Numerical Modeling of Concrete under Blast Loading

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Abstract:
Normal strength concrete requires higher strength to improve their impact and blast resistance. The basic objectives of the simulations has been modeling of steel fiber reinforced concrete composite for blast loading and numerically simulate the response of concrete under different strain rates and finally optimization of the properties of steel fibre reinforced concrete composite for improved responses. The effects of dynamic loads on the materials can be studied with the help of the Split Hopkinson Pressure Bar. It is generally used for testing the material under high strain rates generally between $10^2$ to $10^4$ s$^{-1}$. In the present study ABAQUS FEA software has been used. The stress v/s time graph has been plotted to know the effect of stress on the samples relative to the time. Two samples have been taken for modeling, cube sample and disc sample. Results have shown that the deformation in the disc starts along the diameter of the disc. For this sample, firstly the elements from the edges starts to deform then proceeds to the middle portion along the diameter in which the waves propagate. However in the cube sample the failure pattern observed for simulations, starts from edges and then propagate to the middle portion. The disc sample can resist the blast loads more effectively. The results of the numerical simulations of the SFRC (Steel Fiber Reinforced Concrete) samples can be used to compare the results of the conventional concrete under impact loads.

Keywords: High strain rate, Split Hopkinson Pressure Bar, SFRC, Boundary conditions.

I. INTRODUCTION

Blast is a destructive wave of highly compressed air which spreads outwards resulting from an explosion. Blast near or inside the building can cause huge devastation and catastrophic damage. This can harm the building both externally and internally vis-a-vis structural frames, collapsing of walls, shutting down of life safety systems, fire damage, breaking of glass windows, or complete failure of the structure [1]. This can cause loss of life and injuries to occupants due to direct blast effects, fire, smoke, debris impact, or structural collapse. Sometimes timely evacuation is not possible contributing to additional casualties. Buildings, bridges, pipelines, dams, power-plants, cultural and heritage structures, historical monuments, industries etc. are the structures are of an immense importance to the economy and prosperity of the country and thus must be protected from the devastating effects of the dynamic loadings. These are the structures which are most prone to terrorist attacks [1]. Explosions create a large dynamic load on the structure, much more than the design loads. Efforts have been made in the past to avoid such threats of extreme loading on the structures. Studies were conducted to know the behavior of structure during blast loading, for resisting such blast loads the structural analysis and designing methods were developed and it is still current research topic. For analyzing and designing of the structures which involves the blast loading conditions require a detailed understanding of blast waves and also the structural dynamic responses pertaining to these blast conditions. Brittle materials such as concrete generally involves a non linear behavior under blast or impact loading, resulting on a complex analysis. In the present scenario the risk of terrorist attacks has increased thus require the protection strategies against the Blast. Thus structural engineers are considering it as an important factor for designing and analysis purpose. However every civilian building cannot be made blast resistant. The conventional structures are designed for lower loading conditions as compared to the explosion conditions thus such structures are more prone to blast damage. The potential threats and protective measures can be better understood by the Building owners and occupants thus the design professionals can take steps to implement such protective measures. With the advancement in the technology it becomes possible to perform the numerical simulations of concrete under dynamic loadings such as blast, impact, earthquake loadings etc. The reliability and accuracy of the results of numerical simulations is influenced by many factors. The important factor to be considered among these factors is the material model as it should be universally true to give accurate results under different conditions (i.e. loading conditions, boundary conditions, initial predefined conditions, environmental conditions etc.). These models are already coded in the software like ABAQUS, LS-DYNA, ANSYS etc.

