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A numerical study to evaluate the effect of blast load on unreinforced brick masonry walls

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Abstract
In recent times, the frequency of industrial accidents involving explosions has increased globally. Additionally, there has been a rise in terrorist activities utilizing explosive devices. To enhance the safety of buildings and structures, it is imperative to improve their resistance to explosive forces and to accurately predict the potential damage caused by explosions of varying intensities. A key objective in designing explosion-resistant structures is to determine the dynamic response of these structures to blast wave impacts. This requires assessing the transient pressure loads on the walls of civil engineering structures. Simulating explosions is a complex process, as it involves the propagation of shock waves through the air and their subsequent interaction with a structure. Traditional engineering techniques can estimate the impact of explosive shocks on isolated buildings but fail to consider the complexity of building designs, the presence of nearby structures, and the surrounding environment. However, advanced computer-aided engineering (CAE) software, combined with modern methods of three-dimensional modeling, allows for precise simulation and analysis of explosion effects in urban areas, a capability that was previously unattainable.
This study presents simulation of unreinforced brick masonry wall against surface blast in ABAQUS. The simulation results provided detailed analyses of complex wave structures, along with comprehensive descriptions and explanations of the flow characteristics and pressure history on masonry walls.
Keyword: *ABAQUS, Numerical Modelling, Brick Masonry, Blast Load, Conwep*

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I. Introduction

Protecting civil structures from the threat of terrorist explosions or industrial catastrophes involving explosions is a critical challenge in modern engineering. To enhance the safety of buildings, it is essential to increase their capacity to withstand explosive forces. The first step in this process is to predict the explosion's power and estimate the parameters of the blast impact on the structures being studied. Based on these data, the potential damage to buildings from such impacts can be assessed [1].

The ConWep model (Conventional Weapons Effects Program) is a widely used engineering tool developed by the U.S. Army Corps of Engineers for analyzing the effects of conventional weapons, including blast loading, on structures. The ConWep model, developed by the U.S. Army Corps of Engineers, is a pivotal tool for analyzing the effects of blast loading from conventional weapons on structures. It provides insights into the dynamic pressures and impulses generated by explosive blasts, helping engineers simulate and predict the response of masonry walls to such extreme events [2].

Study by [3] delve into the mechanics of blast wave propagation and the resulting dynamic pressures on masonry structures. These investigations highlight the importance of considering factors such as wall thickness, height, material type, and reinforcement techniques in enhancing blast resistance. This introduction sets the stage for exploring effective strategies to mitigate the effects of blast loads on masonry walls, ensuring structures remain safe and resilient in unpredictable environments.

According to [4] Applying FRP composites externally to brick masonry walls can significantly enhance their blast resistance. FRP wraps or laminates provide additional confinement to the masonry, increasing its lateral strength and ductility. Studies have demonstrated that FRP retrofitting can effectively mitigate blast-induced damage by improving the structural integrity and limiting crack propagation in masonry wall.

he use of polypropylene oligomeric silsesquioxane (POSS) as a protective agent on brick masonry walls against blast loads is an emerging area of research. POSS is a nanocomposite material known for its unique properties, including high thermal stability, mechanical strength, and resistance to environmental degradation. POSS coatings can enhance the wall's ability to absorb and dissipate energy from blast waves, reducing the transmitted pressures to the masonry substrate [5].

Material Model

The Concrete Damage Plasticity (CDP) [6,7,8,9,10] model is a widely used constitutive model in structural engineering and finite element analysis (FEA) to simulate the nonlinear behavior of concrete under various loading conditions, including blast loads. The CDP model combines concepts from plasticity theory and damage mechanics to simulate the behavior of concrete, which exhibits both plastic deformation (irreversible deformation) and damage accumulation (micro-cracking).

