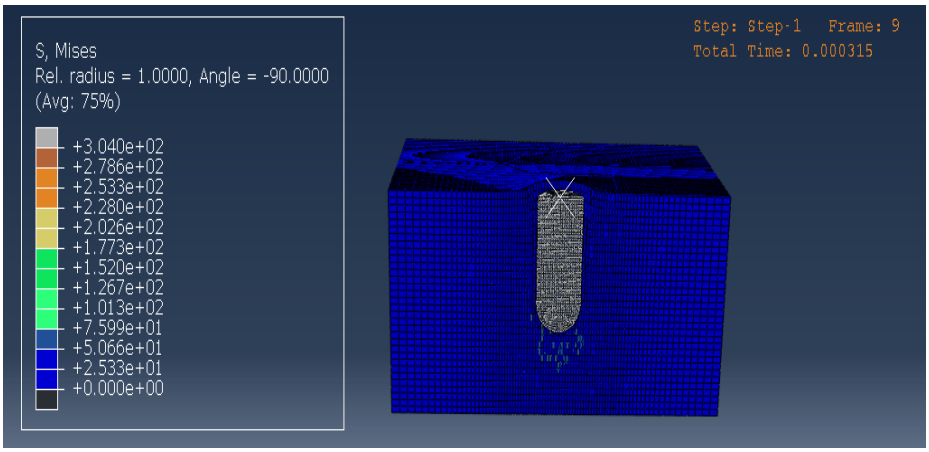
The projectile is penetrated at a speed of 600m/s on concrete panel in which the different penetration was taken place at different time of penetration. At time t=0.0001 s the projectile is starts to pentrated in concrete panel. At time t= 0 there is mno penetration was happening in a concrete panel. The value of penetration of projectile at time t= 0.0007s is 3.04. The projectile is fully penetrated in concrete panel at a velocity of 600m/s. The figures shown below the penetration of projectile in concrete panel at different time interval.



