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# Geometric Optimization and Reinforcement Strategies for Blast-Resistant Concrete Walls: Insights for Protective Infrastructure Design

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*Abstract*
**The growing frequency of blast-related incidents has highlighted the vulnerability of conventional infrastructure in terrorism-prone regions. This paper builds on finite element simulations to propose design strategies for blast-resistant walls. Three wall geometries—flat, L-shaped, and U-shaped—were analyzed under 100 kg TNT blasts at a 1 m stand-off distance, with and without reinforcement. Results indicated that U-shaped reinforced concrete (RC) walls achieved superior blast resistance, sustaining minimal stress (~0.3 MPa), strain (~3 mm/mm), and deformation (<10 mm), with negligible structural damage. By contrast, plain flat walls failed catastrophically. These findings were synthesized into design recommendations, emphasizing the combined role of reinforcement and geometry in mitigating blast effects. The study provides engineers and policymakers with practical guidelines for designing protective structures in high-risk environments.**

***Keywords*: Blast resistance, Reinforced concrete, Protective structures, Geometric optimization, Infrastructure resilience,**

ANSYS AUTODYN

## 1. INTRODUCTION

Blast-induced structural failures remain a significant challenge for civil and military infrastructure. Conventional hollow block and plain concrete walls, commonly found in schools, transport hubs, and government facilities, are incapable of resisting high-intensity dynamic pressures [1]. Their collapse under blast loads has led to widespread casualties and loss of critical assets.

While reinforced concrete (RC) has long been recognized as more ductile and energy-absorbing, recent research indicates that structural geometry plays an equally critical role in blast resilience [2–4]. However, design codes in many regions provide limited guidance on blast-resistant systems, especially for non-military buildings [5].

This paper aims to bridge the gap between numerical insights and practical design recommendations. Using data from finite element analyses, it identifies optimal wall geometries, highlights reinforcement strategies, and discusses applications for protective infrastructure.

## 2. RESEARCH METHODOLOGY

The study employed finite element analysis in ANSYS AUTODYN to simulate the blast response of flat, L-shaped, and U-shaped walls, each in plain and reinforced configurations. A 100 kg TNT charge was applied at a 1 m stand-off distance. Stress, strain, deformation, and damage indices were extracted. Statistical validation was carried out using one-way ANOVA.

Results from this analysis provided the basis for developing practical design recommendations for protective wall systems.

## 3. RESULTS OVERVIEW

- Stress Distribution: U-shaped RC walls sustained the lowest stress (~0.3 MPa), while flat plain walls peaked at ~9.2 MPa.
- Strain Response: Plain flat walls reached strain levels >13 mm/mm; U-shaped RC walls maintained ~3 mm/mm.
- Deformation: Plain flat walls deformed by ~385 mm; U-shaped RC walls showed <10 mm displacement.
- Damage: Plain walls suffered catastrophic damage, while U-shaped RC walls remained virtually intact.

These results confirm that reinforcement alone is insufficient without geometric optimization.

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## 4. DESIGN RECOMMENDATIONS

### 4.1 Wall Geometry

- Flat walls should be avoided in high-risk environments.
- L-shaped walls provide moderate resistance but still experience significant damage.
- U-shaped RC walls offer the best resistance, combining confinement and stress redistribution to minimize deformation and damage.

### 4.2 Reinforcement Strategy

- Reinforcement significantly delays failure progression.
- In flat walls, reinforcement reduces peak stress but does not prevent collapse.
- In U-shaped walls, reinforcement synergistically enhances confinement, producing negligible damage.

### 4.3 Material Considerations

- High-strength concrete with ductile reinforcement (steel or hybrid composites) should be preferred.
- Future applications may incorporate advanced materials like Fiber-Reinforced Polymers (FRP) for added resilience.

### 4.4 Structural Integration

- Protective walls should be incorporated into the overall building layout rather than added as isolated elements.
- Symmetry and compact structural layouts reduce stress concentrations and promote redistribution during blasts.

## 5. PRACTICAL APPLICATIONS

1. Public Infrastructure: Schools, hospitals, and transport hubs in terrorism-prone regions can incorporate U-shaped RC walls at perimeter boundaries for enhanced safety.
2. Military and Security Facilities: Blast-resistant walls should be standard for guard posts, bunkers, and entry points.
3. Policy and Codes: Findings support the inclusion of blast-resistance provisions in civil engineering codes, especially in regions with recurrent insurgent activity.
4. Retrofitting Existing Structures: Flat RC walls can be retrofitted with U-shaped modules or reinforced overlays to improve performance.

## 6. CONCLUSIONS

This study demonstrates that the combination of reinforcement and geometric optimization is critical for designing blast-resistant walls:

- Plain flat walls are structurally inadequate under blast loads.
- Reinforced flat walls offer limited improvement.
- U-shaped reinforced concrete walls achieve optimal blast resistance with negligible damage.

Recommendation: Engineers and policymakers should adopt U-shaped RC walls as a baseline for protective infrastructure design in high-risk regions.

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