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ANALYTICAL STUDY ON BEHAVIOUR OF CONCRETE STRUCTURAL ELEMENTS SUBJECTED TO IMPACT LOADING

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ABSTRACT

The impact loads on structures such as accidental effect from transportation, blasting, gunshots, projectile impact from terrorist attacks can cause a structure to sudden failure. So there is a need of dynamic loading design instead of static loading for the structures to save many lives. The numerical technique is the better economical way than experimental technique to predict the possible failure mode of concrete members subjected to impact loading. The present analytical study is to investigate the behaviour of concrete structural elements subjected to impact loading by using finite element analysis software AUTODYN 12.0.1. The structural elements such as cube, cylinder and beam were modelled and low velocity impact loading was applied to examine the compression, tension and flexural behaviour of concrete elements subjected to impact loading. The damage level was monitored and the Energy absorption capacity (toughness index) of the structural elements were determined and presented.

KEYWORD: Impact load, Energy absorption, low velocity impact load, AUTODYN 12.0.1

1.0 INTRODUCTION

In many structural or mechanical design problems the requirement is to provide proof That the structure remains substantially intact, even though damaged. Finite element analysis (FEA) is a numerical method, which provides solution to analyze all structures. The numerical investigations were performed with commercial software AUTODYN version 12.0.1. Concrete may sometime be required to withstand dynamic loads due to impact or explosion. Civil structure often experiences various dynamic loads. Some of them are: Shock loads, Blast loads, Explosion, blast phenomenon and Impact loads. Impact loads are the loads resulting from collision between two bodies during the small interval of time. One of the most important types of impact test is drop weight hammer impact, which helps to determine the energy absorption capacity (toughness) i.e., Extent to which a material absorbs energy without fracture. AUTODYN 12.0.1 is used to simulate the elements subjected to drop weight hammer.

2.0 NUMERICAL MODELLING

The AUTODYN program has much finite element analysis capability ranging from a simple, non-linear explicit dynamic analysis where it Builds the model, Apply loads and obtain the solution and Review the result. Structural analysis is probably the most common application of the finite element method. It is mainly based on four principles. The following are the principles: Lagrange solvers, Euler solvers, ALE solvers (Arbitrary Lagrange Euler),
SPH solver (Smooth Particle Hydrodynamics) using these we can define the material behaviour, structural behaviour, contact/interaction, fluid structure interaction.

2.1 Lagrange Solver

Lagrangian mechanics is a re-formulation of classical mechanics using the principle of Stationary action. In Lagrangian mechanics, the trajectory of a system of particles is derived by solving the Lagrange equations in one of two forms, either the Lagrange equations of the first kind or the Lagrange equations of the second kind. It is a combination of NEWTON, D-ALEMBERTZ, and HAMILTON'S PRINCIPLE. The core element of Lagrangian mechanics is the Lagrangian function, which summarizes the dynamics of the entire system in a very simple expression. Lagrange solvers generally use mesh-based lagrangian methods.

2.2 ANALYSIS OF VARIOUS ELEMENTS USING LAGRANGE SOLVER

All the analysis of the specimen given below are done using AUTODYN.12.0.1.

2.2.1 Analysis of Cube Element

A concrete cube of size 150mm x150mm x 150mm using **M35** grade is simulated in AUTODYN 12.0.1.The element types for this model are shown in Table 1. The **M35** grade cube and **S-4340** steel ball were used. The material model was tabulated in Table 2.

Table 1 Element type

Material type	AUTODYN Element
Concrete	M35 Grade
Steel Ball	S-4340

Table 2 Material Model

Material name	Equation of state	Strength model
Concrete- 35MPA	P-ALPHA	RHT CONCRETE
S-4340	LINEAR	JOHNSON COOK

The material name is Concrete 35Mpa and equation of state indicates p-alpha (i.e.), p-alpha model to describe the pore compaction hardening effects and thus give a realistic response in the high pressure regime. Strength model is RHT concrete; it is an advanced plasticity model for brittle materials developed by Werner Riedal et al [9]. It is particularly useful for modelling the dynamic loading of concrete.S-4340, the first two digits indicates a 1.8% of Nickel-Chromium-Molybdenum alloy steel the last two digits indicates carbon content roughly 0.4 percent.

