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Blast Loading Effect on RCC Components by Simulation in Software

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Keyword
Blast Load,
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Reinforced Cement Concrete,
Standoff Distance,
Ambient Temperature,
Explosive Temperature,

Abstract
Blast loads action on structures are very critical due to increasing threats from accidental and industrial accidental explosions. This study investigates the behaviour of reinforced concrete structures subjected to blast loading using simulation in Ansys software. Finite element modelling is performed to assess deformation, stress distribution, and failure mechanisms. The results highlight the importance of structural design considerations for blast resistance of structures and accordingly measures. Blast loads are high intensity, short duration loads. This paper presents investigation of blast loading on RC structures using simulation. Procedure to apply load, preprocessing, processing and postprocessing, result, graph etc.
The primary objective of this study is to investigate the structural response under blast loading using explicit dynamic analysis in ANSYS Explicit Dynamics.

1. Introduction:

With the rise in industrial accidents and security threats, the need for blast-resistant structures has become essential. Blast loads differ significantly from conventional loads due to their high intensity and short duration. Structures subjected to such loads experience extreme pressure waves, which create
Very high temperatures than ambient temperature due to this catastrophic failure occurs.
This study focuses on understanding:

- Nature of blast waves
- Structural response under blast loading
- Methods to improve blast resistance
- Retrofitting of existing structures to resist blast loading
- Stand-off distance to provide barrier

ANSYS is a engineering simulation tool used to analyse how structures behave under loads like blast, wind, earthquake, etc.
ANSYS Workbench (Explicit Dynamics simulation used with RC component model with support conditions , under TNT blast load application, result in Ansys software give output in the form of deformation, equivalent Stress (von Mises), stress distribution like counter, and graphical presentations of results .

2. Methodology:

Explicit Dynamics (often used in ANSYS Explicit Dynamics) is a numerical analysis method used to simulate high-speed, highly nonlinear events where traditional static or implicit methods fail. Explicit dynamics is based on explicit time integration, where the state of a system at the next time step is calculated directly from the current state (no need to solve large simultaneous equations).
It is widely used in transient dynamic problems involving large deformations, material failure, contact and impact in the cases like

- Blast & Explosion Analysis

- Impact & Crash Analysis
- Metal Forming & Manufacturing
- Failure & Fracture Analysis

3. Literature Review:

- G. F. Kinney and K. J. Graham fundamental understanding of blast wave characteristics, including peak overpressure, impulse, and pressure-time variation.
- Tuan Ngo et al. (2007) conducted comprehensive studies on blast loading and its effects on structures, highlighting the importance of parameters such as charge weight, standoff distance, and confinement.

1. Advantages to use of explicit dynamics:
2. No convergence issues (unlike implicit methods)
3. Handles severe nonlinearities easily
4. Efficient for short-duration events
5. Accurate for high strain-rate problems.
6. Accurate capture of shock wave propagation

Numerical methodology:

Due to the highly transient nature of blast waves and associated nonlinearities such as large deformation, material failure, and complex contact interactions, the explicit time integration scheme is adopted.

The formulation is based on Newton's Second Law, where the dynamic equilibrium of the system is expressed in terms of nodal accelerations, velocities, and displacements.

Governing Equations

The motion of the structure is governed by:

$$M\ddot{u}+C\dot{u}+Ku=F(t)$$

Where:

M= Mass matrix
C= Damping matrix
K= Stiffness matrix
u= Displacement vector
F (t) = Time-dependent external force

Material Modelling

Materials are modeled considering strain-rate effects due to high-speed loading. For concrete and steel, appropriate constitutive models such as:

Elastic–plastic behaviour
Strain hardening
Failure criteria

Blast Load Modelling

Blast loading is applied using empirical relations based on explosive charge weight and stand-off distance. The pressure-time variation follows typical blast wave characteristics:

Rapid rise to peak overpressure
Exponential decay phase
The blast effect is modelled using:
TNT equivalent mass
Scaled distance concept

Contact and Boundary Conditions

Contact interactions between structural components are defined using:
Frictional or frictionless contact
Automatic contact detection

Boundary conditions are applied to represent realistic support conditions such as fixed or simply supported constraints.

Meshing and Time Step Control

A fine mesh is adopted in regions expected to experience high stress gradients. The time step is automatically controlled by the solver based on element size and wave propagation speed to ensure numerical stability.

Pressure Distribution on Structure

The pressure contour represents the propagation of the blast wave over time. A sharp peak pressure is observed initially, followed by gradual dissipation as the wave interacts with the structure.

Steps:

1. Pre-Processing

1. (Model Creation) Geometry: Modelling of structure or component
2. Assingn Material Properties to structure or component like
3. Concrete (M30): Elastic modulus, density
4. Steel (Fe500): Yield strength
5. Assign environment surrounding like air block, ambient temperature.
6. Meshing: Divide structure or component into small elements and smaller mesh
7. Apply TNT charge weight at some distance called standoff distance
8. Apply load point on the surface at which effect is to be determine.

2. Processing

1. Use of Explicit Dynamics in Ansys
2. Workbench
3. Boundary Conditions: Fix supports at base or support ends and gravity load
4. Blast load: TNT equivalent method
5. Assign time period of blast in milliseconds

3. Computation Stage

ANSYS solves dynamic equations of motion calculates:

Displacement
Velocity
Acceleration
Stress

4. Post-Processing (Results)

- Total Deformation: Shows how much structure bends
- Equivalent Stress (von Mises): Shows critical stress zones
- Pressure Distribution: Blast wave impact on structure
- Failure zones: Cracks, yielding, collapse regions
- Graphs generated.

