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Assessing the Damage Mechanism in Reinforced Concrete Beams under Repetitive Low Velocity Impact Loading

Sajina K[1], Reshma C[2]
[1]PG Scholar, [2]Assistant Professor, Civil Engineering Department, SNIT Adoor, India

***Abstract*— Reinforced concrete beams are widely used in various civil structures such as residential, industrial, and commercial buildings. The use of RC beams reduces the cost of the construction and the time of execution. Rockfalls, accidental events, explosions, projectile, missile or aircraft impacts, terrorist attacks and ice impacts are the typical examples of sudden loads. Experimental studies can be impractical and require expensive devices to observe crack pattern and failure due to impact loading. Similar results can be obtained through non-linear finite elements analysis. In this study, RC beam is modelled and analyzed for changing impact velocity. Beam properties like clear cover is varied to access the damage in beams.**
***Keywords*— Beam, Bridges, Impact velocity**

I. INTRODUCTION

Reinforced concrete beams are widely used in various civil structures such as residential, industrial, and commercial buildings. The use of RC beams reduces the cost of the construction and the time of execution. Also, in structural cases such as short spans, RC beams are more economical and less complicated to implement. However, their resistance to impact damage caused by threats such as rock fall or other impact loads is currently under high interest. Here is growing recognition of the importance for resistant structures and, in consequence, a need for tolerable, related evaluation and design processes. Common example of these conditions includes transportation structure subjected to vehicle crash impact, marine structure subjected to water vessels direct impact, wind and storm generated missiles, accidental collisions of train, aircraft, motor vehicle, dropped objects on to prestressed structures etc. Response of structures to impact is different from that caused due to static load. Also, impact load is a particular type of dynamic loading which needs special attention. Broadly, the impact load can be classified into i) low velocity impact and ii) high velocity impact. The first category involves collision of vehicle into crash barriers, piers of bridges, drop of an object on slab etc. Whereas the second one includes bullet or missile hitting structures, birds hitting airplane etc.

II. METHODOLOGY

– To investigate dynamic response and damage mechanism characterization of RC beam under single and repeated low-velocity impacts
– To study the influence of the impact velocity
– To investigate the impact behaviours of the beam by varying the cover

III. DYNAMIC EXPLICIT NON-LINEAR ANALYSIS

An alternative for nonlinear dynamic analyses is that the explicit dynamics procedure available in Abaqus/Explicit. As discussed in Abaqus Basics, the specific algorithm propagates the answer as a stress wave through the model, one element at a time. In contrast, the Nonlinear Dynamic Procedure (NDP), or Time History Analysis, attempts to completely represent the seismic response of buildings with none of those major simplifying assumptions. The LDP is probably the foremost common analysis procedure utilized in the planning office for multistorey building design. In nonlinear implicit analysis, solution of every step requires a series of trial solutions (iterations) to determine equilibrium within a particular tolerance.

IV. INTERPRETING THE STRESS PATTERN AND DETERMINATION OF TYPE OF FAILURE

A. Varying Impact Velocity

Impact velocity vector means the geometric quantity which describes both the speed and direction of travel of the vehicle at the instant of impact with the pole. The impact velocity vector points within the direction of travel of the vehicle. The origin of the impact velocity vector is that the centre of gravity of the vehicle and its magnitude (length) describes the impact speed of the vehicle.