2.2.2 Analysis Of Cylinder Element

Cylinder of size 150 mm x 300mm using M35 grade concrete and steel ball of S-4340. Element, Equation of state, Strength model are same as above and it is a 3-D model and the units are **mm, ms, mg.**

2.2.3 Analysis of Beam Element

Beam of size 500 mm x 100 mm x100 mm using M35 grade concrete and steel ball of S-4340. Element, Equation of state, Strength model are same as above and it is a 3-D model and the units are **mm, ms, mg.**

3.0 ANALYTICAL INVESTIGATION

The specimens that are used for the analysis are cube element, cylinder element and the Beam element. The Low velocity impact loading was applied by steel ball of S-4340 Element on the concrete models to examine their compression, tension and flexural behaviour subjected to impact loading.

3.1 Before Impact Load and its Corresponding Gauge Points

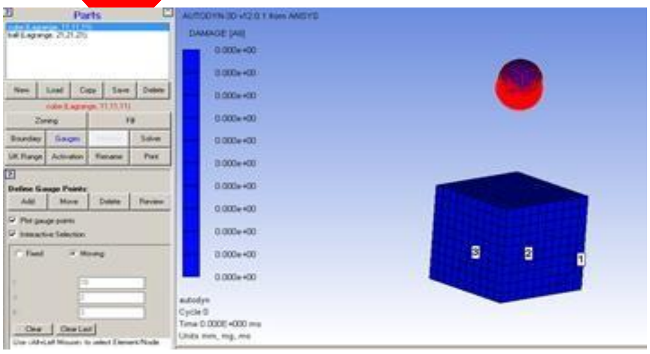

Fig.1. Cube specimen before impact load and the gauge points

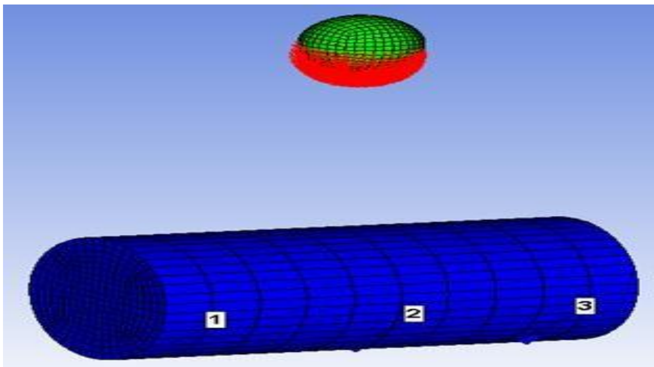

Fig.2. Cylinder specimen before impact load and the gauge points

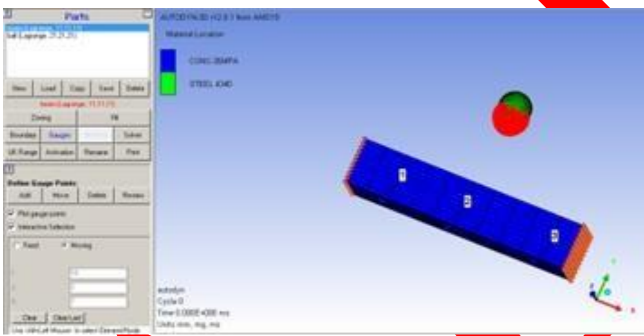

Fig.3. Beam elements before impact and the gauge points

The figures mentioned above are the specimens before exhibiting impact loading and the corresponding gauge points.

3.2 After Impact: Specimen and its Damage Effects

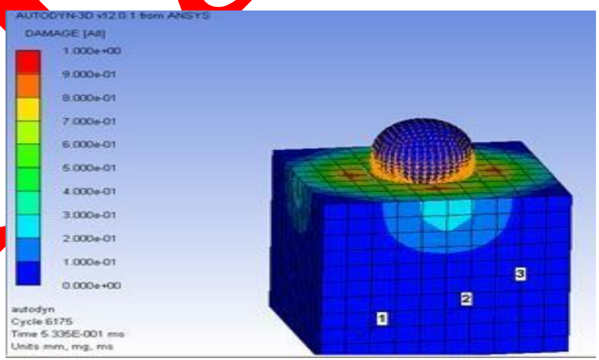

Fig. 4.Damage level of cube after impact

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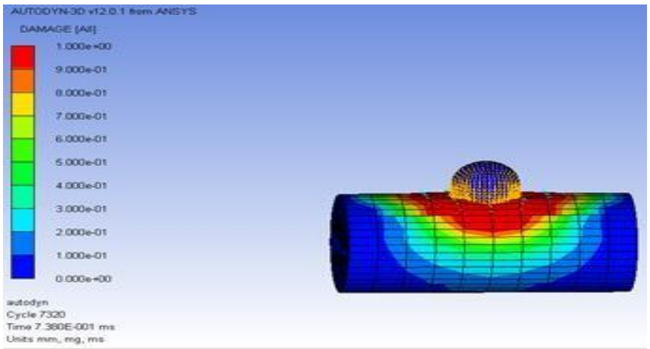