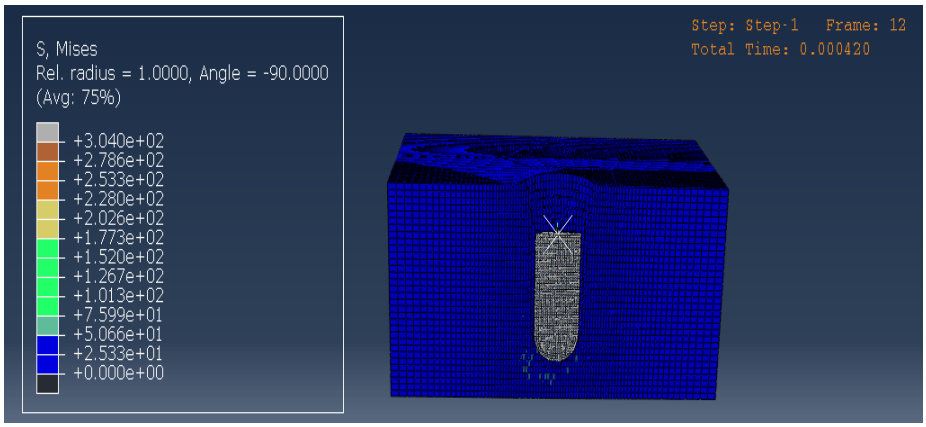
(a) t= 0.0001s



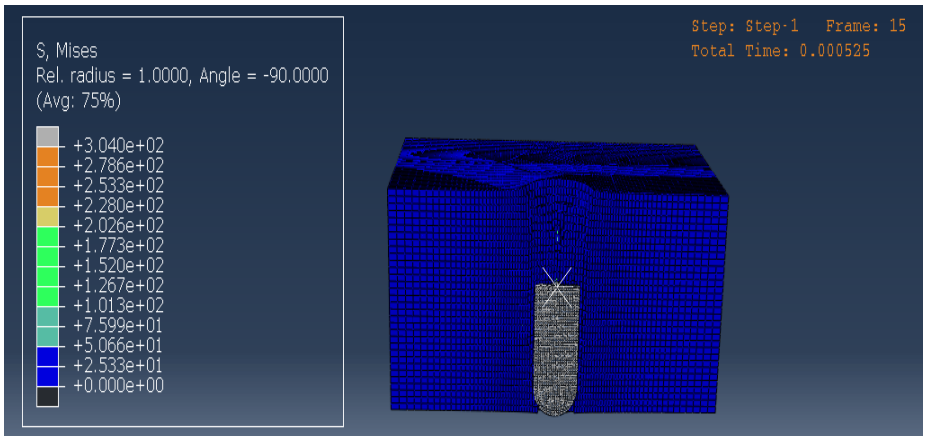
(b) t= 0.0002s



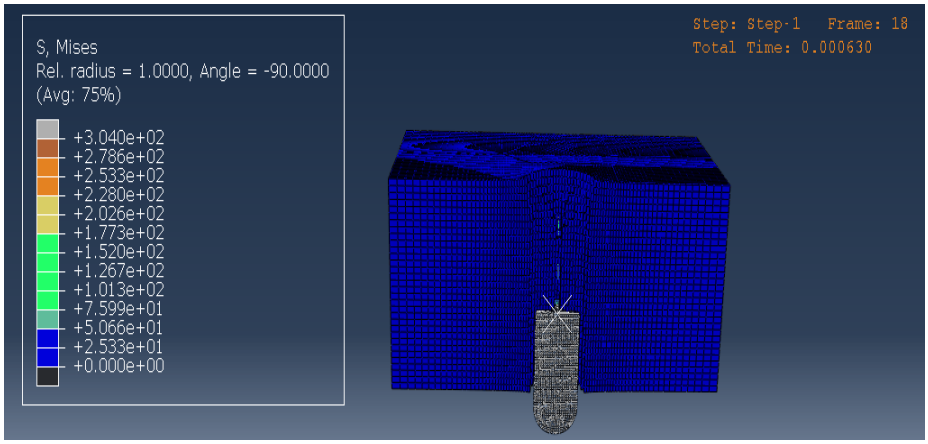
(c) t= 0.0003s



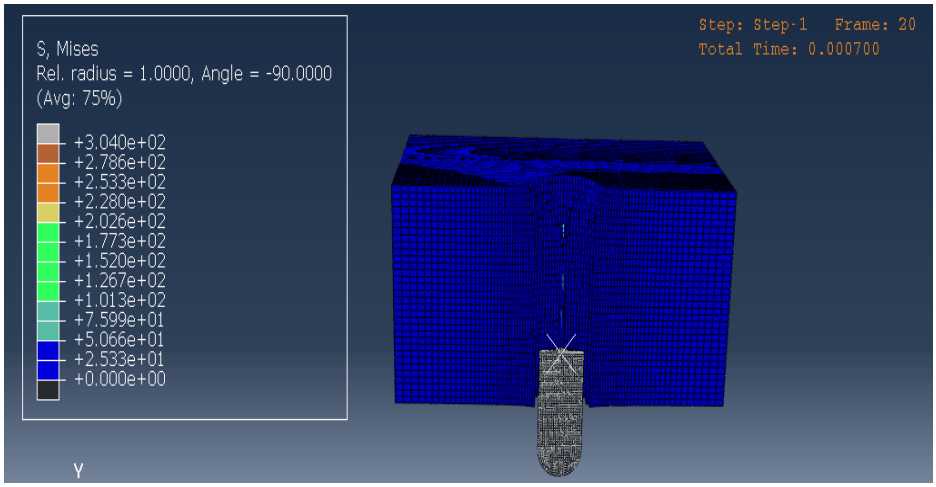
(d) t= 0.0004s



(b) t= 0.0005s



(e) t= 0.0006s

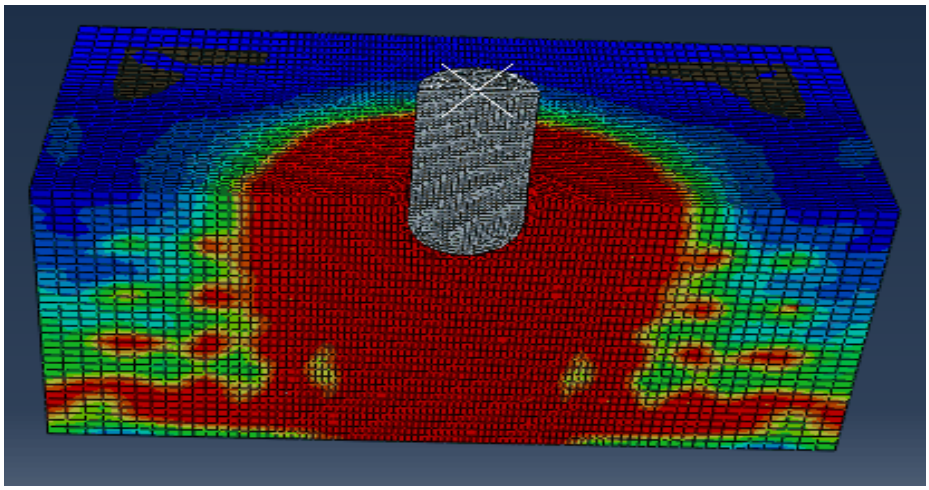


(f) t= 0.0007s

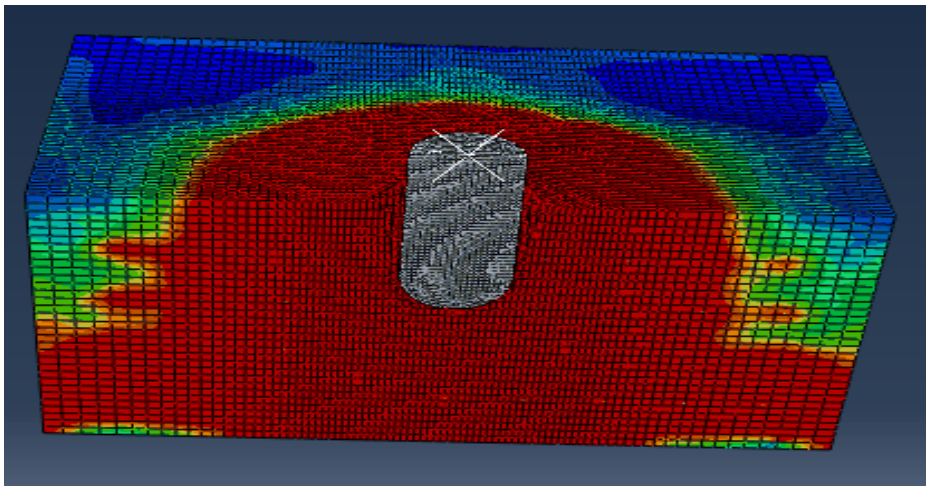
Fig.4.22. (a) to(g). penetration of projectile-2 at velocity 600m/s in concrete panel

4.8.3 Damage

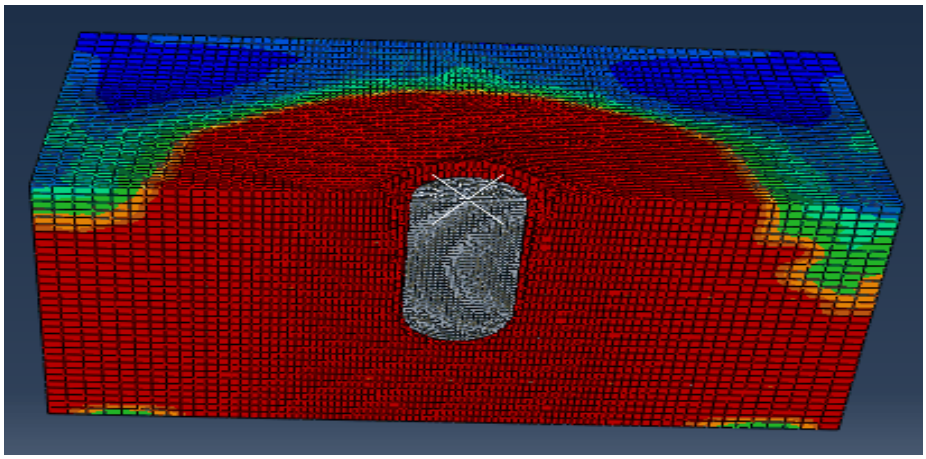
The damage in concrete panel is takes place by the impact of projectile. At a time t=0.0001s there is some damage is created in the upper region of the panel, where the projectile is starts to penetrated. There is large damage in the middle of the panel by the projectile. The initial value is 0.0 and final value is 1.0, undamaged and fully damaged. Due to the projectile the damage can also occurs is the all region of concrete panel. There is small damage can occurred in the opposite face of concrete panel where projectile is not penetrated. Fig 4.11 (a)-(g) shows the damage in concrete panel by the penetration of projectile at time interval 0.0001s to 0.0007s.