1) Single Load:

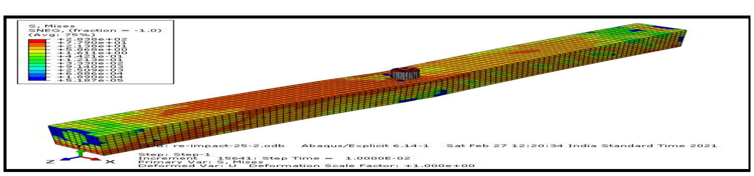

Fig. 1. Beam with 25m/s

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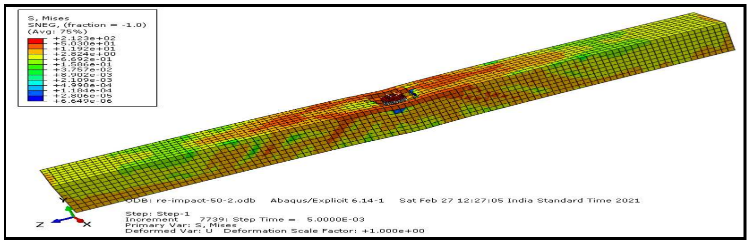

Fig. 2. Beam with 50 m/s

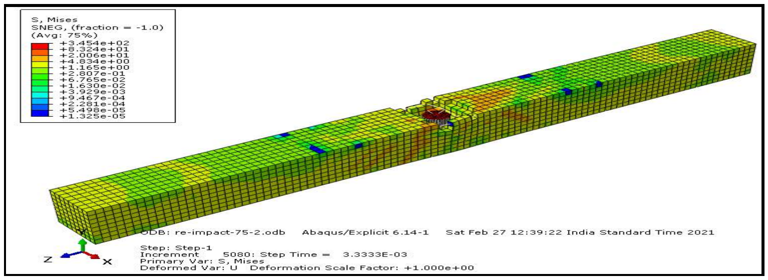

Fig. 3. Beam with 75 m/s

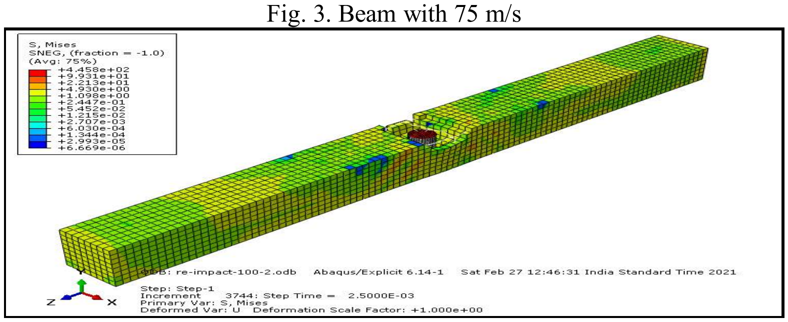