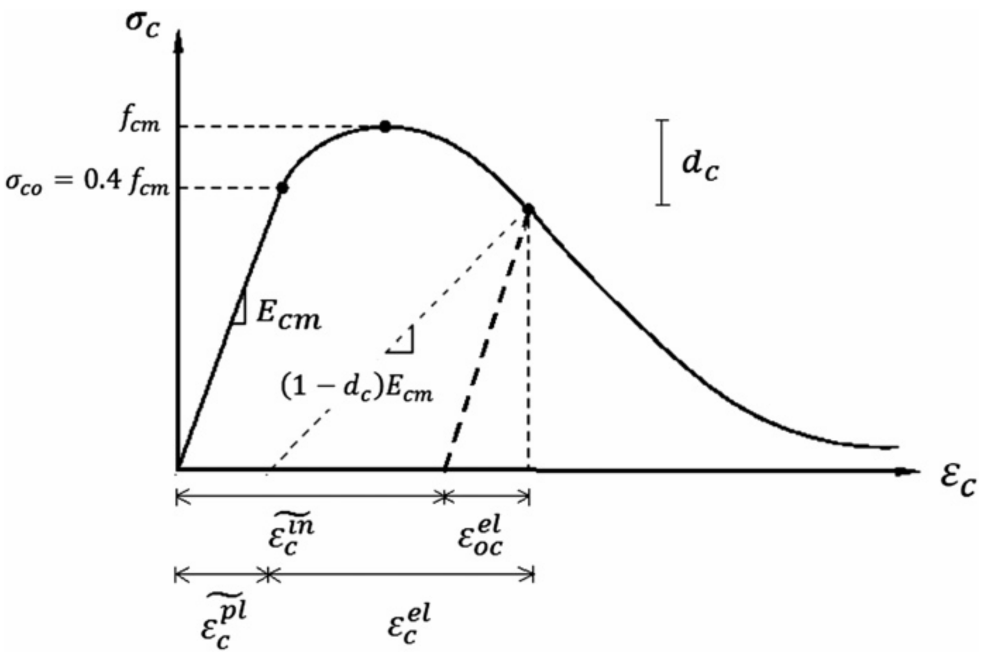


Fig.1. Concrete damage plasticity model

(MPa) Eq.(1)

(MPa) Eq.(2)

= Nominal tensile stress, = Nominal compressive stress, = Compressive strain

II. Methodology

The plane view of the Walls experimentally tested by [1] are illustrated in Figure-2. The encircled model is simulated against 4.34kg of TNT in ABAQUS using macro-scaled modeling.

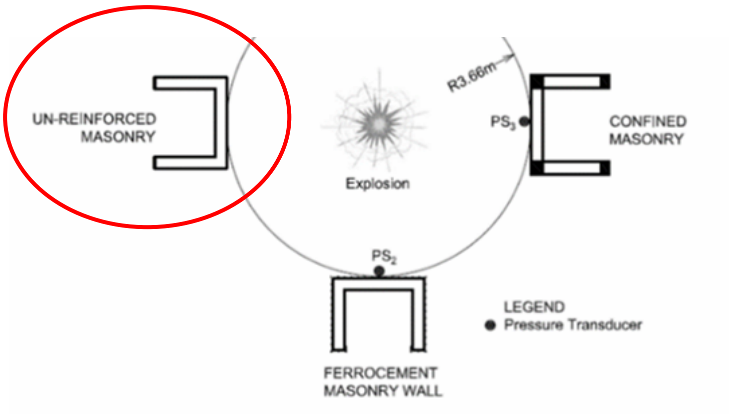


Fig.2. Experimental Setup details [1]

A TNT charge at elevation of 1m from ground surface was detonated to examine the performance of unreinforced brick masonry wall. The pressure transducer (PS-3) was installed on the face of wall at same elevation as charge as shown in figure-3.

