Imperial College London

SIMPLIFIED SINGLE DEGREE OF FREEDOM AND FINITE ELEMENT DYNAMIC ANALYSIS OF HIGH STRENGTH STEEL PLATES SUBJECTED TO BLAST LOADING

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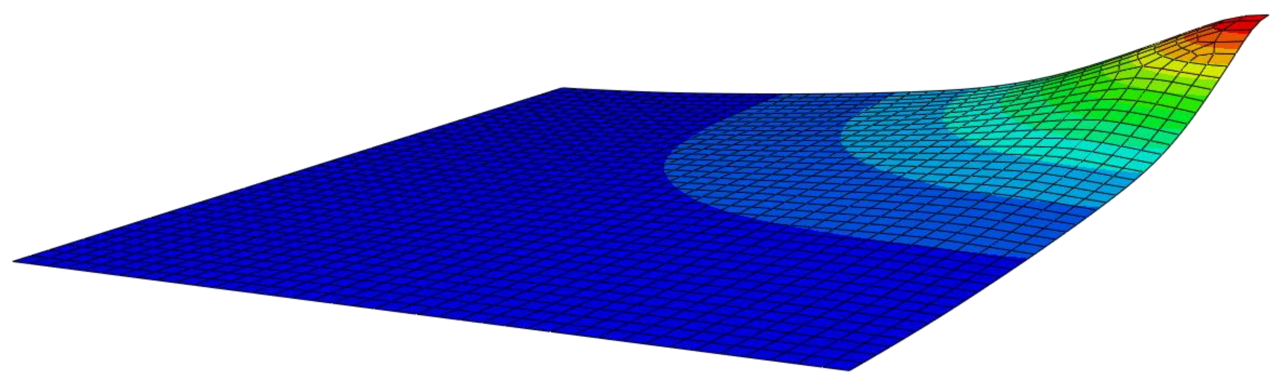
1. INTRODUCTION

Blast loading can have extremely damaging effects on civil engineering structures and vehicles, possibly causing complete destruction and loss of life. It is therefore vital to provide adequate protection by limiting the deformations and damage caused by the explosive forces. High strength steels are widely used as protective elements due to their low weight and high strength and hardness. In this project two numerical models have been constructed to determine the response of a 0.4 m × 0.4 m ARMOX 440T high strength steel plate to localised blast loading. Some experimental data was examined to validate the models.

2. FINITE ELEMENT MODEL

An ABAQUS model was constructed allowing for the global deformations and overall shape of the plate to be examined along with the central, maximum deflections over time. The finite element software allows for complex loading and extreme deformations to be modelled with great accuracy, however is more computationally expensive. The finite element model can then be used to help validate the simpler single degree of freedom model.

