IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 6, June 2026
Impact Factor: 8.2

Effect of Blast Loading on Circular Elevated Storage Reservior Using Etab Software

Harshvardhan Pravin Thorat, Krushna Babasaheb Unde
Prajwal Gorakshanath Tajane, Rushikesh Bhausaheb Padekar, Dr. S. B. Kandekar
Department of Civil Engineering.
Amrutvahini College of Engineering, Sangamner

Abstract: *Elevated Service Reservoirs (ESRs) are important structures used for water storage and distribution. This study analyzes the effect of blast loading on a circular ESR using ETABS software. The structure was modeled and analyzed under dead load, live load, water load, and blast load conditions. Blast parameters were calculated using IS 4991:1968 and time-history analysis was performed to study the dynamic response of the structure. The results showed that blast loading increases displacement, stresses, and member forces in the ESR. The study helps in understanding the structural behavior of ESRs under explosion effects and improves the safety and stability of water storage structures*

Keywords: Blast Loading, ESR, ETABS, Time-History Analysis, Circular Water Tank, Dynamic Analysis

I. INTRODUCTION

Elevated Service Reservoirs (ESRs) are essential components of modern water supply systems as they provide continuous water distribution through gravity flow [1]. Circular reinforced concrete ESRs are widely used because of their structural efficiency, durability, and ability to resist hydrostatic pressure uniformly [2]. These structures are generally designed to withstand conventional loads such as dead load, live load, wind load, and earthquake load according to Indian Standard codes [3].

In recent years, the safety of critical infrastructure against accidental and man-made explosions has become an important concern in structural engineering [4]. Blast loading produces extremely high pressure within a very short duration, resulting in severe stresses, deformation, and possible structural failure [5]. Elevated water tanks are particularly vulnerable to blast effects because of their height, slender staging system, and dynamic behavior [6]. Failure of such structures may lead to interruption of water supply and serious risk to nearby areas [7].

To understand the structural performance of ESRs under blast conditions, advanced analysis tools such as ETABS are used for modeling and dynamic analysis [8]. Time-history analysis helps in evaluating the response of structures subjected to rapidly varying blast pressures [9]. Therefore, this study focuses on analyzing the effect of blast loading on a circular elevated storage reservoir using ETABS software and comparing the structural response with and without blast loading conditions [10].

II. PROBLEM STATEMENT

Elevated Service Reservoirs (ESRs) are important lifeline structures used for storing and supplying water to urban and rural areas. In conventional design practice, these structures are mainly designed for dead load, live load, wind load, and earthquake load, while the effect of blast loading is generally neglected. However, accidental explosions, industrial hazards, and intentional blast events can generate extremely high pressure waves within a very short duration, causing severe damage to structural components. Due to the elevated height and slender staging system of circular ESRs, they are highly sensitive to dynamic loads and may experience excessive displacement, cracking, stress concentration, or even structural failure under blast conditions. Failure of an ESR can interrupt water supply systems, damage nearby infrastructure, and create serious safety risks. Therefore, there is a need to study the structural behavior of circular

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elevated storage reservoirs under blast loading conditions using advanced analysis software like ETABS. This study aims to evaluate the effect of blast loading on the ESR structure and compare its performance with conventional loading conditions to improve structural safety and reliability.

III . OBJECTIVES

- To model a circular Elevated Service Reservoir (ESR) using ETABS software.
- To analyze the ESR under dead load, live load, and water load conditions.
- To calculate and apply blast loading parameters on the structure using relevant standards.
- To study and compare the structural response of the ESR with and without blast loading.
- To evaluate the safety, stability, and performance of the ESR under blast effects and suggest suitable improvements.

IV. WORKING OF SYSTEM

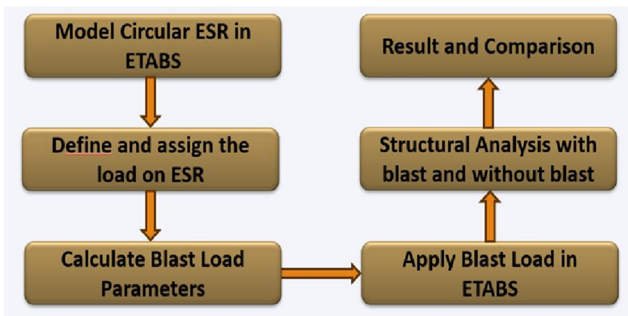

Fig 1: Methodology

1. **Model Circular ESR in ETABS**
   The circular Elevated Service Reservoir (ESR) is first modeled in ETABS software using suitable frame and shell elements. Structural components such as tank wall, slab, columns, bracing, and ring beams are created with proper dimensions and material properties according to Indian Standard codes.
2. **Define and Assign Loads on ESR**
   After modeling, different loads acting on the structure are defined and assigned. These include dead load, live load, and hydrostatic water load. The loads are applied to the appropriate structural elements to simulate actual service conditions.
3. **Calculate Blast Load Parameters**
   Blast load parameters such as scaled distance, peak overpressure, and positive phase duration are calculated using IS 4991:1968 and TM 5-1300 guidelines. These parameters are essential for determining the intensity and duration of blast pressure acting on the structure.
4. **Apply Blast Load in ETABS**
   The calculated blast pressure is applied to the ESR model in ETABS using time-history analysis. Blast loads are assigned on exposed shell elements and equivalent line loads are applied on frame elements like columns and bracings.
5. **Structural Analysis with and without Blast Load**
   The ESR structure is analyzed under two conditions: normal loading and blast loading. ETABS calculates important structural responses such as displacement, drift, stresses, base shear, and member forces for both cases.