II. LITERATURE REVIEW

Xudong Chen et.al (2016), worked with the Split Hopkinson Pressure Bar which is the device used to test the blast effects at the laboratory. Here this test is performed over different sets of loading angles and impact velocities. Strain gauges are attached to the SHPB apparatus to know the strain rate values. Stress equilibrium can be achieved under lower impact velocities. In that case the stress-state of specimen is similar to that of quasi-static condition. In quasi static state [3] initiation of crack is at the centre and propagation along the loading diameter direction. Stress equilibriums is harder to achieve at the higher velocities. At some points multiple cracks and ribbon fracture pattern appear at the centre of specimen. Local stress distribution is affected significantly by the loading angle. While the velocity plays an important role in the fracture pattern. Loading angle can improve the responses effectively. Results shows that when the impact pressure keeps constant, the mean value of dynamic tensile strength increases with the increase of the loading angles, while the tensile strength
obtained from the standard arc loading is close to the results of 20th loading. More impact pressure more will be the tensile strength with the same loading angle. Complicated stress distribution is obtained for Brazilian disc under dynamic loading. Stress equilibrium should be evaluated at time and space fields simultaneously. Lower the velocities more chances of stable stress equilibrium. The first crack usually initiates at disc centre and propagates along the loading direction. Higher the velocities more difficult to reach the stress equilibrium rather impossible [3]. Three primary kinds of failure pattern of concrete were observed in dynamic splitting tensile tests. When stress reached equilibrium, start-split location appeared at the centre of specimen and cracks propagate along the loading diameter direction, and the specimen is split into two pieces completely. As the impact velocity increased, specimen fractured before stress equilibrium. The initial crack location was uncertain and multiple cracks propagated at the same time, with a larger fragment zone at the center of specimen. Impact velocity plays a significant role in the failure pattern of concrete specimens under dynamic loading. Using 20th arc loading can improve the local stress state and reduce the local failure, which approximated to the real failure pattern under dynamic loading [3]. Stress distribution and failure process simulated by software LS-DYNA are coincided with experimental results. LSDYNA code is used for simulations. Stress and failure pattern are coincidental with the test results for this study. Sumanta Kundu et.al (2015), presented a statistical model in this for Brazilian test of rock samples. Increasing the force beyond its load capacity results in breakage of elements which is irreversible. Once this breaking gets initiated the nearby elements gets weakened and loose its load carrying capacity.

Defected zone expands as more deletion and breakage happens. Stress strain behavior for Brazilian disc sample has been obtained in this. Numerical simulations are also performed. Some Brazilian tests on Sandstone and Chalk samples are performed to know the responses. Qualitatively agreement is well established with the laboratory testing data. Peak value obtained for stress strain curve is similar to the Brazilian test experiments [6]. The Brazilian test is indirect tensile strength test. Here its performed over two rock types - Castlegate sandstone (CG) and Mons chalk (MC). Both rocks have a fairly homogeneous and isotropic structure. Specimen discs have geometries as 22 mm thickness and 52 mm diameter. Masking tape is used along circumference [6]. This is done smoothen contacting surface between rock and steel curved jaws is then placed in a loading frame. Load is applied generating 7500 and 48000 3-dimensional SOLID164 elements for projectile [14] and the bars respectively. Specimen's elements length is 0.25 cm and meshed elements are 3000 in number. Surface to surface was set between the bar and the specimen. Velocity of striking was 11 m/s.

The projectile has mass density= 7800 kg/m3, Young's modulus= 231 GPa, Poisson ratio= 0.30. After the striker strikes the incident bar, stress wave gets generated. These propagate along the z-axis direction [14]. This results in fracture or failure. When the value of principal strain is critical value (0.0035) the failure occurs in the upper portion of the specimen. As the critical value increases, the failure of the element further develops in the upper end and at the same time, it moves down along z axis. This is due to the effect of reflected wave. At t=400 µs, there is no element failure in the specimen. At t=500 µs the element in both the upper and lower portions are deleted in terms of the erosion criterion. When t=750 µs, the rupture near the lower end begins to consolidate closely due to compression of wave [14]. The stress strain curve for SFRC under quasi static condition and the medium strain rate loading are different. Former the damage softening prevails and in the latter case pressure dependent plastic hardening prevails. From the literature review it can be easily inferred that there is a dire need to study the behavior of concrete under blast loading keeping in view the increased number of terrorist attacks in the last decade.

### III. MODELLING AND NUMERICAL SIMULATIONS

The geometrical properties to be adopted for the modeling purpose are given in the TABLE I. And material properties for the samples is shown in the TABLE II. The velocity adopted for the striker bar is 14 m/s, 10 m/s, 7m/s for the three different cases to be taken for simulations. The cube and the disc samples are analyzed separately for different velocity conditions and results are compared.