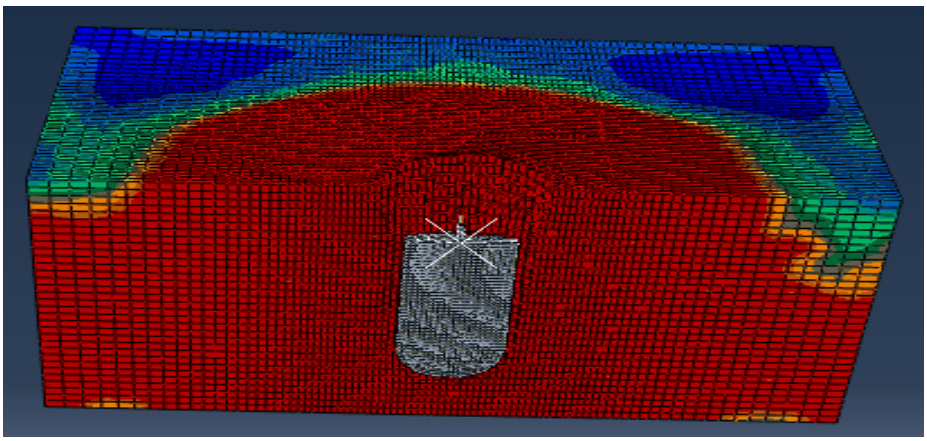
(a) t= 0.0001s



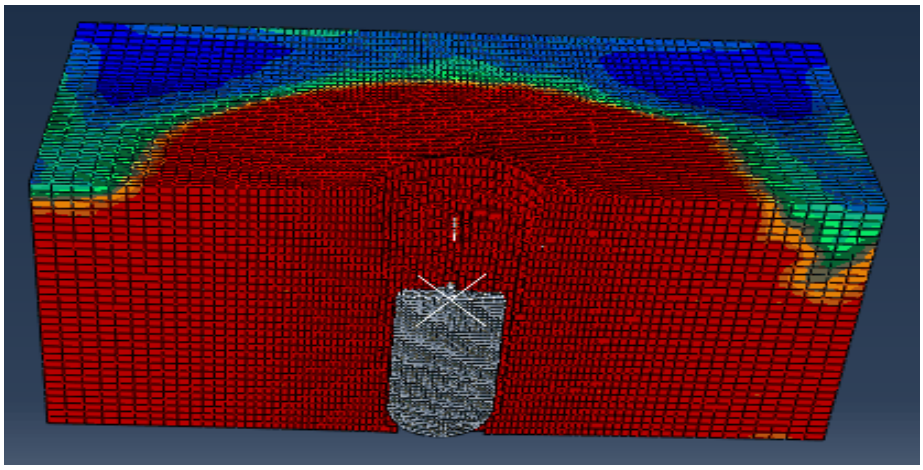
(b) t= 0.0002s



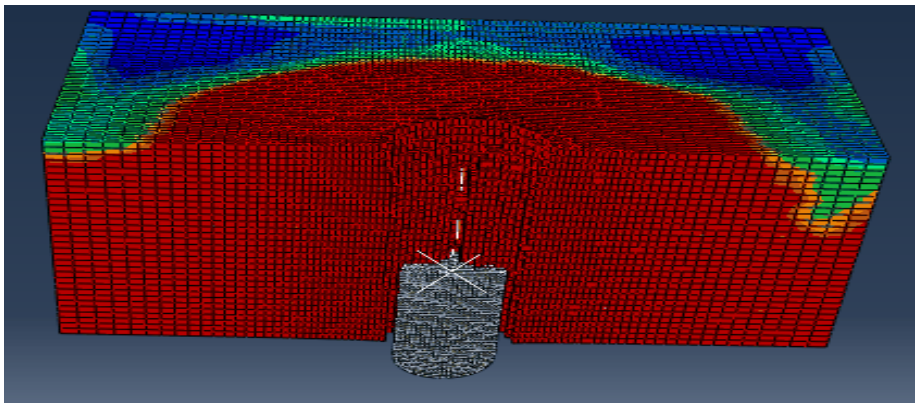
(c) t= 0.0003s



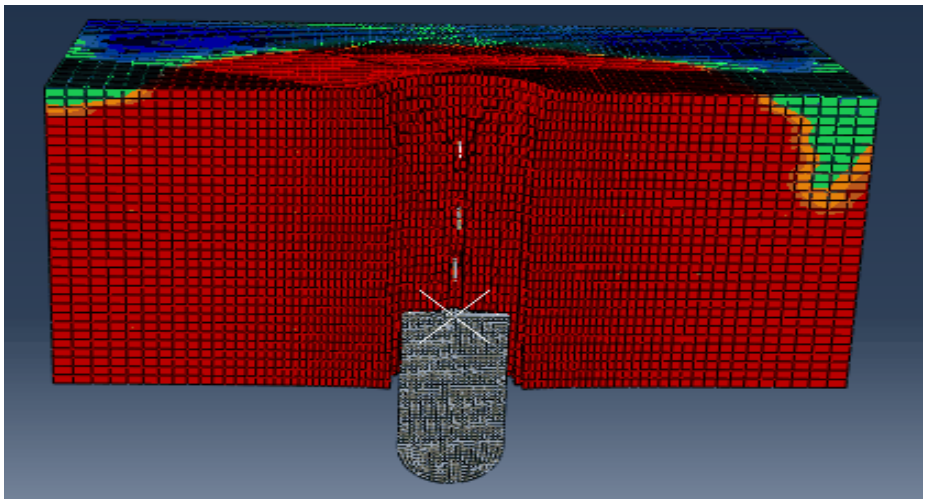
(c) t= 0.0004s



(d) t= 0.0005s



(e) t= 0.0006s

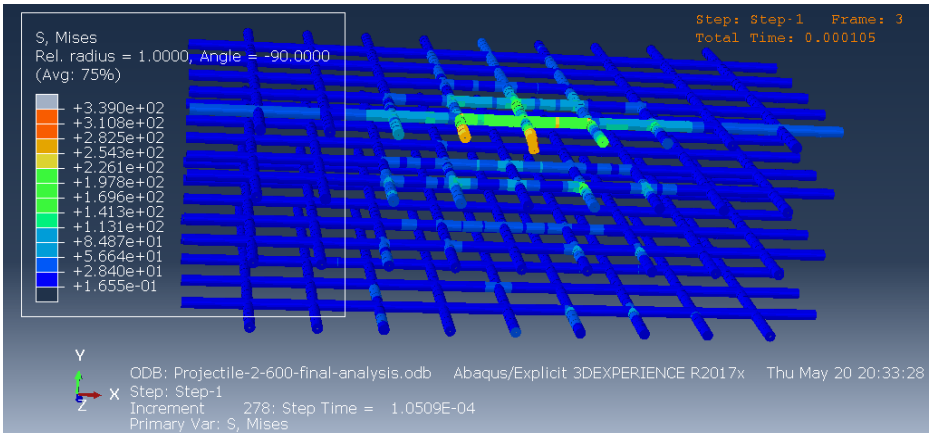


(f) t= 0.0007s

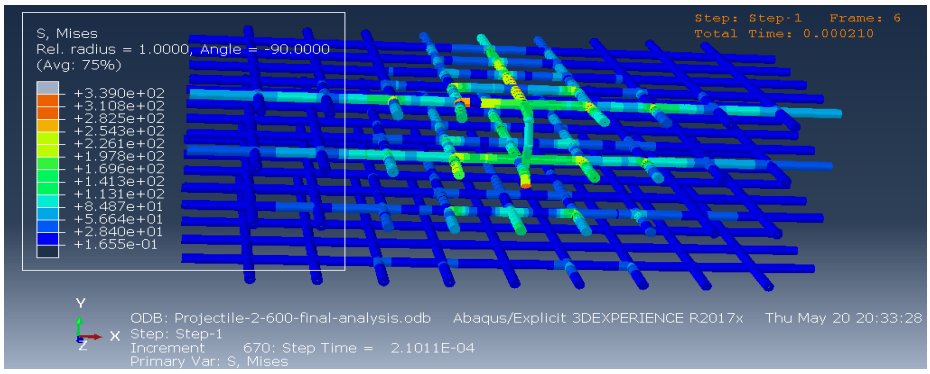
Fig.4.23. (a) to(g). Damage in concrete panel by projectile-2 (V= 600m/s)