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6. **Result and Comparison**
   Finally, the results obtained from both analyses are compared to evaluate the effect of blast loading on the ESR. The comparison helps in identifying critical structural behavior, increase in forces and displacement, and the need for blast-resistant design improvements.

V. SYSTEM DESIGN

1. System Overview:

The proposed system focuses on analyzing the effect of blast loading on a Circular Elevated Service Reservoir (ESR) using ETABS software. The ESR is modeled as a three-dimensional reinforced concrete structure consisting of tank walls, bottom slab, columns, bracing members, and ring beams. The system is designed to study the structural behavior of the reservoir under normal loading conditions as well as under blast loading conditions.Initially, the ESR model is developed in ETABS by defining the geometry, material properties, and structural components according to relevant Indian Standard codes. Conventional loads such as dead load, live load, and hydrostatic water load are applied to simulate actual service conditions.

1. ESR Modeling Module

This module is responsible for creating the three-dimensional model of the Circular Elevated Service Reservoir (ESR) in ETABS software. Structural components such as tank wall, bottom slab, columns, bracing members, and ring beams are modeled using shell and frame elements. Material properties and sectional dimensions are assigned according to Indian Standard codes.

2. Load Definition Module

In this module, all conventional loads acting on the ESR are defined and assigned. These loads include dead load, live load, and hydrostatic water load. The loading conditions are applied to the respective structural elements to simulate actual working conditions of the reservoir.

Component	Load Value
Self-weight of structure	Automatically calculated in ETABS
Tank wall + slab	6–10 kN/m²
Water load	9.81 kN/m³

3. Blast Load Calculation Module

This module is used to calculate blast load parameters based on IS 4991:1968 and TM 5-1300 guidelines. Parameters such as scaled distance, peak incident overpressure, impulse, and positive phase duration are determined using TNT equivalent charge weight and stand-off distance.

4. Blast Load Application Module

The calculated blast loads are applied to the ESR model in ETABS using time-history analysis. Blast pressure is assigned to shell elements such as tank walls and slabs, while equivalent line loads are applied to frame elements like columns and bracing members.

5. Structural Analysis Module

This module performs the analysis of the ESR under both conventional loading and blast loading conditions. ETABS calculates structural responses such as displacement, drift, stresses, axial force, shear force, bending moment, and base shear.

6. Result and Comparison Module

The final module compares the results obtained from analysis with and without blast loading. The comparison helps in evaluating the effect of blast pressure on structural behavior, material requirement, and overall stability of the ESR structure.

7.Structural Configuration of ESR

Parameter	Value
Type of Structure	Circular Elevated Storage

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	Reservoir
Tank Shape	Circular
Total Height (Staging + Tank)	24 m
Tank Diameter	12 m
Water Storage Capacity	500 kL
Number of Staging Levels	4
Staging Type	RCC Braced Frame
Location	Seismic Zone III (Assumed)

8. Model Creation in ETABS

A 3D structural model of Circular Elevated Storage Reservoir (ESR) is created in ETABS. Geometry is defined based on design dimensions (height, diameter, staging levels). Structural components such as columns, beams, bracings, and tank walls are modeled. Shell elements are used for tank walls and slab, frame elements for staging system.

9. Material and Section Definition

After model creation, appropriate material properties are assigned to the structure. Concrete of grade M30 and steel Fe500 are considered for design. The density, modulus of elasticity, and Poisson's ratio are defined as per standard design codes. Structural members such as columns, beams, bracings, tank walls, and slabs are assigned specific cross-sectional dimensions to ensure realistic structural representation in the software

10. Blast Load Modelling and Time History Analysis

The blast load is defined using a time-history function representing variation of pressure over a short duration of time. The pressure rapidly increases to a peak value and then gradually reduces to zero. This dynamic load is applied to the structure using nonlinear time history analysis in ETABS. The analysis captures the transient response of the ESR under sudden blast loading conditions.

VI. RESULTS

The structural analysis of the Circular Elevated Service Reservoir (ESR) was carried out in ETABS under both conventional loading and blast loading conditions. The results obtained from time-history analysis indicate that blast loading produces a significant increase in displacement, storey drift, internal forces, and material demand compared to the normal loading case. Under blast loading, the staging system experiences higher lateral deformation due to the sudden application of impulsive pressure. Increased shear forces, bending moments, and axial forces were observed mainly in columns, bracing members, and ring beams. To resist these additional dynamic forces, larger member sizes and higher reinforcement quantities were required. The comparative study clearly shows that blast loading has a major impact on the structural behavior and safety of the ESR, emphasizing the need for blast-resistant design considerations in critical infrastructure structures.