Fig.4. Beam with 100 m/s

2) Repetitive Load

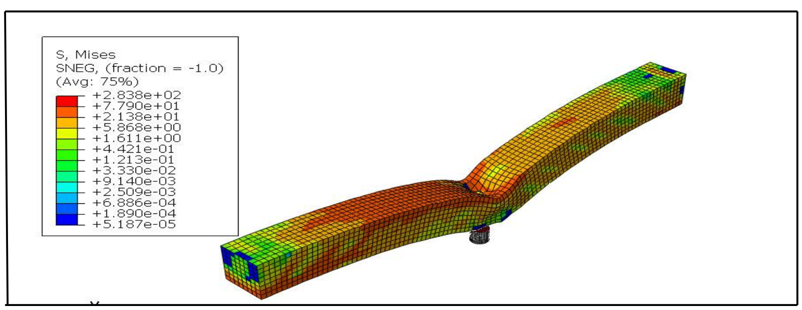

Fig. 5. Beam with 25m/s

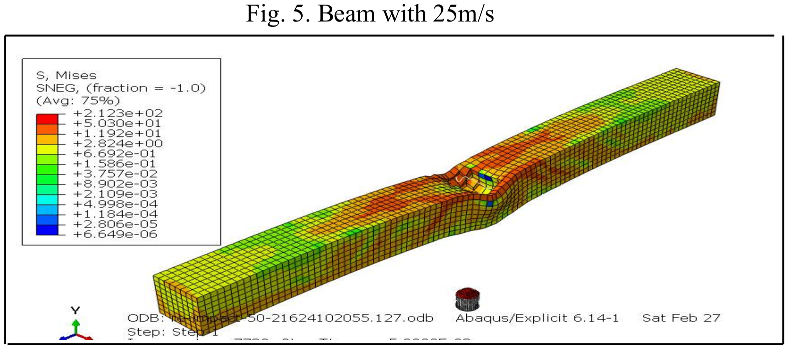

Fig. 6. Beam with 50 m/s

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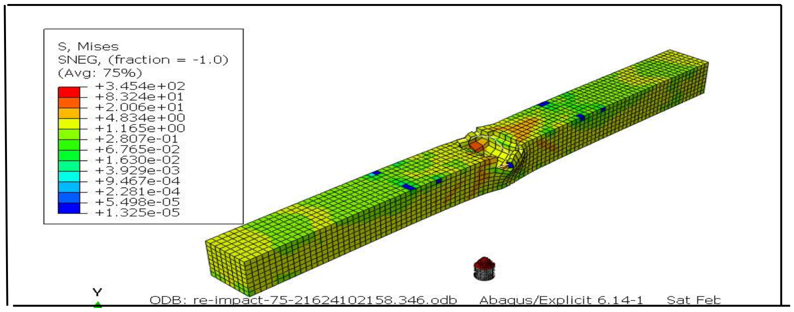