4.8.4 Damage in reinforcement

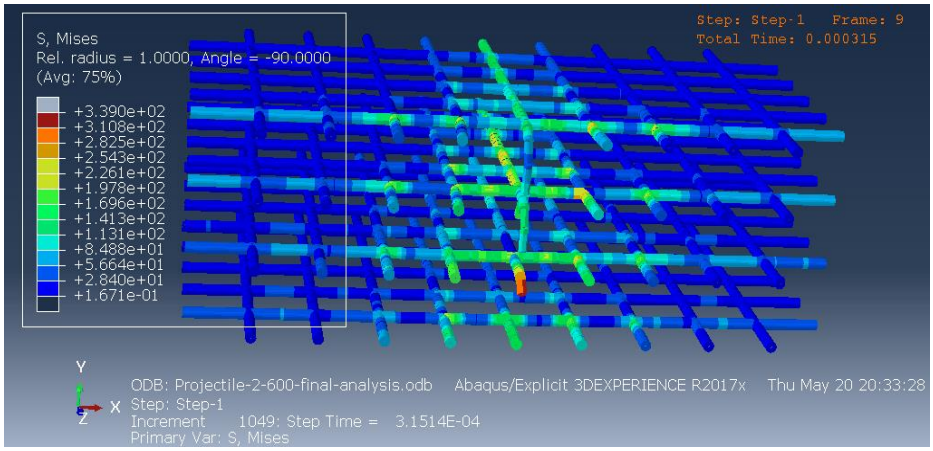
When the projectile is penetrated in a concrete panel the damage is created in the inner region of concrete panel. In the inner region of concrete panel the reinforcement is provided. At a time of penetrations can happens the stresses are created on the reinforcement also. When a penetration can happens , there is large stresses are created on a reinforcement at time t= 0.001s the maximum stresses are created in a concrete panel. The projectile can damaged the side region of reinforcement also. At time t=0.007s when projectile is fully penetrated the values are 2.65 and 1.67. The fig 4.12 (a)-(g) shows the stresses/ damage created in reinforcement by projectile.



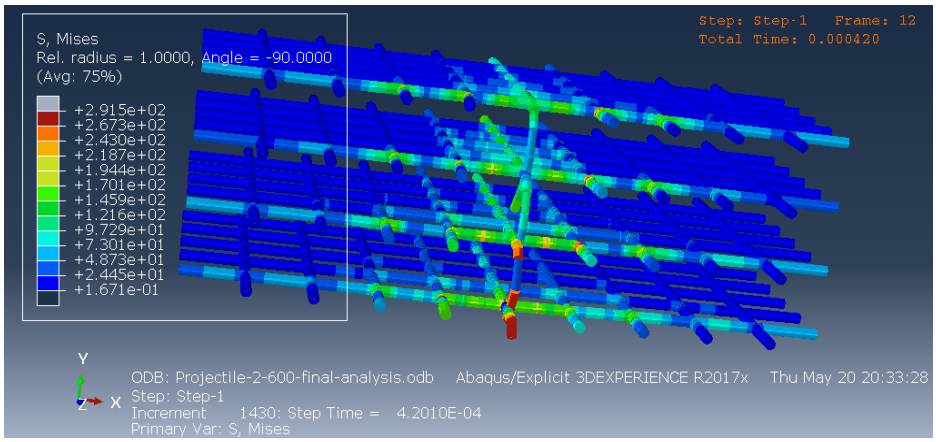
(a) Duration = 0.0001s



(b) Duration = 0.0002s



(c) Duration = 0.0003s



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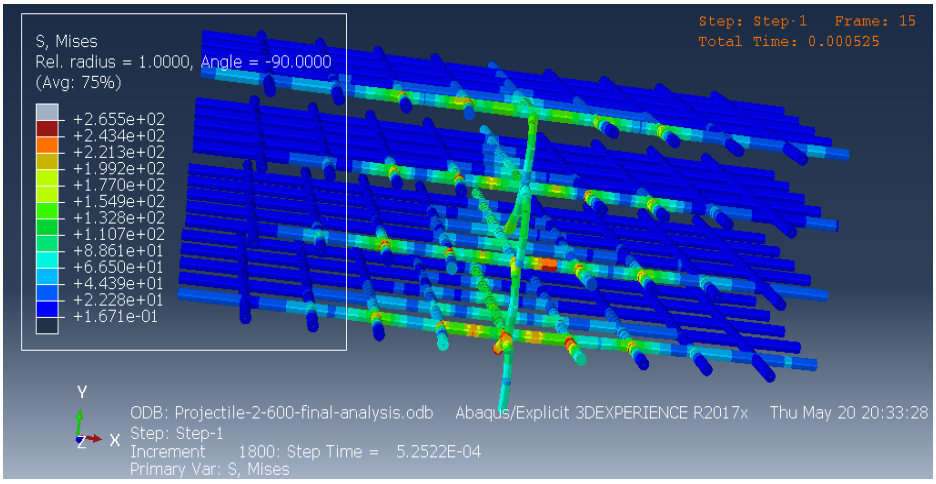

