MATERIAL AND GEOMETRIC NONLINEARITY TO ANALYZE COMPOSITE RETROFIT FOR BLAST RESISTANCE

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Abstract

The fundamental goal of this research is to understand how material-level properties (stiffness, strength and ductility) affect structural-level response. In this study, a bi-linear material model was combined with membrane action developed through large deformation sustained when a structure deforms under blast loading. The analytical method was used to predict time history deformation of a wall subjected to blast load. The result was compared with existing data from a full scale blast test of a masonry wall reinforced with GFRP (Glass Fiber Reinforced Polymer). A parametric study was subsequently conducted to investigate how the use of high strength concrete would influence the deformation time history.

Introduction

Lam-Grifith-Doherty [1] developed a single degree of freedom model to investigate the out of plane dynamic behavior of unreinforced masonry walls in vertical one way bending subjected to inertial loading. The observed behavior of the wall undergoing large displacement in their tri-linear model was similar to the existing bi-linear model by Biggs [2]. This led to the selection of the simpler bi-linear model for this research. Although practical, Biggs' method does not include membrane action (stretching due to large deformation) which could play a significant role. This study introduces modification to Biggs Methods to include membrane action effect. Timoshenko-Kreiger [3] categorized and analyzed behavior of plates subject to large deformation and membrane action according to their geometry, material properties, loading and support conditions by solving the system of differential equations.

In 2006, Morison, Colins M. [4] conducted a critical analysis of dynamic response of walls and slabs by Single Degree of Freedom (SDOF) analysis. Maji et al. [5] conducted full scale blast testing on unreinforced masonry walls retrofitted with Glass Fiber Reinforced Plastics (GFRP) as part of an effort to find effective techniques to contain blast loads. The data and results from the 'West wall test' are used in this investigation to validate the analytical model.

Analytical Model

A bi-linear (elastic-plastic) material model was used to model the masonry structure. The parameters of the equivalent system [2] are evaluated based on the assumed deflected shape of the actual structure, *Φ(x)*. This shape is taken to be the same as that resulting from the static application of the particular dynamic load [6]. Each stage is treated as independent and therefore has its own deflected shape based on supports condition.

Biggs [2] combined into a SDOF model the relations between the parameters of the equivalent system to those of the real structure using transformation factors K (for load, mass and resistance) that depend on the deflected shape u and applied Force F:

$$K_M \cdot M_t \cdot \left(\frac{d^2u}{d^2t}\right) + K_R \cdot k \cdot u = K_L \cdot F_t(t)$$

The Biggs Method does not take into account membrane action effect. Therefore, to include the effect of membrane action, this study derived the shape function *Φ* using deflection equations from Timoshenko-Krieger's membrane analysis and large deformation theory:

$$\Phi(x) = \frac{2\cdot\cosh u}{2-2\cosh u+u^2\cdot\cosh u}\cdot\left[\frac{\cosh\left(u-\frac{2\cdot x\cdot u}{l}\right)}{\cosh u}-1\right]+\frac{2}{l^2}\cdot\left(\frac{2\cdot u^2\cdot\cosh u}{2-2\cdot\cosh u+u^2\cdot\cosh u}\right)\cdot x\cdot(l-x)$$

The resulting shape functions are used in the analysis together with step by step numerical integration method to produce the time history deformation of the wall. Figure 1 below compares this numerical result with actual full-scale test data. The lower line corresponds to the full-scale test and the upper line corresponds to the prediction based on the analytical method described here. It can be seen that the model provides very reasonable prediction.

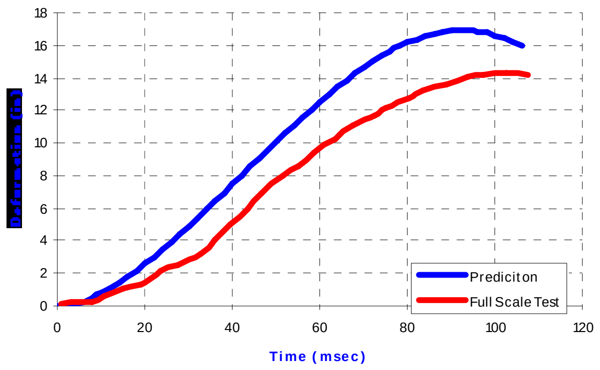

Figure 1

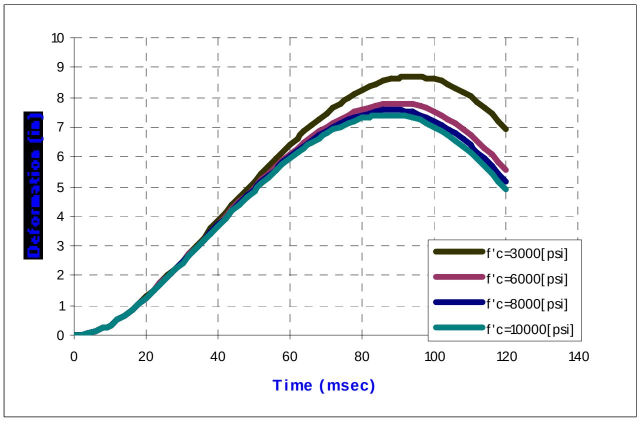

Figure 2

Relation between High Strength Concrete and Time History Deformation

A parametric study investigated the effect of high strength concrete on the overall time history deformation of the wall. The compressive strength of concrete is directly related to key parameters such as modulus E_c, and tensile strength f_r, and indirectly to other parameters involved in the analysis. The time history deformation, for four concrete walls, with different strength of concrete is plotted in Figure 2. To isolate the effect of concrete compressive strength all four walls have the same dimensions, reinforcement and were subjected to the same impulse and duration time. The walls differ from each other only in their concrete compressive strength 3,000[*psi*], 6,000[*psi*], 8,000[*psi*] and 10,000[*psi*]. In Figure 2 the progressively higher curves correspond to progressively increasing strengths of concrete.

As observed (Figure 2), concrete compressive strength has negligible effect on peak displacement. It plays a role only up to cracking, which occurs early and subsequent resistance is primarily due to the composite reinforcement. The variation in stiffness K between the four concretes is also small since it is proportional to $(E \cdot I)$.

Details of the information provided in this paper can be found in the recently complete Masters thesis by Baranes (2008).

Conclusions

Modified Biggs model combined with membrane action showed very reasonable result as compared to full scale test data.

Simply increasing the compressive strength of concrete does not significantly help mitigate blast effect. Fundamental mechanisms of failure need to change to make the concrete more ductile.

References

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