Fig.7. beam with 75 m/s

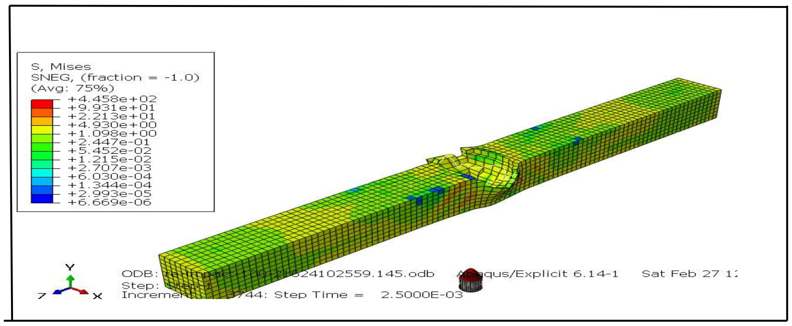

Fig. 8. Beam with 100 m/s

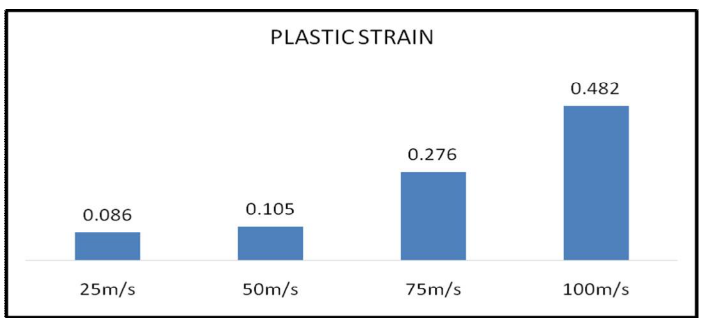

Fig.9. Plastic Strain by varying Impact Velocity

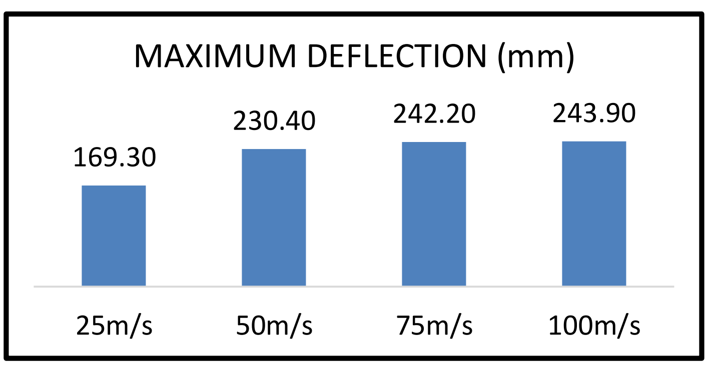

Fig.10. Maximum Deflection by varying Impact Velocity

In this the plastic strain and maximum deflection is evaluated, from this it is clear that at a minimum impact velocity, here at 25m/s the plastic strain is at low value. It shows minimum value at 50m/s and 75m/s. But in the case of deflection, the deflection value is maximum at 100m/s. That means as impact velocity increases the deflection is also increases. The general requirement of the accumulated plastic strain is that it should be based on strain aging and toughness testing of the pipe material. It is stated that due to material considerations a permanent/plastic strain up to 2% is allowable without testing.

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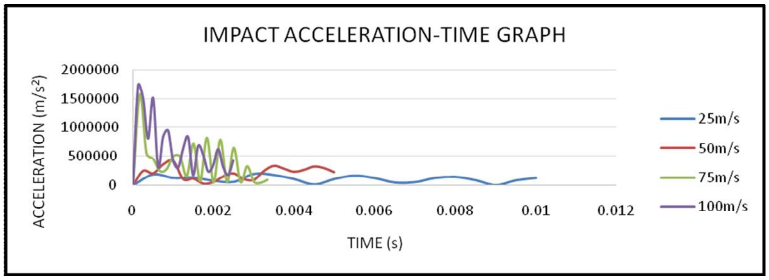

Fig.11. Graphical representation of Impact Acceleration for single load

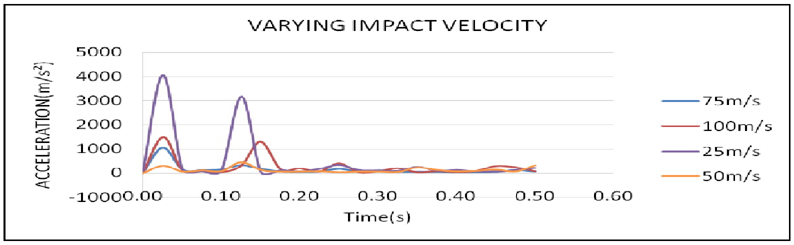

Fig.12. Graphical representation of Impact Acceleration for repetitive

Acceleration suddenly increases and decreases for higher velocities and the failure occurs in very less time. Due to sudden acceleration, only localized damage will occur without spreading throughout the beam. Time taken for complete failure get reduced 60% when the beam under repetitive impact. Also the pattern of acceleration is different for repetitive impact.

B. Varying Cover

The effective cover is that the distance between the exposed concrete surface to the centroid of the most reinforcement. (or) The effective cover is that the distance between the outermost compression face of RCC to the middle of the world of main reinforcement in tension. In simple words, Cover is defined because the small space remains between the surface of the concrete surface to the reinforcement inserted inside that concrete structure. Mostly, the thickness of the reinforcement cover is indicated within the structural drawing, or it shall be obtained from a relevant code of practice of minimum concrete protect reinforcement. As per IS 456(Clause 26.4. 1), the term clear cover is replaced by the term Nominal cover.

1) Single Load:

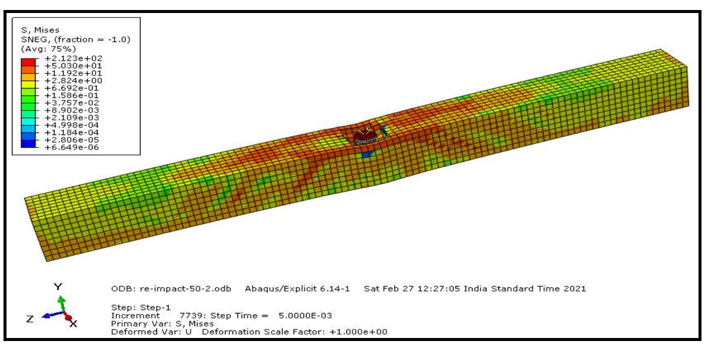

Fig.13. 20mm Cover

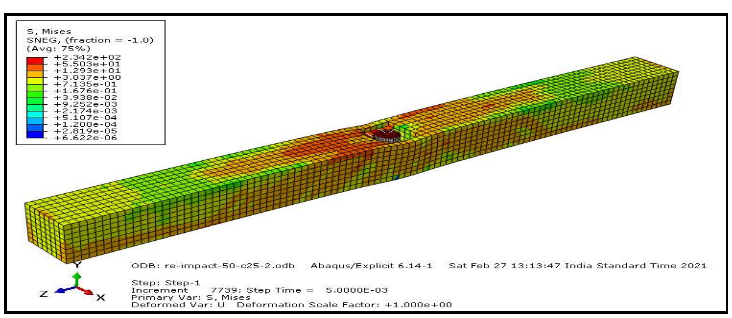

Fig.14. 25mm Cover

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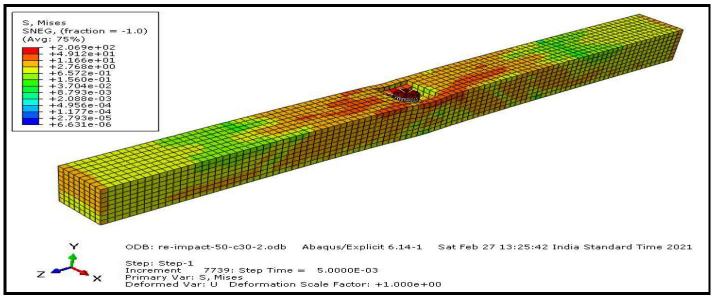

Fig.15. 30mm Cover

2) Repetitive Load:

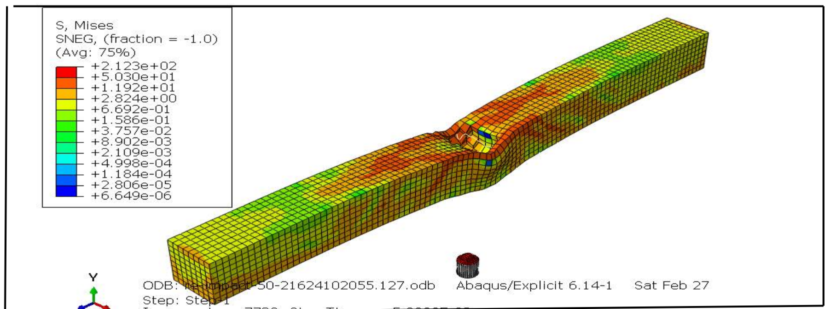

Fig.16. 20mm Cover

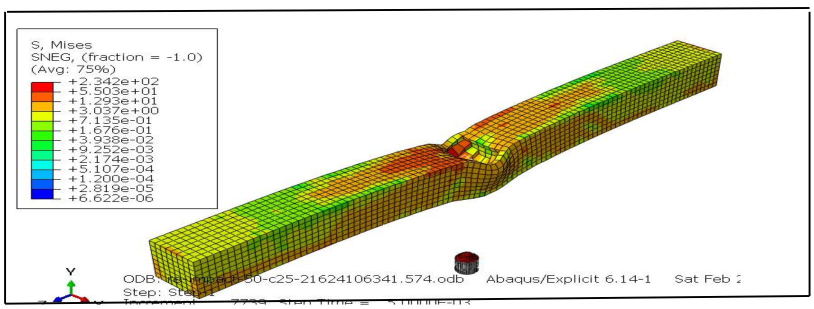

Fig.17. 25mm Cover

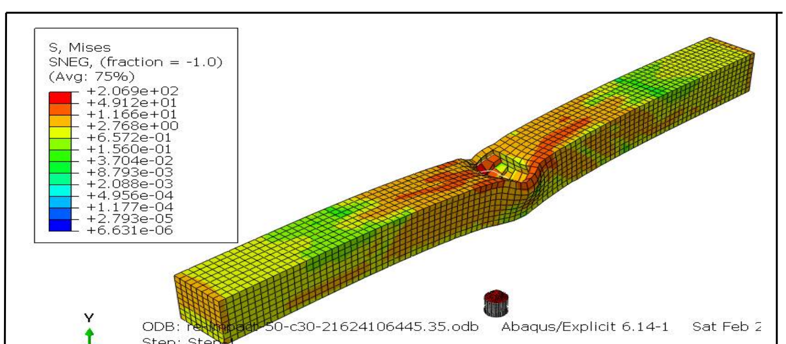

fig.18. 30mm Cover

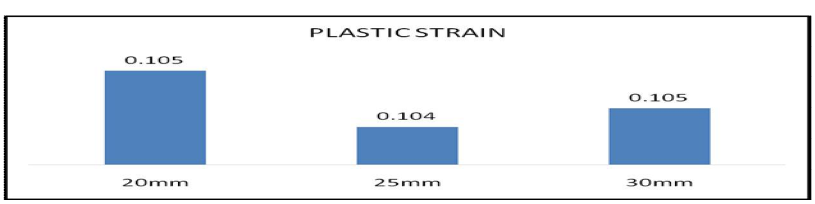

Fig.19. Plastic strain by varying cover

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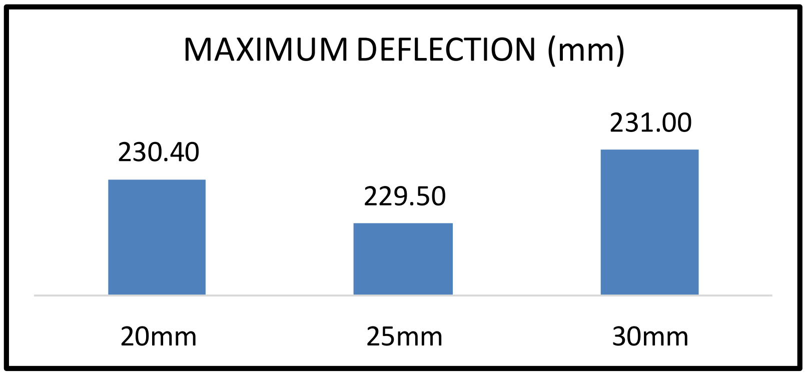