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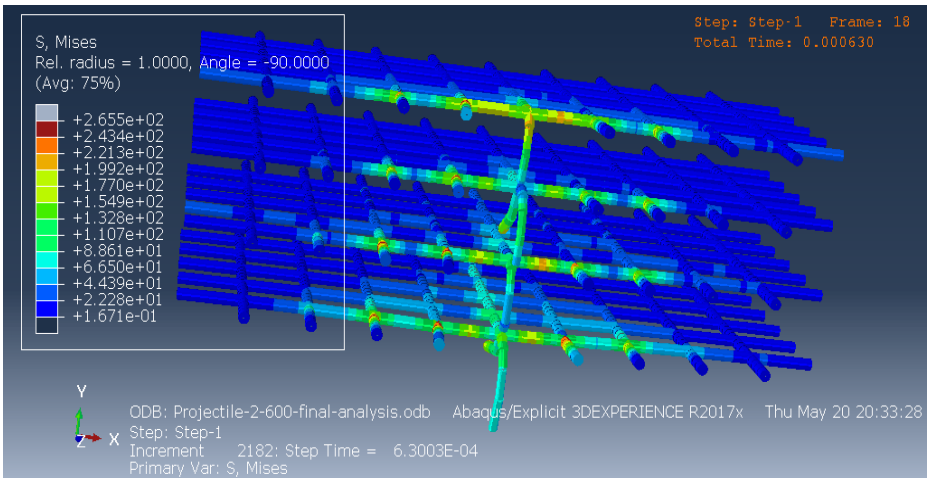
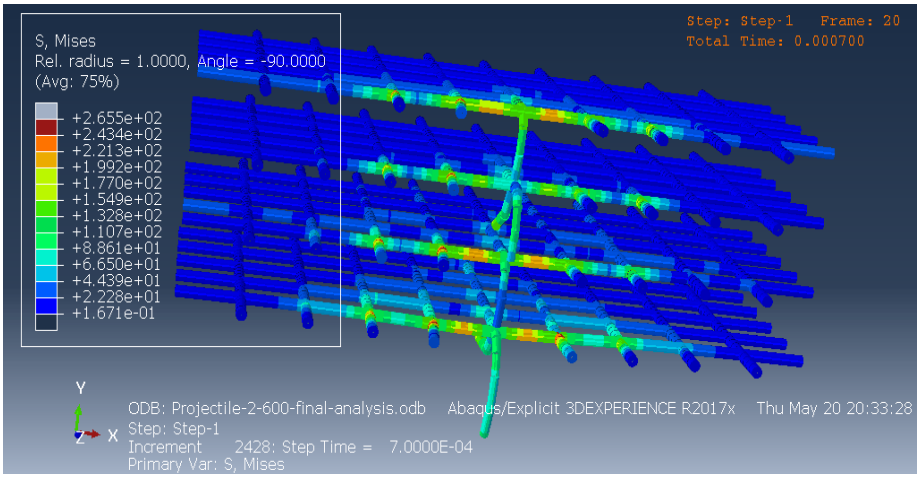


(f) Duration = 0.0006s



(g) Duration = 0.0007s

Fig.4.24. (a) to(g). Stresses or damage on reinforcements by projectile-2 (600 m/s)

4.9 Kinetic energy, internal energy, total energy and strain energy analysis

4.9.1 General

In the projectile-2 penetration on concrete panel at a velocity 600 m/s, the following analysis is take place. The internal energy of concrete panel is increases with time when the penetration is

happen. The value of internal energy of panel is 6.0 at time t= 0.0007s. The kinetic energy of projectile is decreasing with the penetration in concrete panel was occurring with regular interval of time. At a time (t=0.0001s) the kinetic energy of projectile is maximum and at time t= 0.0007s the energy is minimum. The strain energy is also increasing with the penetration of projectile. The maximum value of the strain energy is 1.2 at time t= 0.0005s and constant at a 0.0006s and 0.0007s. The value of kinetic energy at 0.0007s is 5.88 and at time 0.0001s is 6.0. The total energy of the model is 6.02 at the time of fully penetration of projectile in concrete panel. The total energy is also decreases with time. The maximum total energy is 6.05.

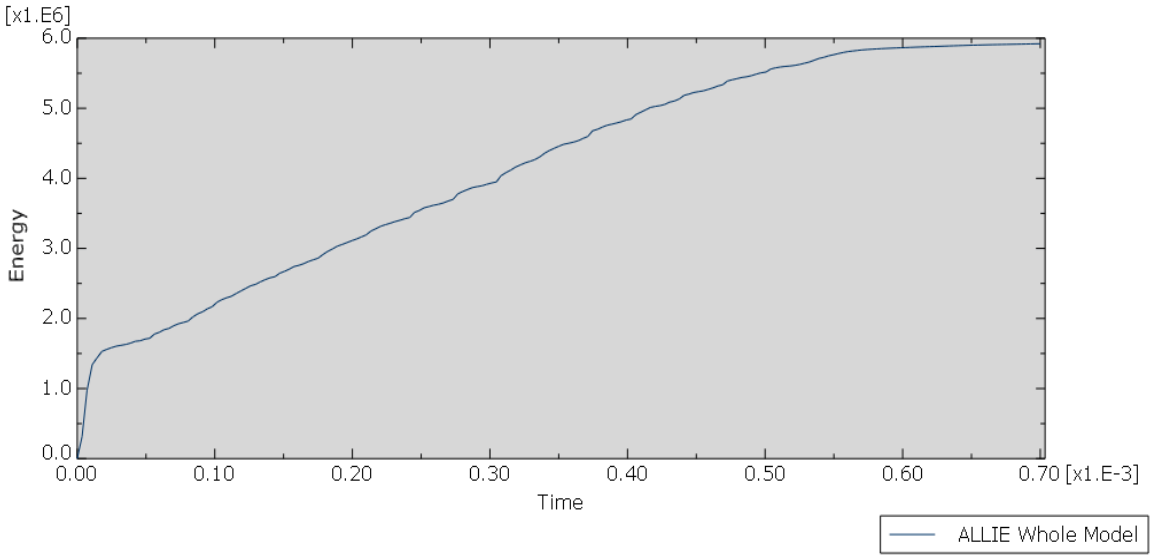


Fig.4.25. Internal energy of concrete panel (V= 600m/s)