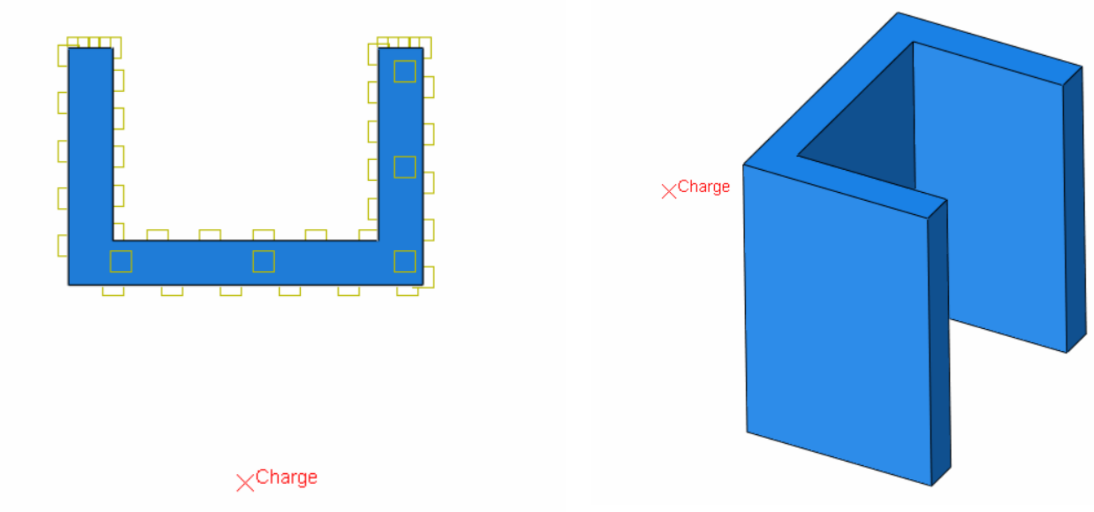


Fig.3. Numerical (FEA) Model

This setup allows for the investigation of complex shock-wave interactions and the resulting pressure distributions in a simulated urban environment, providing insights into the dynamic responses of brick masonry wall under blast loads.

III. Results and Discussion

The wall was tested for same TNT weight of 4.34kg at different standoff distances of 1m and 1.5m. in the first event at 1m standoff distance the numerically simulated model for scaled distance of 0. 61m/kg$^{1/3}$ the upper half part of the wall was damaged with some degradation at base as well as joints at peak pressure of 5.45MPa.

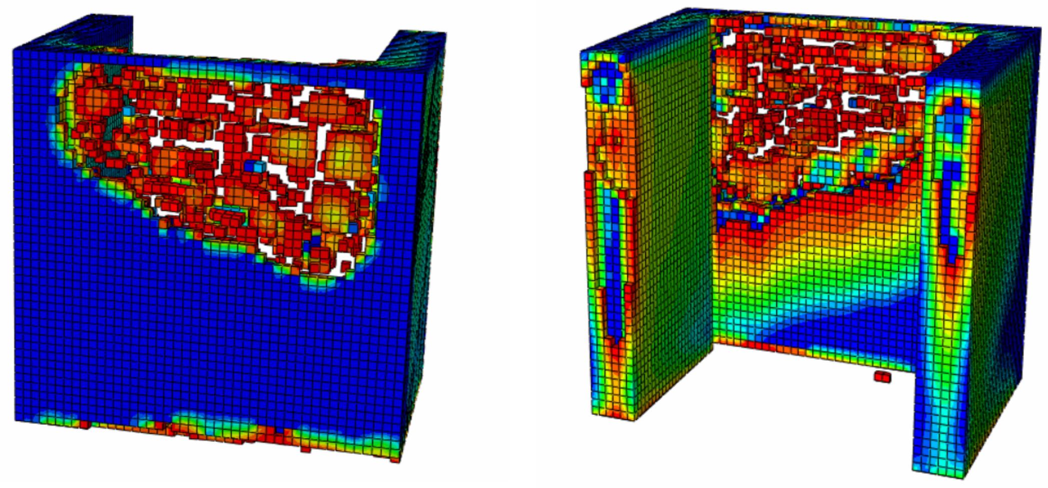
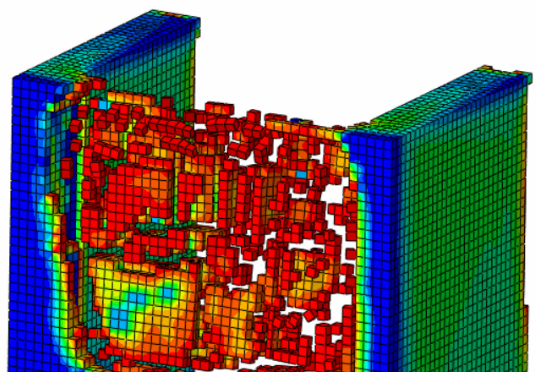


Fig.4. Tensile Damage (scaled distance 0.61m/kg$^{1/3}$)

In the second event, for same TNT weight at standoff distance of 1.5m and scaled distance of 0.910m/kg$^{1/3}$ the entire wall got damaged at lower peak pressure of 1.2MPa showing that larger portion of shock wave was taken by the wall as compared to first event.