Important Results

1. **Maximum Story Displacement**

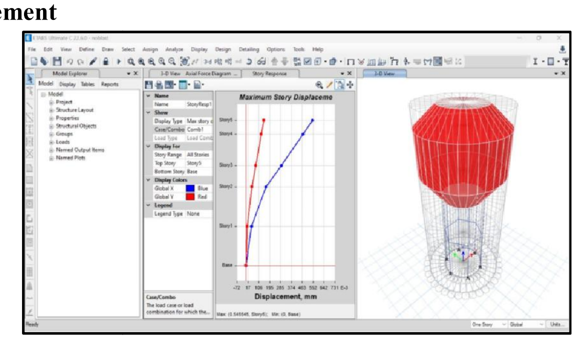


Fig.2 Maximum Story Displacement

- Without Blast Load = **0.546 mm**
- With Blast Load = **25.024 mm**
- Increase ≈ **4480%**

2. Maximum Story Drift

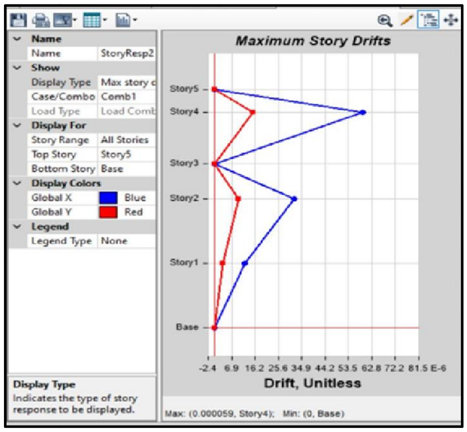


Fig.3.Maximun Story drift

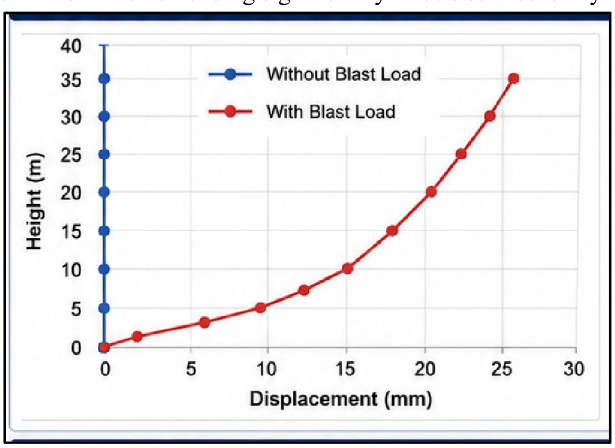
- Without Blast Load = **0.177 mm**
- With Blast Load = **10.746 mm**
- Increase ≈ **5970%**

3. Increase in Material Requirement

- Concrete Increase = **31.30%**
- Steel Increase = **50%**

Maximum Load Blast

The drastic increase in drift confirms that blast loading significantly affects serviceability and structural safety.



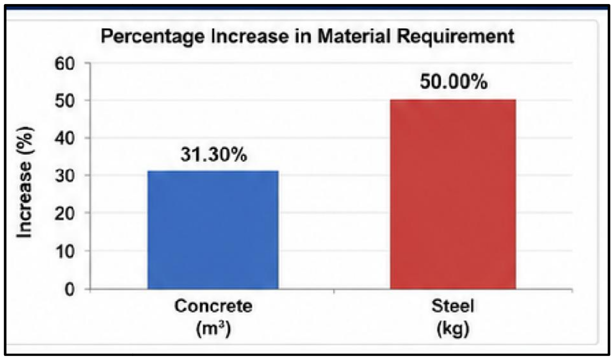
Graph 4: Maximum Load Blast

The Maximum Story Drift graph represents the relative deformation between consecutive stores under both loading conditions. Under blast loading, the ESR structure shows a very high increase in drift values, indicating severe inter-storey deformation. This can lead to cracking, joint failure, and possible instability in the staging system.

Condition	Maximum Story Drift (mm)	Increase
Without Blast Load	0.177 mm	—

With Blast Load	10.746 mm	+5970%

Percentage Increase in Material Requirement



The material demand graph shows the comparison of construction material requirements under normal and blast loading conditions. Due to higher internal forces induced by blast effects, the structure requires enhanced reinforcement and increased concrete volume to maintain safety and stability.The results indicate a significant rise in both steel and concrete consumption, which directly reflects the severity of blast loading on design optimization.

Material	Without Blast Load	With Blast Load	Increase
Concrete	100% (Base Case)	131.30%	+31.30%
Steel	100% (Base Case)	150.00%	+50.00%

VII. CONCLUSION

The present study evaluated the effect of blast loading on a circular elevated water storage reservoir using ETABS. Blast loads were calculated as per IS 4991:1968 and TM 5-1300 and applied through time-history analysis. Results indicate a steel quantity increase of approximately 50% and a concrete volume increase of about 32% compared to the conventional design. This confirms that blast-resistant design significantly enhances structural safety, stiffness, and ductility in compliance with IS 456:2000.

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