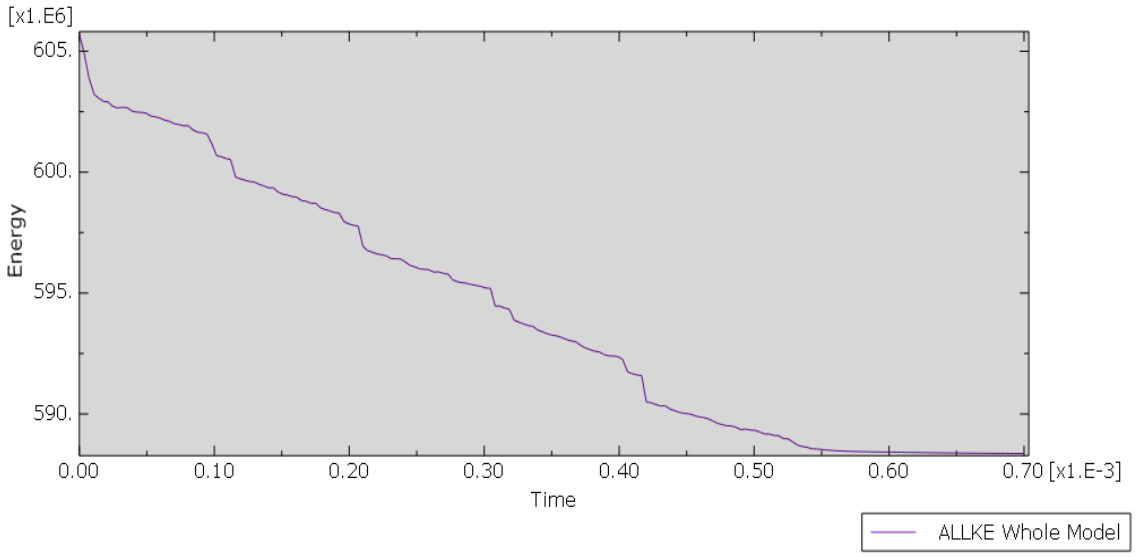


Fig.4.26. Kinetic energy of projectile-2

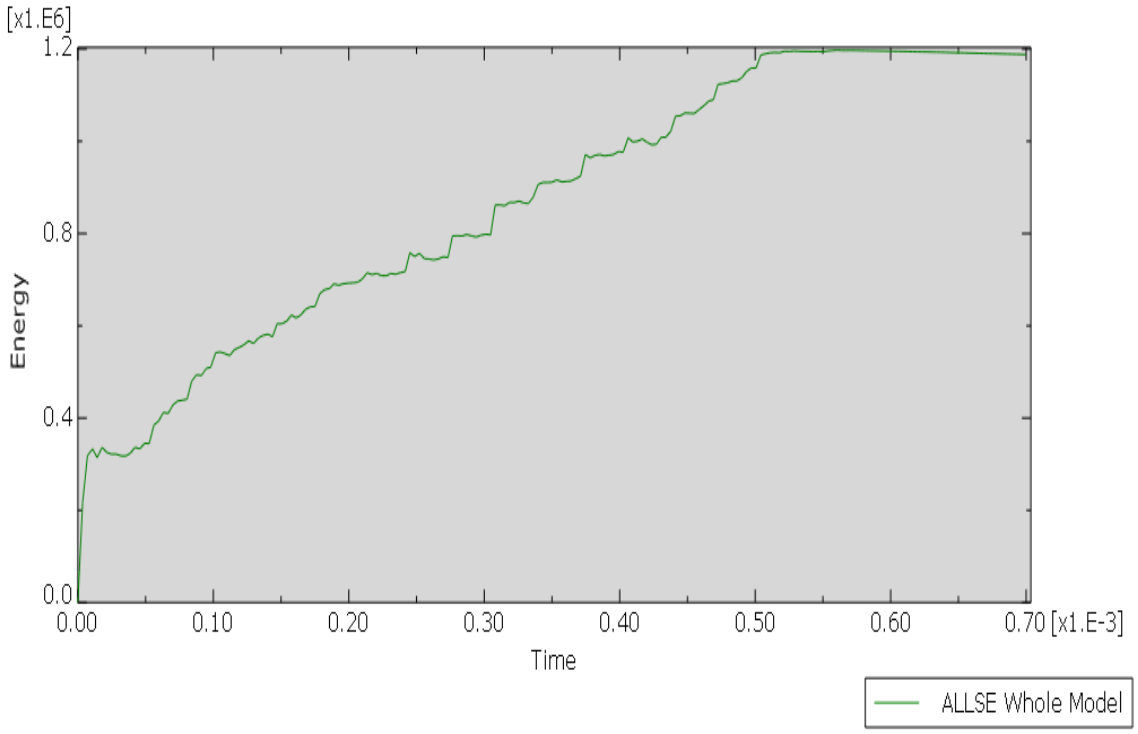


Fig.4.27. Strain energy of whole model (600m/s)

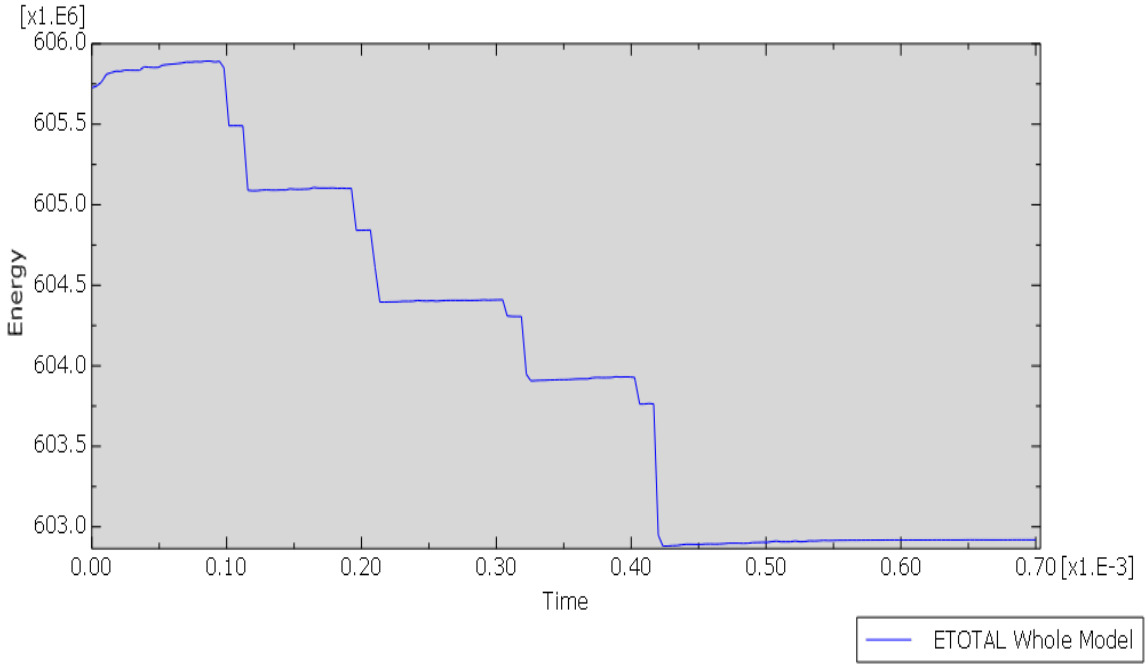


Fig.4.28. Total energy of model (600 m/s)

CHAPTER 5

CONCLUSIONS

5.1 CONCLUSION

From study conducted the conclusion is:

A numerical simulation modeling is done on a concrete panel by penetration of two projectiles, projectile-1 and projectile-2 at a velocity 400m/s and 600m/s. The panel was customizing by using Johnson- Holmquist (JH2) model. The length of the projectile-1 is 150mm and projectile-2 is 180mm in length, both projectiles are of deformable type. In this modeling, we estimate the damage created in concrete panel by projectiles, damage or stresses created in reinforcement and depth of penetration of both projectiles. The internal energy of concrete panel, Kinetic energy of projectiles, strain energy of model ,total energy absorb by whole model is simulated:

- The kinetic energy of projectile-1 is lesser than the kinetic energy of projectile-2. The concrete panel absorbs more energy in the penetration of projectile-2 as compared to projectile-1 at a velocity 400m/s. The kinetic energy for projectile-1 is 2.57 and in case of projectile-2 is 2.61 at time (t=0.0007s).