#### Table.1 Geometrical Properties

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>PROPERTY</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Diameter of the bars</td>
<td>0.02 m</td>
</tr>
<tr>
<td>2.</td>
<td>Length of Incident bar</td>
<td>2.00 m</td>
</tr>
<tr>
<td>3.</td>
<td>Length of Transition bar</td>
<td>1.00 m</td>
</tr>
<tr>
<td>4.</td>
<td>Length of Sticker and Absorber bars</td>
<td>0.30 m</td>
</tr>
<tr>
<td>5.</td>
<td>Diameter of the Disc</td>
<td>0.02 m</td>
</tr>
<tr>
<td>6.</td>
<td>Thickness of the Disc</td>
<td>0.01 m</td>
</tr>
<tr>
<td>7.</td>
<td>Side length of the Cube</td>
<td>0.013 m</td>
</tr>
<tr>
<td>8.</td>
<td>Velocity of the Striker bar</td>
<td>14 m/s, 10 m/s, 7 m/s</td>
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</tbody>
</table>

#### Table.2. Material properties for sfrc

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>MATERIAL PROPERTY</th>
<th>VALUE</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Density, ρ</td>
<td>2550</td>
<td>kg/m³</td>
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<tr>
<td>2.</td>
<td>Elastic Modulus, E</td>
<td>30.09</td>
<td>GPa</td>
</tr>
<tr>
<td>3.</td>
<td>Poisson's ratio, ν</td>
<td>0.190</td>
<td>-</td>
</tr>
<tr>
<td>6.</td>
<td>Tangent modulus, E</td>
<td>08.90</td>
<td>GPa</td>
</tr>
<tr>
<td>4.</td>
<td>Compressive strength</td>
<td>179.2</td>
<td>MPa</td>
</tr>
<tr>
<td>5.</td>
<td>Initial yielding stress</td>
<td>88.22</td>
<td>MPa</td>
</tr>
</tbody>
</table>
IV. MODELING AND SIMULATIONS

1. GEOMETRY
Parts of geometry as shown in FIGURE I are assembled together as required for SHPB (Split Hopkinson Pressure Bar) apparatus.

Figure.1. Parts of the geometry in abaqus
(a) striker bar (b) incident bar (c) output bar
(d) concrete cube sample (e) brazilian disc

2. ASSEMBLY
FIGURE II and FIGURE III shows the zoomed view of assembly of the cube sample and the disc sample respectively. The incident bar, transition bar and the samples are shown in these figures while the striker bar and absorber bars are also available in assembly at the same distance as mentioned earlier in TABLE I.

Figure.2. Assembly of cube sample
Figure.3. Assembly of disc sample

3. MESHING
The number of elements generated for incident and the transition bars are 39984 and 19992 respectively. For the striker and absorber bars this number is equal to 5992. For the cube sample and disc sample number of elements generated are 125000 and 169330 respectively. These elements are Linear Hexahedral Elements of type C3D8R.

Figure.4. Meshing of the disc sample
4. INTERACTIONS
Surface to surface interaction property has been selected for this project work. And contact property mechanical tangential frictionless has been adopted over here. There are four interactions that are to be adopted here in this work. These are surface of the striker bar interacting with the input bar, other end surface of the input bar that is going to interact with one end surface of the sample, other end surface of the sample interacting with the output bar, and last one is the interacting surfaces of the output bar and the absorber bar. Although it is a versatile and user friendly software but with the only disadvantage that that user has to keep track of the units of the variables to be assigned. The results given after the job will be in the same units as initially assigned to the variables by the user but displayed in numbers only.

V. RESULTS
For this simulation model cubical sample with same geometrical and material properties as mentioned in TABLE I and TABLE II. The velocity of striker bar is taken as 14 m/s.

1. FOR CUBE SAMPLE
The FIGURE VI(a) represents the time history curve for the cube sample in element number 1. Element number 1 has been represented here. It is the element situated at the top edge which is adjacent to the incident bar, rather one face of which is in direct contacting surface with the incident bar. From the graph it is clear that the peak value of stress is equal to 21 MPa and at 956 µs. After reaching