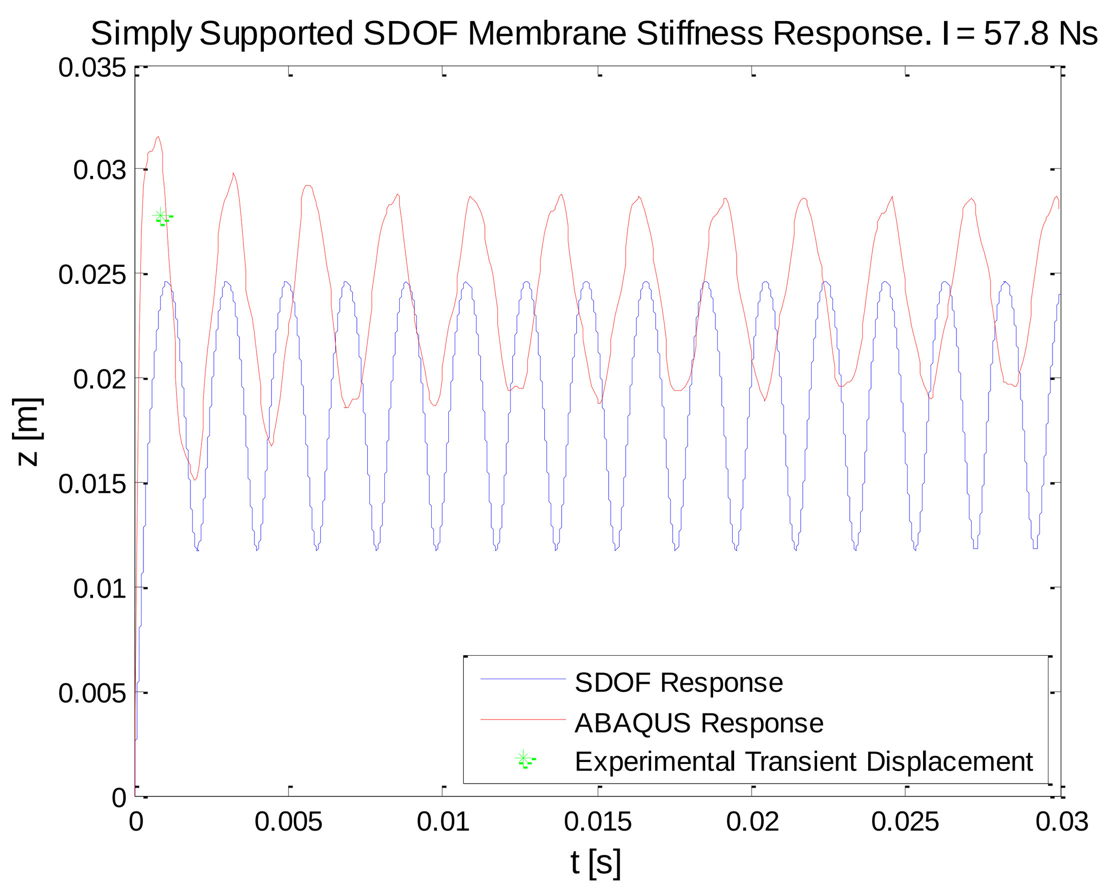


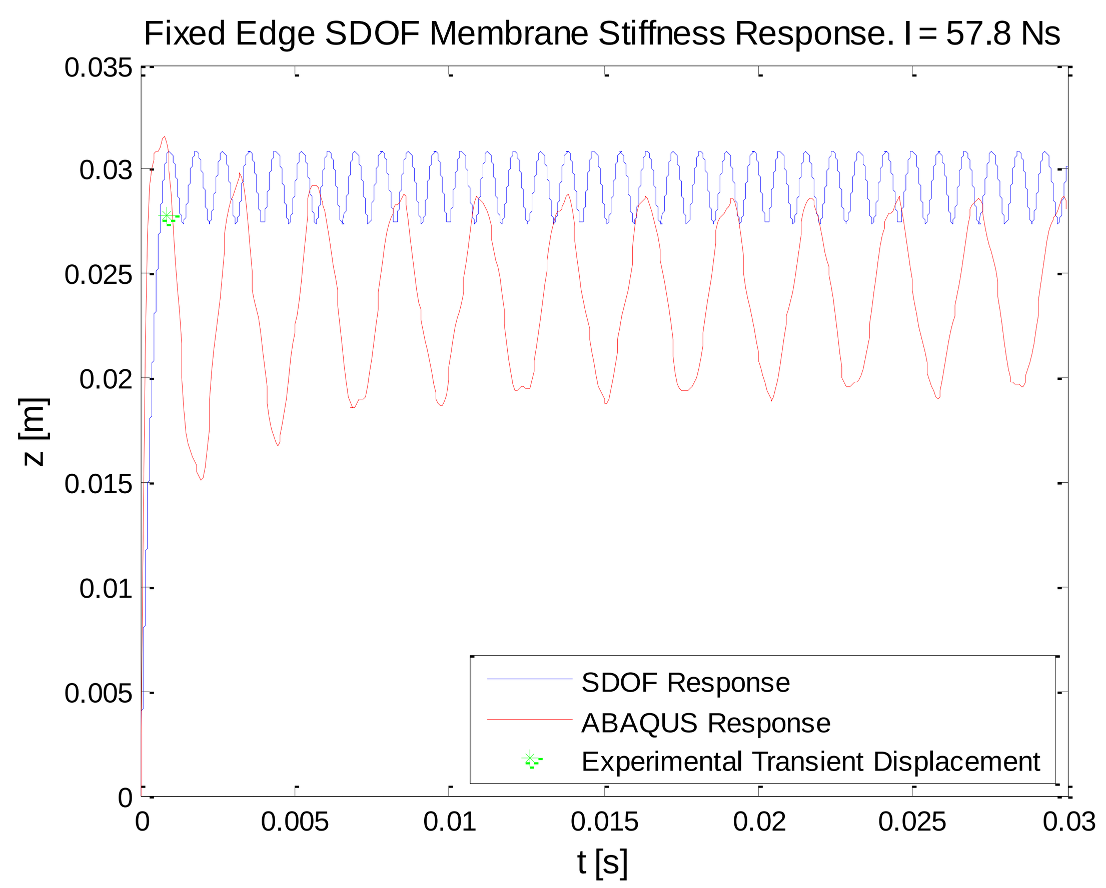
ABAQUS provides a good matching of overall deformed shape with experimental results, showing a mode I failure: a global dome topped by a localised dome (Jacob et al., 2004).