- Under an impact of both projectiles (p1) and (p2) at a velocity 400m/s, the total energy is observing in whole model. The total energy due to projectile-1 is 2.66 and due to projectile-2 are 2.67. The projectile-2 shows better penetration as compared to projectile-1 on concrete panel at a velocity 400m/s.

- The strain energy in model due to (p-1) and (p-2) impact at velocity 400m/s. In case of projectile -1, the strain energy is firstly increases at the time of penetration happens then decreasing with regular interval of time, at time t= 0.0007s the strain energy is negative. For projectile-2, the strain energy is positive at the time of penetration started and fully penetrated at velocity 400m/s.

- At a velocity 600m/s the kinetic energy of the projectile-1 is 5.8421 and total energy

absorb by the concrete panel due to the impact of projectile-1 is 6.005, where for projectile-2 the kinetic energy is 5.83 and total energy is 6.0292. The strain energy of model due to penetration of projectile-1 is negative, in case of projectile-2 is positive.

- The projectile-2 shows more damage than projectile -1in concrete panel at a velocity 400m/s and 600m/s. The projectile is not fully penetrated at time t=0.0007s in case of 400m/s for both projectiles, due to the minimum velocity of penetration.

- At velocity 600m/s the damage in concrete panel by projectile-2 is more as compared to projectile-1. There is less damage and less stresses generated in the reinforcement due to projectile-1 at both velocities.

- In a projectile-2 penetration in concrete panel, there is more damage and stresses are created in an inner region of concrete panel. The damage of reinforcement is maximum due to the projectile-2 and minimum due to projectile-1 at both the velocities.

- At velocity 600m/s, both projectiles are fully penetrated in concrete panel. At velocity 400m/s, not fully penetrated in concrete panel.

- The projectile-2 shows maximum damage in both the velocities 400m/s and 600m/s. The projectile-1 shows minimum damage.

REFERENCES

1) Chahmi Oucif , Luthfi Muhammad Mauludin [2018]. Numerical modeling of high velocity impact applied to reinforced concrete panel (2019)1-9.
2) Jian Liu, Chengqing Wu, Yu Su, Jun Li, Gang Chen, (2017). "Experimental and numerical studies of ultra-high performance concrete targets against high-velocity projectile impact*". Engineering Structures 173*, pp. 166 – 179.
3) M. H. Zhang and G. Yang , (2005). "Resistance of high-strength concrete to projectile impact". *International Journal of Impact Engineering , Vol.31, No.7, pp: 825-841.*
4) P.P Li, H.J.H Brouwers, Qingliang Yu, (2019). "Influence of key design parameters of ultra-high performance fibre reinforced concrete on in-service bullet resistance". *International Journal of Impact Engineering* 136, pp. 1-11.
5) Wu, Z., Shi, C, and He, W., 2017. Comparative study on flexural properties of ultra high performance concrete with supplementary cementitious materials under different curing regimens. *Construction and Building Material*, 136, pp.307-313.
6) P. Maca, R. Sovjak ,(2013). "Resistance of Ultra High Performance fibre Reinforced Concrete to Projectile Impact". *International Journal of Impact Engineering,* Vol. 126, pp. 261-272.
7) Radoslav Sovjak, Tomas Vavrinik, Jan Zatloukal, Petr Maca , Tomas Micunek, (2014). "Resistance of slim UHPFRC targets to projectile impact using in-service bullets". *International Journal of Impact Engineering,* Vol.76, pp. 166-177.
8) Garas, V.Y., Kahin, L.F. and Kurtic, K.E, 2009.Short-term tensile creep and shrinkage of ulta-high performance concrete, *Cement and Concrete Composites.*
9) Holmquist TJ, Johnson GR and Cook WH (1993) A computational constitutive model for concrete subjected to large strains, high strains rates, and high pressures. In: The 14th international symposium on ballis-tic, Quebec, Cananda, 26-29 September, pp.591.
10) Sovjak, R., Vavvrinik, T,. Maca, P., Zatloukal, J., Konvalinka, P. and song, Y., 2013. Experimental investigation of ultra high- performance fiber reinforced concrete slabs subjected to deformable projectile impact. *Procedia Engineering*, 65, pp.120.
11) Sovjak, R., Vavrinik, T., Zatloukal, J., Maca, P., Micunek, T. and Frydryn, M., 2015. Resistance of slim UHPFRC targets to projectile impact using in-service bullets. *International Journal of Impact Engineering, 76*, pp. 166-177.
12) Rajput, A., Iqbal, M.A. and Gupta, NK., 2018. Ballistic performances of concrete targets

subjected to long projectile impact. *Thin-Walled structures*, 126,pp.171-181.

13) Rajput, A. and Iqbal, M.A., 2017. Impact behavior of plain, reinforced and prestressed concrete targets. Materials & Design, 114, pp.459-474.
14) Ren, G.M., Wu, H., Fang, Q. and Kong, X.Z., 2017. Parameters of holmquist-Johnson-cook model for high-strength concrete-like materials under projectile impact. *International Journal of Protective Structures*, 8(3), pp.352-367.
15) Lai, J., Yang, H., Wang, H., Zheng, X. and Wang, Q., 2018. Propeties and Modeling of Ultra-High-Performance Concrete Subjected to Multiple Bullet Impacts. *Journal of Materials in Civil Engineering*, 30(10), p.04018256.
16) Jovanca Smith, Gianluca Cusatis, 2016. Numerical analysis of projectile and perforation of plain and fiber reinforced concrete slabs. *International Journal for Numerical and Analytical Methods in Geomechanics,*
17) H. Othman, H. Marzouk, (2016). "Performance of UHPFRC plates under repeated Impact Load", *International Journal of Impact Engineering* , 95 ,pp: 1-8.
18) Solhmirzaei R., Kodur V.K.R. ,(2017). "Modeling the response of ultra high performance fiber reinforced concrete beams". *Science Direct* , Vol. 210, pp: 211-219.
19) K. Sai Abhinav, N. Srinivasa Rao, (2016). "Investigation on impact resistance of steel fiber reinforced concrete". *International Research Journal of Engineering and Technology*, Vol.3, No-7, pp: 954-958.
20) Dr. Mark Rebentrost , Dr. Gavin Wight, (2013)."Investigation of UHPFRC Slabs Under Blast Loads". *Designing and Building with UHPFRC*, pp. 363-376.
21) H. Othman, H. Marzouk, (2016). "Performance of UHPFRC plates under repeated Impact Load", *International Journal of Impact Engineering*, 95, pp: 1-8.
22) Jianzhong Lai, Xujia Gou, Yaoyong Zhu, (2015). "Repeated penetration and different depth explosion of ultra-high performance concrete ", *International Journal of Impact Engineering*, Vol.84, pp: 1-12.
23) Qin Fang, Hao Wu (2017), "Numerical Simulation of Projectile Impact on Concrete Targets".*Springer*, pp *255-321.*
24) P.A. Radchenko, S.P. Batuev, A.V. Radchenko, and V.s.Plevkov. " Numerical Simulation of Projectile penetration into massive reinforced concrete barrier", *AIP conference Proceedings(2017)* Vol.1893,Issue 1.