the peak value curve starts to fall and attains a zero value at 962 µs. The FIGURE VI(b) represents the time history curve for element number 1325. This is the element present in the middle of the face of the cube with incident bar at right side and transition bar at left side. This element is in the middle of the face as the effect of waves is smaller in this portion of the face as compared to the corners or edges of the cube. This can also be seen from the peak stress value which is equal to 17 MPa at about 956 µs. The loading and unloading is between 953 µs to 963 µs. At 953 µs the curve starts to increase in values then reaches a peak and afterwards start to decrease to reach the zero value. The FIGURE VI(c) shows the time history curve for stress in element number 2500. This element is the lowermost element at the bottom edge having contacting surface at right side with the incident bar. Here the graph starts to increase in value from zero to 15 MPa at 1000.20 µs than falls back upto 1MPa. Again an increase in values can be seen at about 1020 µs of time. It attains its highest peak at about 1020.10 µs. After that point it starts to decrease in value and finally it gets a failure beyond 1020 µs. The deformation exceeds the failure value so the curve gets a halt point at 1020.20 µs. It has its maximum peak stress of 23 µs. After getting the failure value for the curve the solution gets to a stop for this element representing the maximum erosion criteria has been reached for this element. Element gets deleted for this situation. This shows that the element is the most critical element and the failure firstly starts from the lower edge element which is in contact with the incident bar.
FIGURE VII(a) shows the time history curve for strain of the element number 1. Here the curve can be seen with a rising limb, peak points and a falling limb. The rising and the falling limbs are due to change in strains due to loading and unloading conditions. The zero values are at 953 µs and 967 µs. The peak value is 0.0130 at about 955 µs. Then another peak is obtained after 1 µs i.e. at 956 µs. This peak value is about 0.0135. Beyond this time after 956 µs. After the receding curve it falls back to zero at about 967 µs. beyond 968 µs it has a little hump in the curve up to the next 2 micro seconds. Finally it reached the zero value. FIGURE VII(b) shows the time history for strain value of the element number 2500, which is the lowermost corner element in the sample. The curve covers a time period from 1020 µs to 1027 µs. At 1020 µs curve increases almost linearly. At 1022 µs it attains its first peak value of 0.015. Then it falls back up to a value of 0.014. Again an increase can be seen in the curve which is equal to the peak value. But now the peak point is obtained at 1023 µs. Zero value is reached at 1027 µs. From the strain values it can be easily inferred that this element reaches a critical value of strain earlier. Thus failure can be seen in this element first rather than the other elements situated in the top edge or in the middle portion of the sample. The element number 3500 is located in the middle portion of the face of the cube sample. FIGURE VII(c) shows the variation of this element with respect to time. It can be seen from the graph that at 953 µs the waves travelling from the sample plays its part of deforming the sample. There is an abrupt increase in the curve between the time period from 953 µs to 956 µs. At 956 µs it achieves its peak strain value of 0.011. Then an abrupt decrease in the value can be seen up to 958 µs. A constant value is seen from 958 µs to 959 µs. Then again a recession comes in the graphical value. These ups and downs continues to 976 µs. And after 974 µs the value reaches a zero value. Comparing this curve with the other elements curves for strain it can be seen that in the middle portion the value of strain. This signifies that the middle portion elements are deformed much lesser than the edge elements. While the lower edge corner elements are deformed more and reaches the failure point much earlier than those in the other portions. And the deformation in the upper corner point is in between these two cases.

2. FOR DISC SAMPLE
The next model consists of disc sample with properties exactly as mentioned in TABLE I and TABLE II. The velocity has been taken equal to 14 m/s. Various graphs has been plotted for this model and are shown in this section. The various results plotted are depicted for the disc sample are shown in the FIGURE VIII(a), VIII(b), VIII(c). The detailed perspectives regarding these graphs are then discussed in detail in this section. Element number 1845, 1771, and 562 have been analysed for the disc sample.
Element number 1845 is the element situated at the diameter along the loading direction. FIGURE VIII(a) shows the time history curve for stress in element number 1845. It is situated at the extreme corner position, one face of which is in contact with the incident bar. As the element is in the loading direction this element is the most critical element giving the maximum values for stresses and strains. The curve achieves a rise at 954 µs and reaches a peak point at 41 MPa for stress. Then the curve suddenly falls down to have a zero value at about 968 µs. The element number 1771 is the element situated at the extreme position along the loading diameter adjacent to the transition bar, one face of which is in contact with the transition bar. FIGURE VIII(b) shows the time history curve for strain in element number 1771. At 955 µs of time the curve starts to rise and reaches a peak value at the 38 MPa at 959µs. Then it falls back to zero at 968 µs of time. The maximum value of stress for this element is lower than that of the opposite portion element which is element number 1845. Thus here the effect of waves is smaller than that of the former element as is shown in FIGURE VIII(a). The element number 562 is the element present at almost the middlemost position in the meshed sample. This element is also present along the loading diameter. 14m/s velocity has been given to the striker bar and the effects for stress has been noted here. The graphical representation for time history of stress has done and represented in FIGURE VIII(c). It is clear from this curve that the stress value rises in this element and attains a peak of 27 MPa at 957 µs. Afterwards the curve recedes in value and reaches a zero point at about 1000 µs of time. The strains developed here are of greater magnitude for the disc sample of steel fibre reinforced concrete. The velocity of the striker bar has been changed for next modeling and taken equal 10 m/s. All other necessary properties are adopted as specified earlier in TABLE I and TABLE II. Time history curve for stress in the element number 1845 has been plotted for this simulation model and represented here in this section in FIGURE X (a). It can be seen in this figure that the peak value is 20 MPa for stress. Peak arises at 1335 µs of time.