Figure 1: ABAQUS model showing deformed plate displaying mode I failure (only quarter of plate modelled)

3. SINGLE DEGREE OF FREEDOM (SDOF) MODEL

A simple SDOF model was then constructed, finding an equivalent mass, stiffness, and loading using shape functions. It was found that the simply supported edge condition gave a response that matches better with the ABAQUS and experimental results than the more representative fixed edge result. Both bending and membrane effects were included in the models.





It could be said that the simply supported model gives an upper bound, or unsafe, solution and the fixed edge a lower bound, or safe, solution.

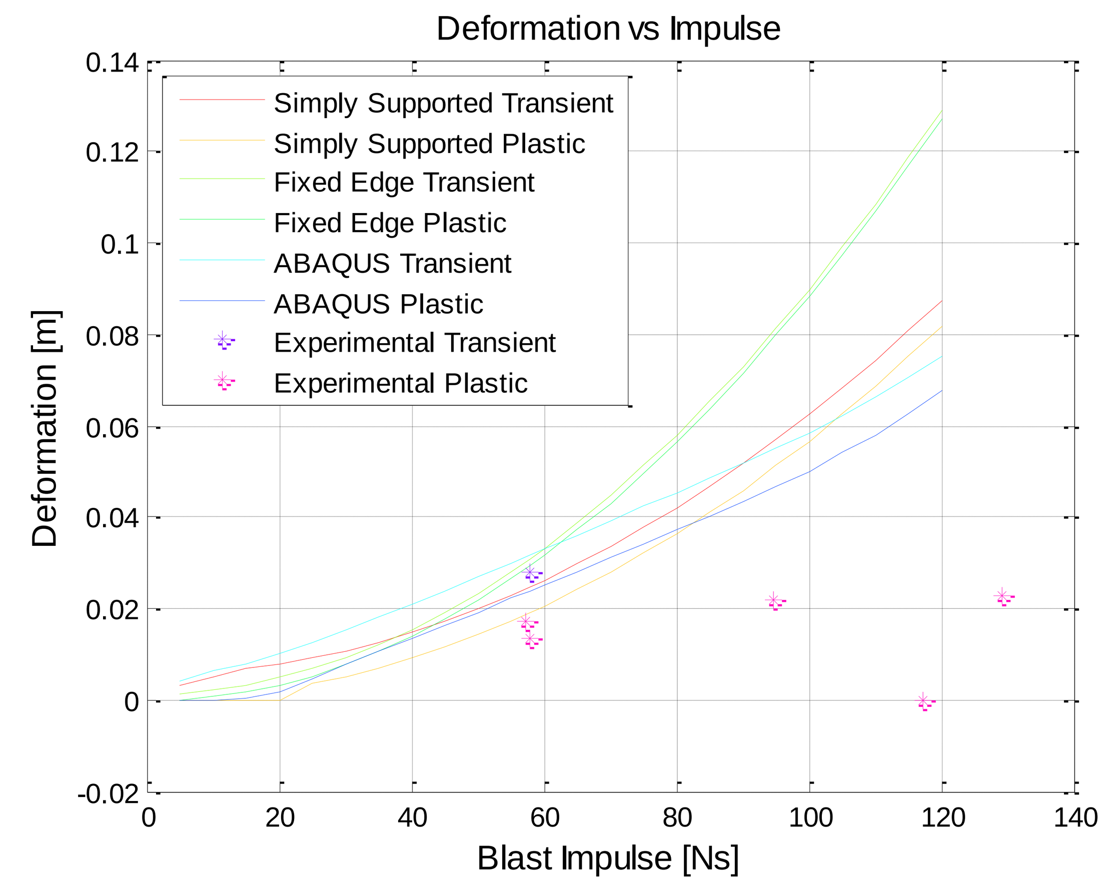
ACKNOWLEDGEMENTS

I would like to thank Dr Louca for his continued assistance throughout this project and Reuben Brambleby for his help with the ABAQUS models.