Fig.5.Damage level of cylinder after impact

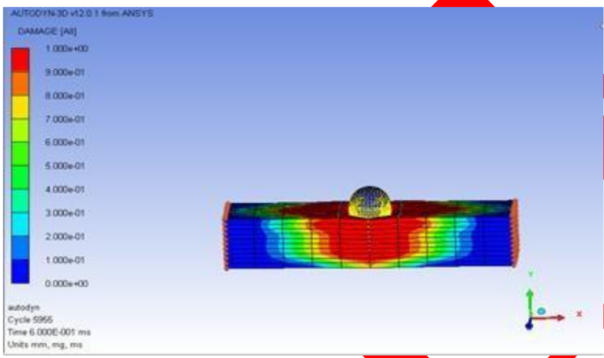

Fig.6. Damage level of beam after impact

The figures mentioned above are the specimens after exhibiting impact loading and the corresponding damage results.

The given results are based on the principle of LAGRANGE SOLVER

Calculation of energy absorption for cube

Shape of ball = sphere Velocity to
the ball = 300mm/ms Height of fall
= 150mm Radius of ball = 30mm
Volume of Sphere (v) = 4/3πr3

= 1.33 x 3.14 x 33
= 113.04 cm3
Mass of ball (m) = density of steel (β) x volume of sphere (v)
= 7.83 x 113.04
= 885.10 gms (0.885 kg)
Interaction gap size = 0.2121

Safety factor = 0.2
Cycle limit = 6175
Time limit = 0.6ms
Time increment = 0.05 ms

Calculation of energy absorption capacity for cylinder

Shape of ball = sphere Velocity
to the ball = 300mm/ms Height of
fall = 150mm Radius of ball
= 35mm Volume of Sphere (v) = 4/3πr3
= 1.33 x 3.14 x 3.53
= 179.50 cm3
Mass of ball (m) = density of steel (β) x volume of sphere (v)
= 7.830 x 179.50
= 1405.5 gms (1.40 kg)
Interaction gap = 0.2424
Safety factor = 0.2
Cycle limit = 7320
Time limit = 0.738ms Time
increment = 0.05 ms

Calculation of energy absorption capacity for beam

Shape of ball = sphere Velocity
to the ball = 300mm/ms Height of
fall = 150mm Radius of ball
= 35mm Volume of Sphere(v) = 4/3πr3
= 1.33 x 3.14 x 3.53
= 179.50 cm^3
Mass of ball (m) = density of steel (β) x volume of sphere (v)
= 7.830 x 179.50
= 1405.5 gms (1.40 kg)
Interaction gap = 0.2424
Safety factor = 0.2
Cycles = 5955
Time = 0.6 ms

