Numerical Analysis of the Dynamic Response of Masonry Structures Subjected to Impact Loading

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ABSTRACT

Due to various accidental or intentional events concerning some of the most important structures in the world, explosive loads have brought considerable attention in the recent years. Today, structural engineers need to comply with the design and construction of public buildings providing life safety in the face of explosions and heavy impact loadings. This paper represents the work of an investigative project and contains a general overview of numerical analysis and dynamic response of masonry structures subjected to impact loading. The aim of the report is to introduce the reader to the Finite Element Method which is critical when analysing dynamic response to masonry structures. In this paper the reader will be introduced to Abaqus software (developed by Simula), the paper will also explain and discuss particular model cases subjected to various impact loadings. With these models the paper aims to generate a basic understanding of how the FEM works, and hopes to enable a clearer understanding of the failure of masonry structures showing the clear results of stress, strain and deformation transferred throughout the walls.

Keywords: Masonry; Numerical analysis; Abaqus; dynamic response; impact loading; FEM

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INTRODUCTION

Due to various accidental or intentional events concerning some of the most important structures in the world, explosive loads have gained considerable attention in recent years. Today, structural engineers need to comply with the design and construction of public buildings providing life safety in the face of explosions and heavy impact loadings [1]. Man-made hazards such as terrorist attacks are not the only credible extreme events that can cause staggering life and economic loss. Natural hazards including earthquakes, floods, tornadoes, fires and hurricanes have caused huge losses in the past [2].

With regard to structures subjected to impact loading, the main issue which has recently become the focus of renewed research interest is the design and analysis of masonry structures. What is likely to affect the outcome or success of structural rigidity is the type of impact the building has to restrain when subjected to various impact loadings. This will be dictated by the type of impact which the structure is subjected to, and the type of masonry used when analysing the dynamic response with the use of numerical analysis.

NUMERICAL ANALYSIS

Finite element analysis/method (FEM) is a widely used method to assess the behaviour of a variety of structural systems. FEM views the solution region built up of many small, interconnected subregions or elements. The essence of FEA is to divide the body into finite elements, often just called elements. It is designed to contain the structural properties and the material which specifies how the structure will react under specific loading conditions [3]. Abaqus/CAE is a suite of powerful engineering simulation programs, based on the finite element method that can solve problems ranging from relatively simple linear analyses to the most challenging nonlinear simulations.

MODELLING OF THE WALL

In this study, Abaqus/CAE has been used to analyse the dynamic reaction of the wall under the impact loadings. Thus the report shall successfully show the reaction to how a masonry wall will resist impact, or blast loads and bypasses the need to perform a physical experiment which is too costly and exceeds the factors of safety.

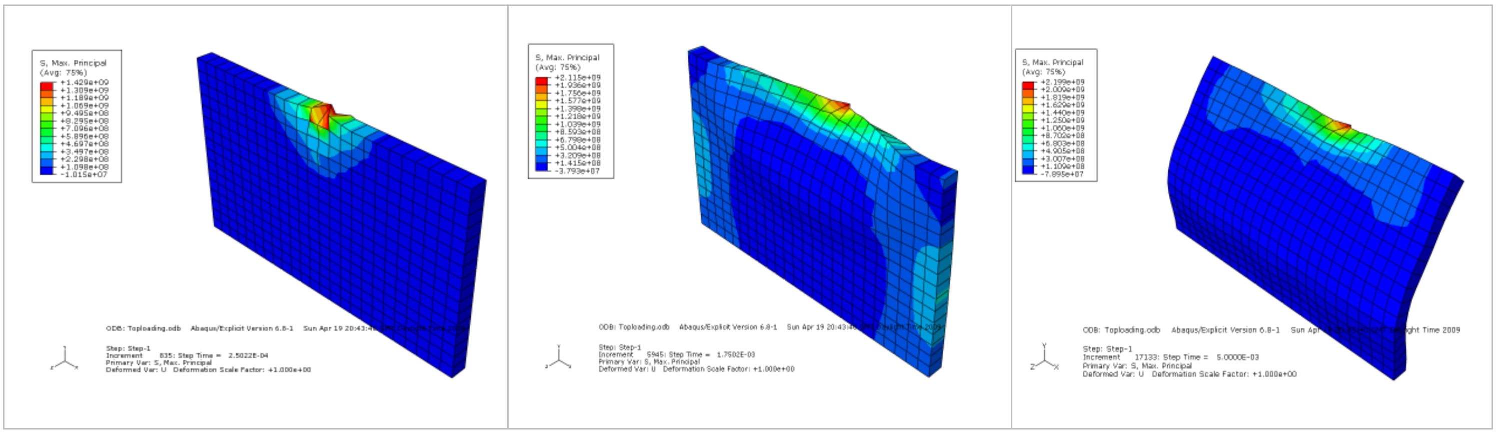
The masonry wall is made out of brick masonry with the same specification as that in the journal 'Failure Mechanisms of Polymer-Reinforced Concrete Masonry Walls Subjected to Blast' with a wall dimension of 3.7m x 2.3m x 0.2m (L.H.D.) [4]. The Density used will be set as 1800 kg/m^3, also specified from the journal above and is a value used in normal cube test data. The Young's modulus and Poisson's ratio shall be taken as 2.68x10 and 0.2. An impact loading of 50 kN shall be pressurised on the wall within 0.005 seconds [5].