4. DEFORMATION VS IMPULSE

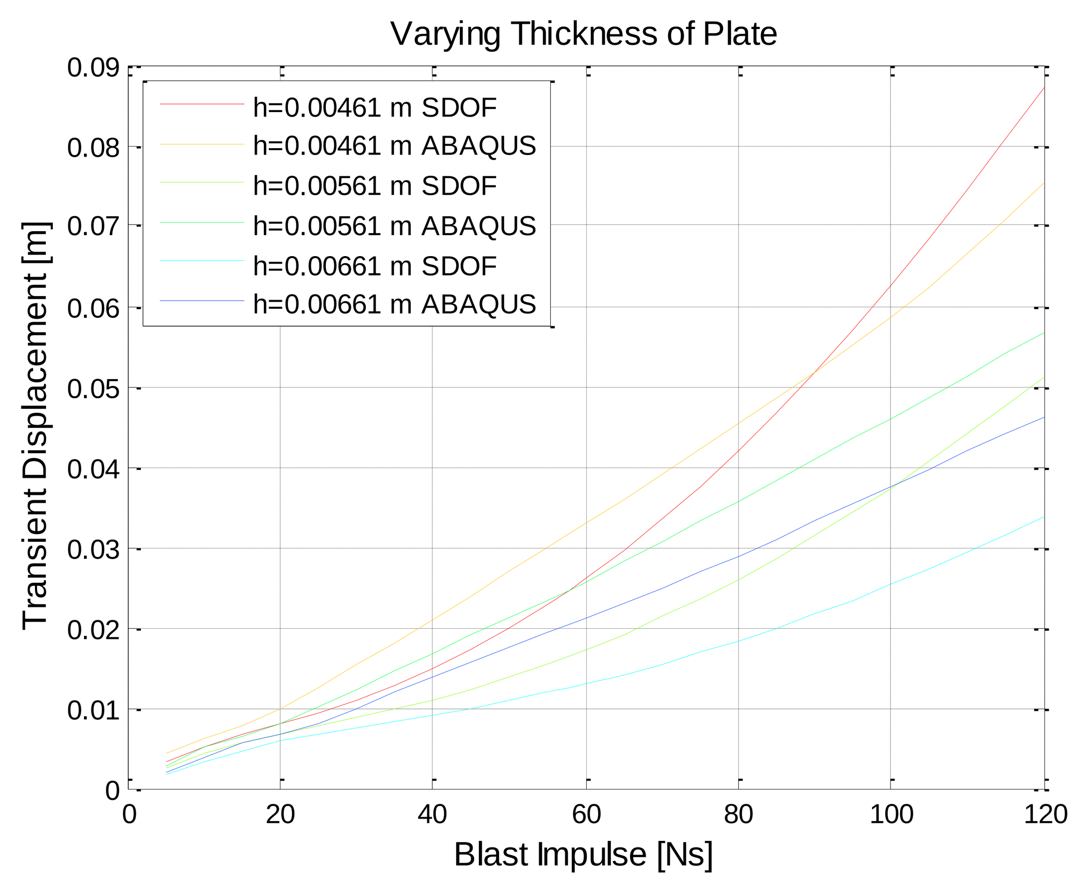
The responses of the plate to varying impulses were examined. Both transient and plastic displacements were determined for each model The fixed edge SDOF model diverges rapidly. from the ABAQUS and simply supported SDOF model at higher impulses due to the overestimations caused by the shape function.