At 1020 µs the curve starts to rise and attains a maximum strain value of 0.015 at 1022 µs. Again it starts to fall for extremely short duration of time then another peak is obtained at 1023 µs. As compared to the results of the model with 90 GPa elastic modulus the strains obtained are of much lower magnitude. Here in the above figure FIGURE IX(b), time history curve for strain in one of the elements of the sample has been shown. This element is the same as discussed earlier in this article. From the curve it is clear that the peak value of strain for this element is 0.045. This peak arises at 957 µs of time. It also has small peaks at some later times. But ultimately curve reaches a zero point at about 1000 µs of time. The strains developed here are of greater magnitude for the disc sample of steel fibre reinforced concrete. The velocity of the striker bar has been changed for next modeling and taken equal 10 m/s. All other necessary properties are adopted as specified earlier in TABLE I and TABLE II. Time history curve for stress in the element number 1845 has been plotted for this simulation model and represented here in this section in FIGURE X (a). It can be seen in this figure that the peak value is 20 MPa for stress. Peak arises at 1335 µs of time.
As compared to the results obtained for the striker bar velocity of 14 m/s, these results are delayed and are much lesser in magnitude. This shows that the stresses value are at a much lower value and thus the ultimate failure in this elements for this model is at much lower values in terms of magnitude and time values. This curve ultimately gets unloaded at about 1360 µs. FIGURE X (b) shows the time history curve for stress in element number 1771. This element is adjacent to transition bar and along the loading diameter of the sample. It attains a maximum value of 32 MPa at about 1335 µs. Ultimately the curve reaches the zero value at 1345 µs. As compared to model given for cube sample, here the stress value is of lower magnitude and at a delayed time period. The magnitude of stress in the former case was 38 MPa at 955µs, while in the latter case this value is 32 MPa at 1335 µs. So it’s clear from this comparison that the velocity of the striker bar has significant impact on the results. And when compared to the model provided for cube sample it takes more stresses. This element is the same as discussed in previous part of this section. FIGURE XI (b) shows the time history curve for strain in element number 1771. From this figure it is clear that the curve rises at 1332 µs of time from zero magnitude. Then reaches a maximum peak magnitude. This maximum value for strain is 0.04 at 1335 µs in this element. Then some lower peaks have also been observed for this curve. Finally the curve falls back to zero magnitude. At time 1345 µs the curve nearly reaches back to zero value. This element seems to be most critical for this case. And the values for strain are also of higher magnitude. Thus more deformation is there in this element as compared to other elements for the same velocity of 10 m/s.

Figure.11. Time history curve for strain in (a) element number 4400 (b)element number 1771

Figure.12.Time history curve for stress in (a) element number 4236 (b)element number 1667 (c) element number 482
Now the velocity of the striker bar has been changed for the next case and taken equal to 7m/s. While all other geometrical as well as material properties has been taken from TABLE I and TABLE II. The results are shown in the following figure FIGURE XII. Element number 4236 is the element present along the loading diameter. Time history curve for stress has been given in FIGURE XII (a) for this element number 4236. Here 1897 µs is the time from where the rising limb of graph appears. This curve than rises upto 15 MPa value. After that point it starts to fall back to zero value. As compared to the earlier cube model, values obtained for this model are much lower and at much delayed time period. For this particular case the peak value is obtained at 1901 µs. This time is a delayed time period as compared to other simulation models. Time history curve for stress has been plotted here in FIGURE XII (b) for element number 1667. This element is along the diameter of the disc sample and at the extreme right corner along the loading diameter, adjacent to incident bar. Peak value of stress is equal to 26 µs and is obtained at 1900 µs. This magnitude is higher as compared to the middle portion elements while it is lower as compared to higher velocity cases. This curve abruptly rise from zero to maximum value and then falls back to zero value comprising of extremely short duration lower valued peaks. Stress is plotted against time axis for element number 482 and is shown in FIGURE XII (c). Element number 482 is the element adjacent to the transition bar and along the loading diameter. Peak value of stress is obtained at 1900 µs with a magnitude of 25 MPa. This shows that as velocity decreases the stress value also decreased in magnitude, while the time is a delayed value. FIGURE XIII (a) shows the time history curve for strain in element number 4236. Element number 4236 is the element present at the middle portion of the disc sample. The velocity for the striker has also been changed and decreased thus the peak values obtained are at a lower magnitude. The peak is 0.022 at 1901 µs of time. After the peak point the curve starts to recede and decreases in magnitude for the strain. Then the zero magnitude is obtained at 1911 µs of time.