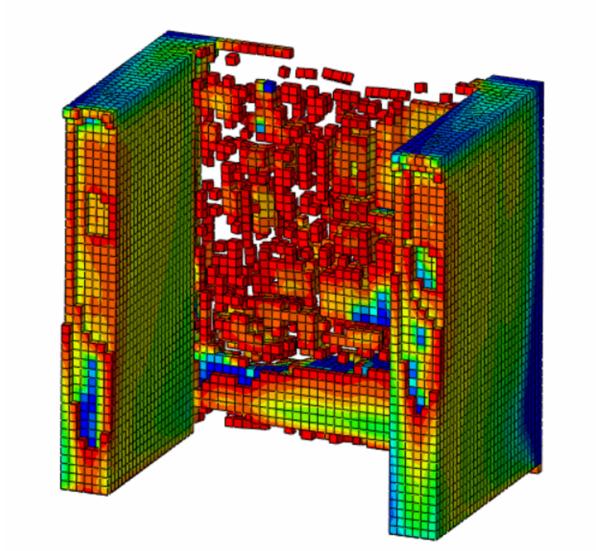


Fig.5. Tensile Damage (scaled distance 0.92m/kg$^{1/3}$)

The pressure time histories for both events are shown in figure-6 below.

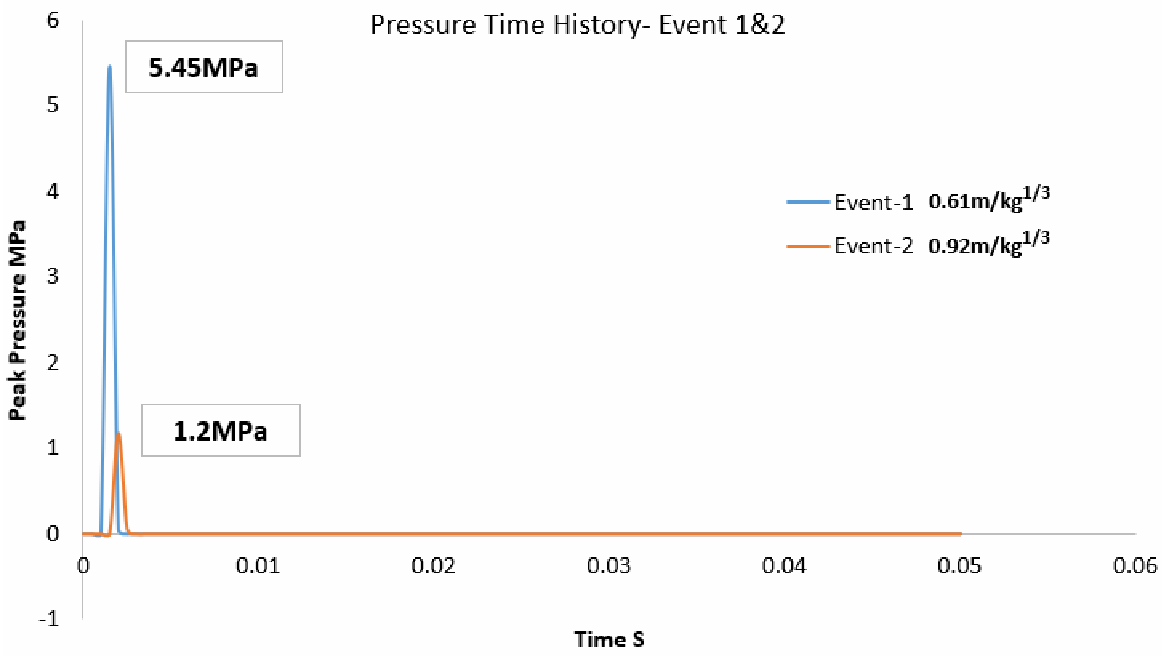


Fig.6. pressure time histories

IV. Conclusion

A macro level finite element model was analyzed for assessing the performance of an unreinforced brick masonry wall against blast load using CONWEP model in ABAQUS. The damage was examined to conclude: The wall was fully damaged at lower peak pressure of 1.2MPa in event-2 which is only 22 percent of the peak pressure 5.45MPa resulted in event-1 as more area of wall got exposed to the explosion.

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