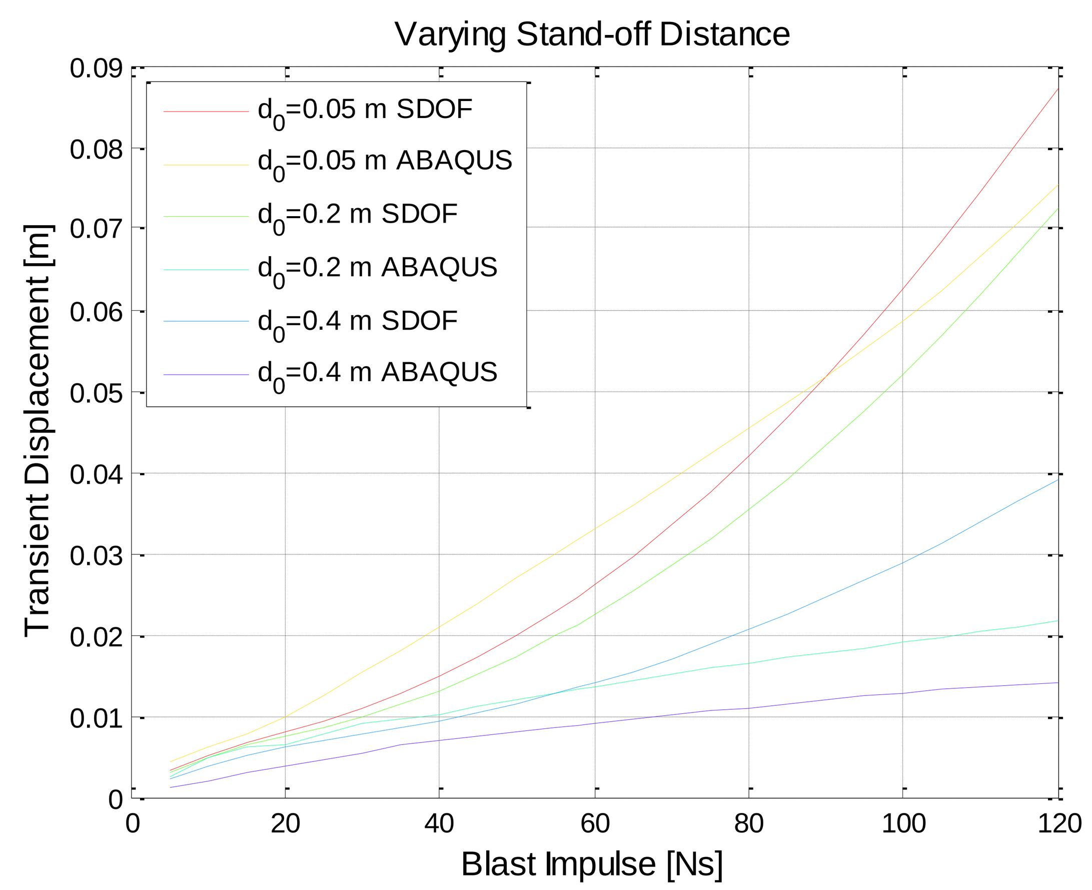
Therefore the simply supported case was taken forward to parametric analysis as it provides better matching with the finite element model across a range of impulses.



5. PARAMETRIC ANALYSIS

Three parameters were altered, two of which are presented here. Only the peak, transient displacements are presented as they are the largest and therefore critical.





It can be seen that increasing the thickness in general decreases the deformation however there is a big divergence between the SDOF and ABAQUS models at the larger thicknesses, with the SDOF model underestimating the deflections. As stand-off distance increased the deformations also decreased. However this time as the loading became more global the SDOF model started to over-estimate the deformations. This is most likely due to the simply supported shape function. For global loading cases a fixed edge shape function may be more fitting.

6. CONCLUSIONS

The SDOF model shows quite good matching with the ABAQUS model and could therefore be considered a quick and simple way to calculate peak transient deflections of ARMOX 440T steel plates due to blast loading. More work is needed to improve the SDOF model's response to changes in parameters, possibly through an improvement in the shape function used.

REFERENCES

Jacob, N., Chung, K. Y., Nurick, G. N., Bonorchis, D., Desai, S. A. & Tait, D. (2004) Scaling aspects of quadrangular plates subjected to localised blast loads experiments and predictions. *Eighth International Symposium on Plasticity and Impact Mechanics, IMPLAST'03. 16-19 March 2003,* UK, Elsevier. pp.1179-208.