This element is the most critical element along the loading diameter. FIGURE XIII (b) represents the time history curve for strain in element number 1667. Maximum value of strain for this case of strain is at 1901 µs and value is 0.032. This magnitude is higher than the previous case of element number 4236. As this element is located near to the incident bar. The effect is more pronounced. FIGURE XIII (c) shows the time history curve for strain in element number 482. This is the element present in the opposite corner point of the element number 1667. The peak value here is 0.025 at 1901 µs of time while for the opposite side element this value is 0.032. After achieving the peak magnitude value the curve starts to fall back to zero value after the removal of residual stresses. Thus it can be known easily that this element deforms less than the opposite side element.

VI. CONCLUSIONS

Steel Fiber Reinforced Concrete is good in taking the stresses as compared to the conventional concrete. The addition of steel fiber can significantly improve its strength, toughness, and resistance to failure. In the cube sample of SFRC the failure pattern starts from edges and proceeds to the middle portion. This behavior is consistent irrespective of the change in velocity of the striker bar. Thus critical zone is along the edges corner portion. The maximum stresses generated are a little higher in magnitude as expected. However a good consistent relation can be developed with the experimental results known from literature. Stress distribution in Brazilian disc under dynamic loads is far more complicated. Stress equilibrium should be evaluated at time and space fields simultaneously. Brazilian disc subjected to low impact velocities tends to have good stress equilibrium. The first crack usually initiates at disc centre and propagates along the load direction. Brazilian disc subjected to high impact velocities is hard to get stress equilibrium. At lower velocities when stress reached equilibrium, start-split location appeared at the centre of specimen and cracks propagates along the loading diameter direction. However a complete different behavior can be seen at higher impact velocity, compressive failure zone was detected at the edge of specimen, and a complete shear failure region arisen at the centre. Stress distribution and failure process simulated by software are coincident with experimental results obtained from literature. As the velocity has been decreased the stress in the elements has also decreased and also the strain values has decreased too. This means that as the impact velocity decreases the deformations...
has also decreased. However the pattern of crack generation have also changed. Time taken for the failure has been delayed with decrease in impact velocities. The multiple peak behavior is due to plastic hardening of the samples. When the results are compared for cube sample and the disc sample much variation in results have been seen for the same impact velocities and same elastic modulus. The stress in the disc sample are increased and thus the deformations have also increased for the disc sample as compared to the cube sample. For same velocity values cube sample takes lower impact loads as compared to disc samples. However the erosion of the material stats from lower portion in both cases. Decreasing the velocity has resulted into a different failure pattern but when compared the results of cube and disc sample, disc has taken higher stresses as compared to cube sample values. Also the cube sample reaches its critical stress and strain values at much earlier time as compared to disc sample values. Thus disc sample performed well in terms of stress and strain resistance.

VII. FUTURE SCOPE

The volume of fibers in the specimens can be increased as this will affect the resistance of the concrete against blast or impact loading conditions. These results can be employed in future studies for knowing the impact loading effects for high rate events. The results of the numerical simulations of the SFRC samples can be used to compare the results of the conventional concrete under blast impacts and fiber reinforced concrete under blast loadings. Fibers improves the strength and resistance against the impact and blast loadings. These simulations can be done by changing the properties of the concrete and incorporating the improved properties for new studies. These results can be employed to know the behavior of structures subjected to blast loads or impact loads. Properties of Reactive Powder Concrete can be inculcated in the samples under simulations and thus blast load impacts can be known and can be compared to this model. Seismically reinforced structures can be also be modeled and impact of blast loading on such structures can be found, and vice versa can also be done.

VIII. REFERENCES