RESULTS

The results below demonstrate the analysis of the model in which figures for the distribution of the maximum principal stresses and the stress across the ZZ direction are provided summarising 20 steps. Results and comparisons are listed in Table 1 (below).

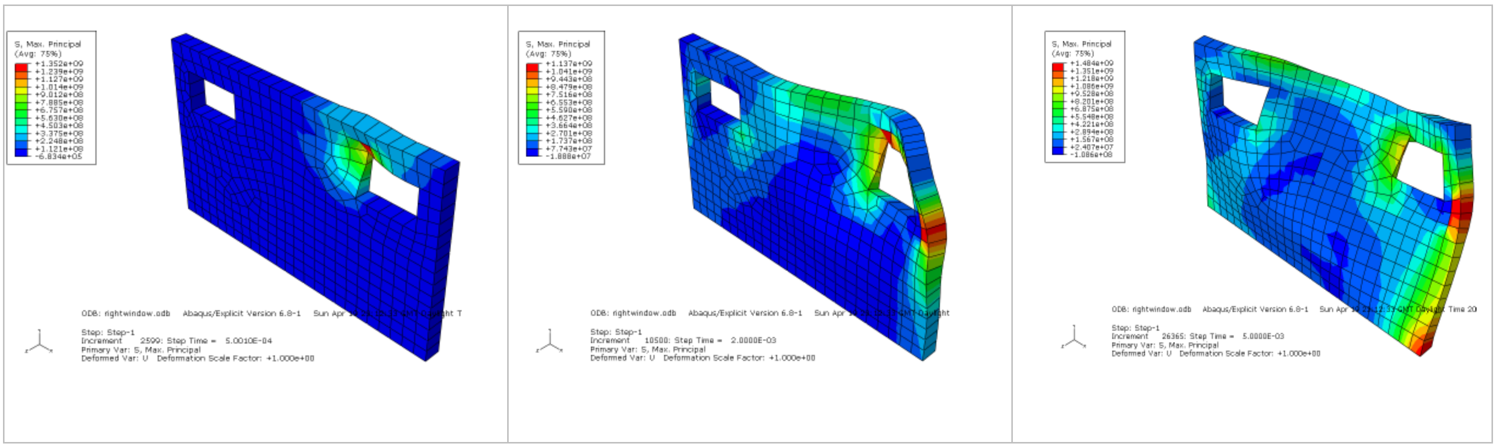
Load case for the Top of the wall

Stress max, Principle (S. Max, Principle)



Edge of the opening Load case

Stress max, Principle (S. Max, Principle)



	1st Load case	Openings - right opening
Max Principle Stress	Stress waves expand horizontally at first eventually transferring to the corners and finally reacting at the fixed boundary corners.	The top left hand side of the right opening of the wall transfers the impact to the right of the wall and the bottom right corner of the boundary. The impact is circular at first when hit, then tends to spread around the openings affecting the right side of the wall.

Table 1. Results and comparison

CONCLUSION

The dynamic loading applied to the wall is in the ZZ direction, notably acting perpendicular towards the wall at the top and the right opening of the wall. The structure is a free standing wall therefore acting like a cantilever which is exposed to flexure and extreme lateral forces. All diagrams and results have been provided for the stress profile. With the bottom of the wall being fixed, the stress from the top loading is considered to be the most vulnerable of areas transferring waves and energy to the corners of the boundary condition. The top right opening impact spreads the energy and waves diagonally throughout the wall deforming both openings. When hit first the impact is circular and tends to spread around the openings affecting the right side of the wall; however the main areas of concern are the bottom right hand side of the wall where the boundary is fixed. It is being pulled due to extreme stress and displacement of the wall.

A small amount of tensile resistance should be provided to avoid numerical instability problems; perhaps the remoulding of masonry bricks may provide a more reasonable sturdy structure which could be more blast efficient. Masonry behaves in an elastic brittle fashion with very low capacity to tolerate strain during heavy impacts. And thus ideas to renovate the material should definitely be considered as not only has the material been placed ‘out of date’, but the fact that there are no solutions to blast effects and terrorism attacks especially in third world countries where all houses which are made out of masonry contain load-bearing walls which are inevitably prone to failure, must be considered.

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