Fig.20. Maximum deflection by varying cover

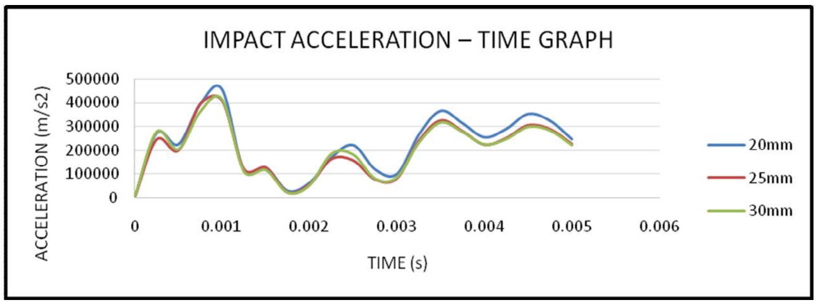

Fig.21. Graphical representation of Impact Acceleration

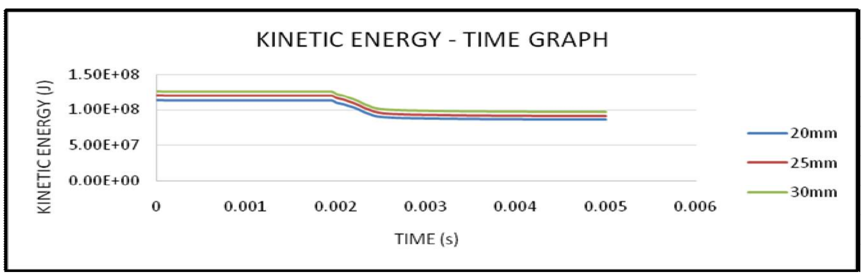

Fig.22. Graphical representation of Kinetic Energy

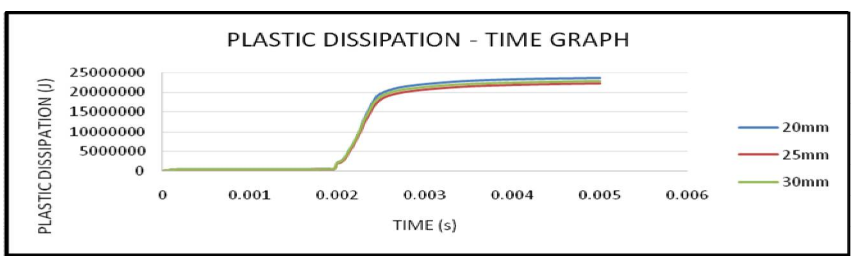

Fig.23. Graphical representation of Plastic Dissipation

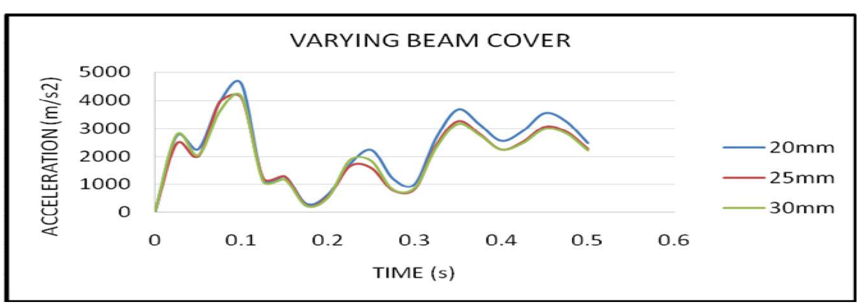

Fig.24. Graphical representation of varying cover at single load

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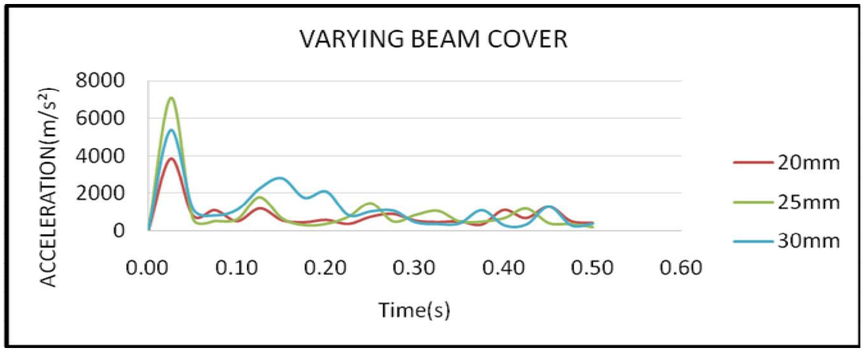

Fig.25. Graphical representation of varying cover at repetitive load

Damage is high at 20mm cover because for small covers the flexural strength on concrete is very less. At 25mm and 30mm cover, the damage is almost same due to the overlapping of flexural and compressive strength of concrete.

V. CONCLUSIONS

High velocity impact takes less time to make the beam to plastic state due to the sudden occurrence of yield point in the stress strain curve of the beam.Plastic dissipation energy get reduced under repetitive impact. High velocity impact imparts punching shear while low velocity impact distribute damage throughout the beam. Effect of impact on beam cover depends on flexural strength of concrete and yield strength of rebar. Effect of impact on beam boundary condition depends on moment, self equilibrium force and support settlement. Effect of impact angle depends on the axial force or thrust on the beam created by the horizontal component of impact.