1. Displacement vs Time,
2. Stress vs Time Variation
3. Pressure vs Time Curve
4. Energy vs Time
5. Deformation vs Standoff Distance

After postprocessing the deformation contour illustrates the maximum displacement experienced by the structure due to blast loading. The peak deformation occurs at the center of the exposed face, indicating maximum energy absorption in that region.

Equivalent Stress Distribution: (Von-Mises)

The stress contour shows the distribution of von-Mises stress across the structure. High stress concentration is observed near supports and blast-facing surfaces, indicating potential failure zones.

Total Deformation Contour

The deformation contour illustrates the maximum displacement experienced by the structure due to blast loading. The peak deformation occurs at the center of the exposed face, indicating maximum energy absorption in that region.

Pressure Wave Propagation

The pressure contour represents the propagation of the blast wave over time. A sharp peak pressure is observed initially, followed by gradual dissipation as the wave interacts with the structure.

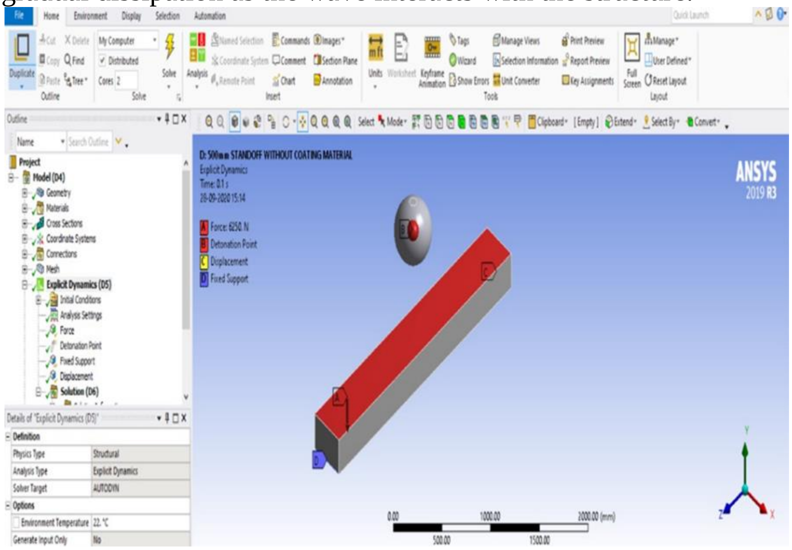

Fig no1. Shows preprocessing phase RCC beam component fixed at ends, TNT charge at stand-oof distance and highlighted surface is point of load application.

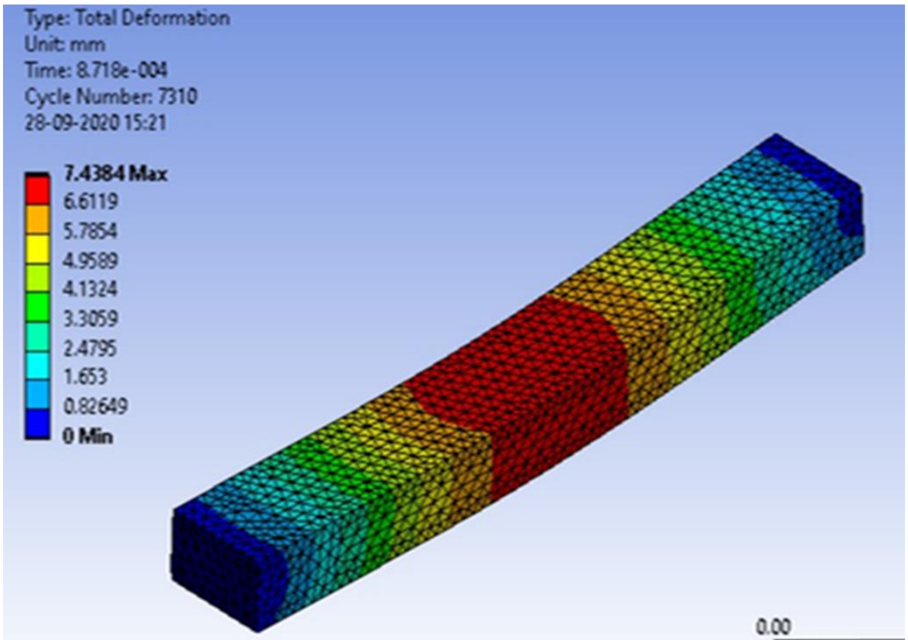

Fig No 2 shows post processing phase. Results are clearly observed in this figure for Maximum deformation in red contour induced at the center and zero at the support.

4. Conclusion:

The results clearly shows that blast loads produce highly dynamic responses characterized by sudden application of extreme pressure within a very short duration. The structural response is significantly influenced by the standoff distance and charge weight, which are related through the scaled distance parameter.

Blast-resistant design requires careful consideration of load characteristics, structural configuration, material behaviour, standoff distance of blast point, ductility of material, and incorporating energy-absorbing mechanisms, retrofitting techniques, reinforcement detailing etc.

The study demonstrates that explicit dynamic analysis in ANSYS Explicit Dynamics effectively captures blast-induced structural behavior. The results highlight the significance of standoff distance, material strength, and structural configuration in mitigating blast effects.

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