ALE Mesh Sensitivity Simulations for Blast Perimeter Walls in Protective Structural Engineering

Sami A. Kilic[1]

[1]*Department of Civil Engineering, Bogazici University, Bebek 34342, Istanbul, Turkey*
e-mail: skilic@boun.edu.tr

Abstract

Perimeter threats for buildings can be reduced by placing blast walls around the protected structure. This study investigates the level of protection provided by blast walls to various amounts of explosive threats placed behind them. Simulations are conducted using the commercial finite element code LS-Dyna. Fluid-structure interaction effects are taken into account by the Arbitrary Eulerian Lagrangian (ALE) approach. The effect of different ALE mesh topology on the results is investigated.

Keywords: Arbitrary Lagrangian Eulerian simulation, blast protection, blast walls, reinforced concrete walls, fluid-structure interaction, nonlinear response of reinforced concrete walls

1. Introduction

The purpose of this study is to investigate the protection provided by perimeter walls to reduce blast damage effects on building structures subjected to external threats. A parametric investigation is provided with numerical simulations that involve varying wall height, stand-off distance, and distance between the wall and the target structure.

2. Numerical Studies

Figures 1 and 2 show the parameters used in the numerical study. The height of the explosive above ground (h_e) and stand-off distance (D_1) are kept constant. The blast wall is a reinforced concrete structural element with grid type of reinforcement placed in two layers. The investigated parameters are wall height (h_w) and distance to the protected structure (D_2). The structure is assumed to be rigid with plan dimensions of 5m by 5m, and height of 15m as shown in Figure 2 [1].

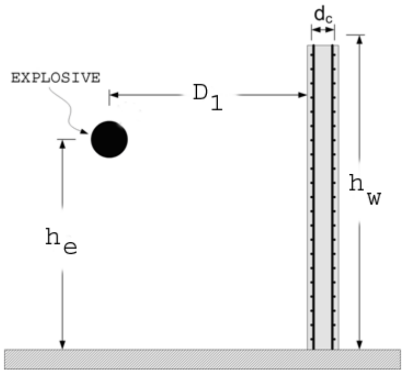

Figure 1: Reinforced concrete blast wall height h_w, height of burst h_e, stand-off distance D_1, wall effective depth d_c and height h_w.

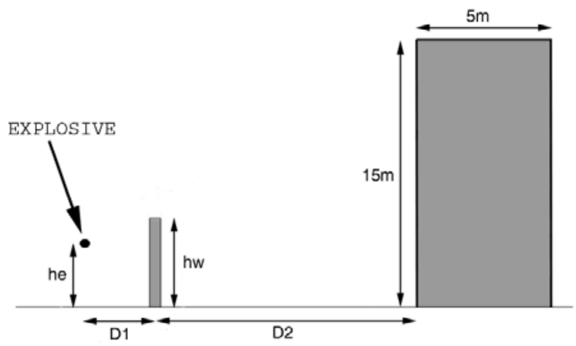

Figure 2: Parameters used in the blast wall numerical study; wall-to-building distance D_2, wall height h_w, and the explosive mass are varied.

The progression of the blast wave engulfing the blast wall and the protected structure is modelled by the ALE method in the LS-Dyna code [2]. Navier-Stokes fluid dynamics equations are solved in a volumetric mesh around the structure. The structure is assumed as a rigid boundary and the emphasis is placed on the fluid flow characteristics of the blast wave. Overpressures on various pressure measurement stations on the structure are plotted in the time domain in order to illustrate the transient effects.

Figures 3 and 4 show the various instances of the blast wave interacting with the target structure as time evolves. Figure 3 shows the isosurfaces of blast pressure in the 10 kPa-100 kPa range and in the 100 kPa-1 MPa range on the left and right, respectively.

ALE simulations employ volumetric meshes that result in significant computational cost for large mesh sizes. Fine mesh resolutions are necessary for the accuracy of the Navier-Stokes equations. In order to reduce the long simulation times, the numerical analyses are run on a 32-processor computing cluster with 4 nodes that are inter-connected via an Infiniband switch for fast communications.

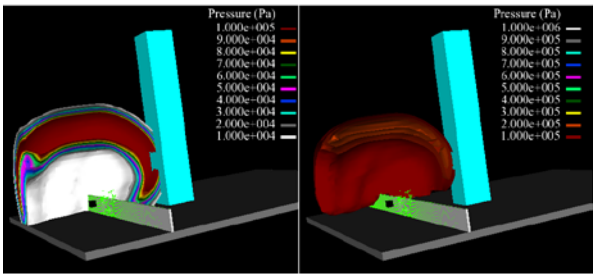

Figure 3: Blast wave pressure progression around the target structure and the perimeter wall

Figure 4 shows the volume rendering of the blast wave progression around the wall and the protected building structure [3]. A specific ALE element is chosen for the pressure output. The topology of ALE elements is a hexahedron with single integration point at its centroid. Integration of the pressure-time response yields the impulse-time curve for the centroid of the element. The pressure-time curve and the impulse time-curve are also plotted in Figure 4.

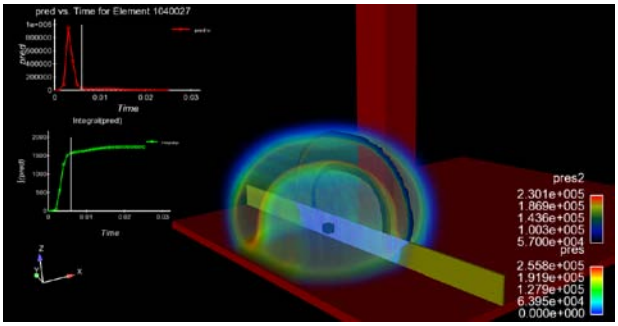

Figure 4: Visualization of the blast wave pressure distribution and the evolution of the impulse generated at a specific point in the mesh.

The second part of the study investigates the effect of different mesh configurations on the Arbitrary Lagrangian Eulerian (ALE) simulations. Results from box shaped Cartesian meshes are presented. The ideal mesh lines are perpendicular to the fluid flow. This condition requires hemi-spherical mesh geometries. Results of the Cartesian meshes are compared with the hemispherical meshes.

3. Conclusions

The effectiveness of blast walls is measurable as long as they withstand the intensity of the explosion while holding their integrity. The maximum bomb threat that can be resisted for a given blast wall structure is presented in terms of numerical simulations. Recommendations are made for the optimum selection of the blast wall parameters such as height, effective depth, and rebar reinforcement. The sensitivity of the ALE results for different mesh topologies is discussed.

4. Acknowledgements

The author is grateful to the support provided by the Turkish Research Council Engineering Division (TUBITAK - MAG) through contract no. 107M002.

References

[1] Kilic, S.A. and Smith, P.D. Behaviour of deformable blast walls for protective structural design, *COST Action C-26: Urban Habitat Constructions under Catastrophic Events, Proceedings of the Final Conference in Naples, 16-18 September 2010*, Mazzolani, F.M. et. al. Ed., Balkema Publishing Ltd., London, 2010.

[2] Hallquist, J.O. *LS-Dyna Theory Manual*, Livermore Software Technology Corporation, Livermore, California, U.S.A., 2006.

[3] Kilic, S.A. and Altay, G.A., Protection of critical structures from blast effects, *TUBITAK Research Project Final Report*, Contract no. 107M002, Istanbul, Turkey, 2010.