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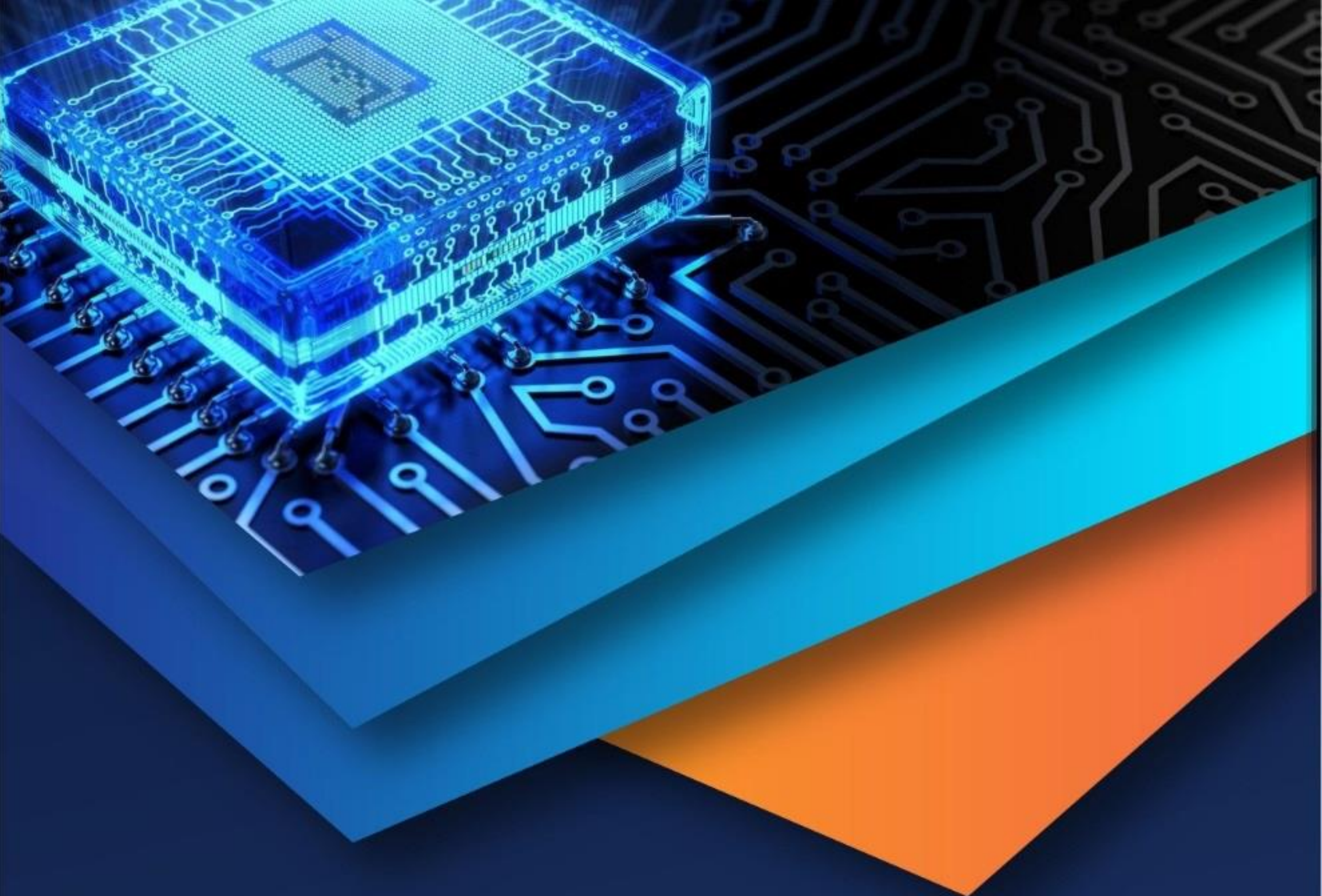

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