25) Jun Feng, Wei-wei Sun and Bao-ming Li,(2018) " Numerical study of size effect in concrete penetration with LDPM", *Science Direct,* Volume 14, Issue 5.
26) S.Z Cai, Q.F. Zhang, X.P.Xu, D.H.Hu and Y.M. Qu (2014)," Numerical Simulation of the Kinetic Energy Projectile Oblique Penetration into the Concrete", *Materials Science & Engineering*., Volume (989-994).
27) Guo Ping Jiang, Shi Huan, Chu Jie Jiao, Wei Jun Tao (2011), "Numerical Simulation on Projectile Penetrating Wedge Concrete",. *Materials Science & Engineering.,* Volume (261-263).
28) Meng Huang, Z.-C.Ou, Yi tong, Zhuo-Ping Duan (2018)," Similarity analysis of Projectile Penetration into Concrete", Defence Science Journal,. pp.417-412.
29) Zakaria bin Che Muda, Kong Sih Ying, F A Salah, Salah Farhan A Sharif (2013) "Local failure on concrete Target due to Projectile Impact*",International Journal of Scientific and Engineering Research*.,4 (1).
30) Yi Bo Xiong, Jian Jie Chen, Yong Le Hu, Feng Chao Wang (2011)," Numerical simulation using FE-SPH method for concrete slabs penetrated and perforated by steel projectiles",.*Advanced Materials Research*., Volumes (378-379).
31) Yu Fu, Yun Peng, Yong Yao (2012), " Numerical Simulation and Analysis of Penetrating Concrete Slabs",.*Advanced Materials Research*., Volumes 446-449.
32) A. Rama Chandra Murthy, G.S. Palani, Nagesh R.Iyer," Impact Analyis of Concrete Structural Components",. *Defence Science Journal,*. pp. 307-319.
33) Dan Li, Jun Lin Tao, Juan Tan (2013)," The Numerical Simulation od Projectile Penetrating into Steel- Fiber Reinforced Ultra High strength Concrete Target",*Material Science & Engineerin,*. Volumes 357-360.
34) V.Mohan, J.Rajasankar &N,R,Iyer, (2015)" Response Simulation of a Micros Reinforced Methods in Engineering Science and Mechanics", *International Journal for Computational Methods in Engineering Science and Mechanics*"., 1550- 2295.
35) Ezzedin Galuta and Wafa Regig (2017)," Numerical Simulations of RC panels Subjected to High Speed Projectile- Erosion Selection in Autodyn-3D code",*International Journal of Innovative Science, Engineering and technology.,* Volume 4,. Issue 8.
36) Yao Qiu Long, Guo Ping Jiang (2012)," Numerical Simulation Used for High strength Concrete Under Impact Loading", Materials Science & Engineering., volumes (193-194).

37) Jimmy (C,M) Kao, Wen- Pei Sung, Ran Chen (2012), " Numerical Simulation used for High Strength Concrete under Imapct Loading",*Materals Science & Engineering,*.Volumes 193-194.

38) Ezio Cadaoni, Marco di Prisco (2011)," Projectile Impacts on Thin Reinforced Concrete Slabs: Tests, Modelling and Simulations" *Applied Mechanics and Materials,*. Volumes 82.

39) Ezzedin Galuta and Wafa Regig," Numerical Simulations of RC Panels Subjected to High Speed Projectile – Erosion Selection in Autodyn-3D code", *International Journal of Innovative Science, Engineering & Technology,*. Volume 8,. Issue 8.

40) Yi Cheng, Zhimin Xiao, Yuan Zhang (2019)," Theoretical and Numerical Investigation on Perforation Resistance of Monolithic and Segmented Concrete Targets with Steel Liners under Normal Penetration", *Advances in Civil Engineering,*. Volume 2019.

41) Weihua Xie, Fan Yang, Li Ding, Fabrizio Scarpa (2019)," Predictive models and experiments for high- velocity and high temperature impacts in Incol- alloy panels", *Materials & Design,*. (IF 6.289).

42) Abhishek Rajput, M A Iqbal, (2016), "Experimental and numerical study of concrete targets under high rate of loading",. *Science Direct,*. 173 (2017) 130-137.

43) Praseetha Ramakrishnan, Dayun Xu, (2015), "Ballistic Impacts Experiment and Numerical Modelling of Parts of sandwich Armor", *Applies Mechanics and Materials,*. Volume 751.

44) Christoper S, Meyer,(2015), " Kinetic Energy Required For perforating Double Reinforced Concrete Targets: A parametric Numerical study Considering Impact Velocity and Penetrator Presented Area", *Science Direct,*. 381 -388.

45) Song Gao, Ya Bin Wang, Xiu Feng Li, (2013), " Numerical Analysis of Deformation and Failure of Penetration into Concrete Target by Projectile", *Advanced Materials Research,*. Volume 804.

46) A. Pavlovic, C. Fragassa , A. Disic, (2017), " Comparative numerical and experimental study of projectile impact on reinforced concrete", *Science direct,*. Volume 108.

47) L. E. Kosteski, J.D Riera, I. Iturrioz, R.K. Singh, T.Kant,(2015), " Assessment of empirical for prediction of the effects of projectile impact on concrete structures",. *Fatigue & Fracture of Engineering Materials & Structures,* Volume 38, Issue 8,. P. 948-959.

48) Guangdong Yang, Gaohui Wang, Wenbo Lu, Peng Yan, Ming Chen, (2017), "Combined effects of penetration ansd explosion on damage characteristics of a mass concrete target",

Journal of Vibro Engineering,. Volume20, Issue 4.

49) A. Nishida, M.Nagai, Y.li (2018), " Evaluation of local damage to reinforced concrete panels subjected to oblique impact- Simulation analysis for evaluating perforation phenomena caused by oblique impact of deformable projectiles" , *Mechanical Engineering Journal*,. 2187-9745.
50) Christian J. Yungwirth, J.h.O Connor, H Wadley ,(2011) " Explorations of Hybrid Sandwich Panle Concepts for Projectile Impact Mitigation" ,*Material Science*,. 29.
51) A. Pavlovic, C. Fragassa, A. Disic ,(2017) " Comparative numerical and experimental study of projectile im[pact on reinforced concrete"., *Science Direct* ,. Volume 108.
52) Xuguang Chen, Fangyun Lu, Duo Zhang, (2018)., " Penetration trajectory of concrete targets by ogive steel projectiles- Experiments and simulations", *International Journal of Impact Engineering*,. Volume 120.

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