3.4 RELATIVE GRAPHS: TIME Vs ENERGY ABSORBTION, VELOCITY

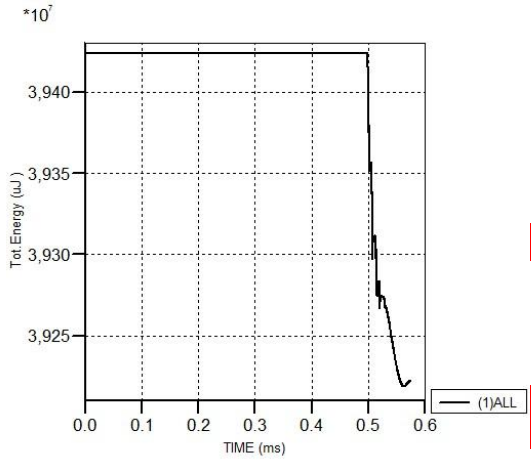

Fig.7. Relation between energy absorption capacity and time for cube specimen

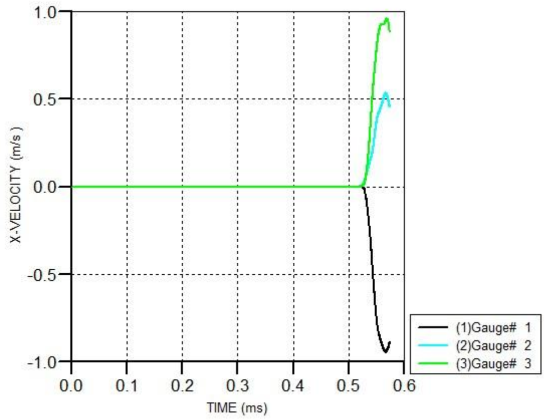

Fig.8. Relation between velocity and time

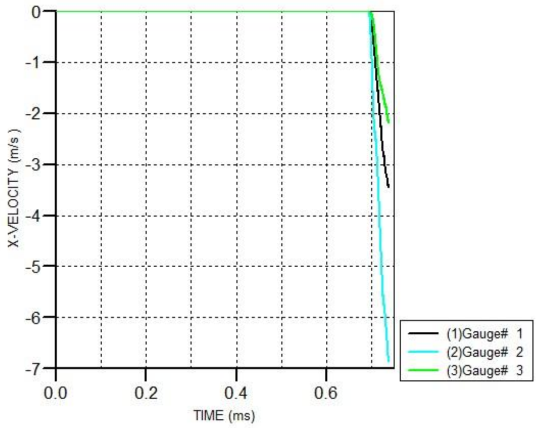

Fig.9. Relation between time and velocity of gauge points

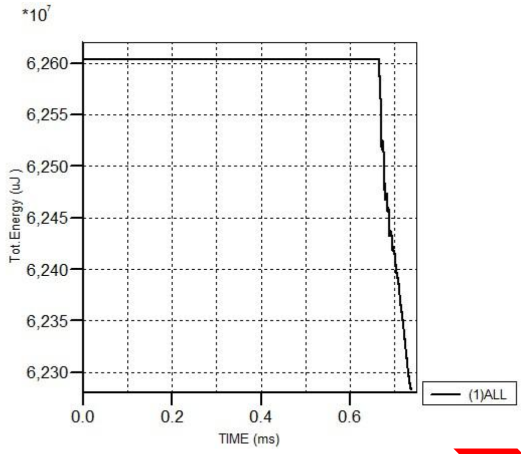

Fig.10. Relation between energy absorption capacity and time for cylinder specimen

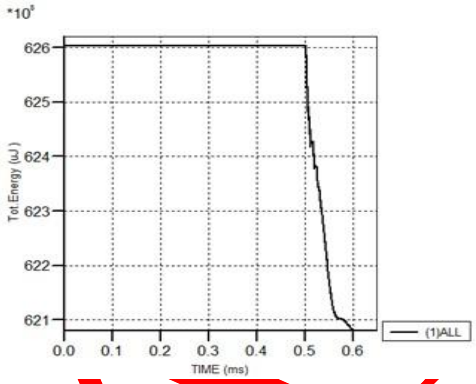

Fig.11.Relation between energy absorption capacity and time for beam specimen

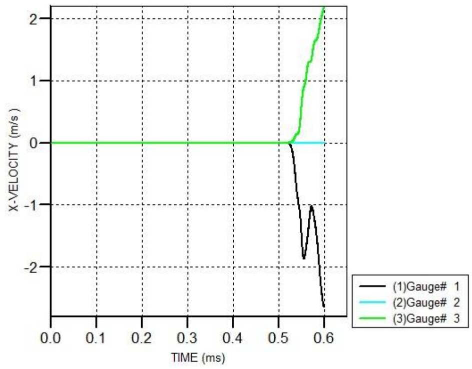

Fig.12. Relation between time and velocity of gauge points

4.0 RESULTS & DISCUSSION

A dynamic load of **885100mg, 1405500mg** was applied at a distance of **150mm** from the model elements and corresponding energy absorption capacity was calculated and damage levels were indicated. Impact load is being represented by time-total energy curve varying at **0,**

0.533, 0.6, and **0.738ms** respectively. Energy absorption capacity for gauge points was determined and tabulated in Table 3 corresponding to number of cycles.

Table 3 Energy Absorption capacity of the specimens

ELEMENTS	ENERGY ABSORBTION CAPACITY (µJ)	NO. OF CYCLES
Cube	3943×10^7	6175
Cylinder	6262×10^7	7320
Beam	626.1×10^8	5955

5.0 CONCLUSION

The Structural models such as cube, cylinder, beam and the steel ball were numerically simulated by using the Finite Element Analysis (FEA) software namely AUTODYN 12.0.1. The Low velocity impact load was applied on the numerical concrete models to obtain their impact resistance. The damage effects were monitored and the energy absorption capacity (toughness index) of cube, cylinder, and beam elements were determined and presented. The damage effects of the concrete models subjected to impact loading is found to be severe. So the Design Engineers are suggested to consider the design of dynamic loading for the structures which may be subjected to impact loads. The measured value is for the low velocity load and this in further can be replaced and processed with the high velocity impact load which can define even more unknown damage effects on these concrete structures.

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