

Response of Offshore Structures to Explosion Loading

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ABSTRACT

This paper describes simplified and advanced methods which can be used in the evaluation of the blast resistance of offshore structures and individual components. For component analysis, improvements to single degree of freedom procedures are suggested, which enable the efficient modelling of the strain-rate effect and the beam-column action. For assemblages, adaptive nonlinear analysis procedures supplement the accuracy of the nonlinear finite element method with considerable computational and modelling savings, rendering its application practicable. Several comparative examples are presented in this paper which illustrate the applicability and relative accuracy of the various methods.

INTRODUCTION

The resistance of offshore structures to explosions represents a major design consideration which is mostly addressed on two fronts; the first is concerned with minimising blast overpressures through improved design details, whereas the second involves the evaluation of the local and global structural response to such overpressures. In the latter context, appropriate consideration must be given to the geometric and material nonlinearities in the structural response, since the behaviour of structures subjected to explosion is usually associated with large displacements and considerable material inelasticity.

This paper discusses two approaches often employed in the evaluation of member and overall structural response under explosion conditions: equivalent single degree of freedom analysis and nonlinear finite element analysis. The applicability of the equivalent single degree of freedom approach to the blast assessment of individual components is appraised, and improvements allowing the modelling of the strain-rate effect and the beam-column action are suggested. The nonlinear finite element approach is then discussed, and established as an accurate, albeit computationally expensive, method for predicting the large displacement inelastic response of structures subject to explosion loading. Previous work by the first author (Izzuddin, 1991; Izzuddin and Elnashai, 1992-93) has shown, however, that modelling and computational savings in excess of 90% can be achieved at no loss in accuracy through the incorporation of adaptive techniques within nonlinear finite element procedures.

The paper presents several examples of components and structures subjected to explosion loading, where the results from the previously discussed approaches are compared. It is shown that the single degree of freedom approximation can provide an accurate assessment of the blast resistance of individual components within a structure, the key requirements being the realistic representation of the boundary conditions, the strain-rate effect and the beam-column action. For the assessment of the overall structural response, the use of nonlinear finite element analysis has become essential, particularly for modelling complex interactions between

the structural components. In this regard, the application of adaptive techniques (Izzuddin, 1991) supplements nonlinear finite element analysis with considerable modelling and computational advantages (Izzuddin and Elnashai, 1992-93), enabling the assessment of the blast resistance of offshore structures to be carried out at a relatively low computational cost whilst maintaining the original levels of accuracy.

SINGLE DEGREE OF FREEDOM ANALYSIS

When the blast response of individual components or assemblages is characterised by a dominant deflection mode, simplified analysis based on an equivalent single degree of freedom (SDOF) system can often be undertaken to evaluate blast resistance. For a component subject to blast overpressures (Fig. 1), the deflection mode shape $\Phi(x)$ is used to transform the actual overpressure, mass, and bending resistance $M(\kappa)$ into equivalent values for the SDOF system according to the following expressions:

$$p_e(t) = \int p(x,t)\Phi(x)dx \quad (1a)$$

$$m_e(t) = \int m(x)\Phi^2(x)dx \quad (1b)$$

$$R_e(u_e) = \int M(\kappa)\Phi''(x)dx \quad (1c)$$

In the last equation, $u_e(t)$ is the displacement of the equivalent SDOF which relates the shape function $\Phi(x)$ to the displacements $d(x,t)$ and curvatures $\kappa(x,t)$ of the original structure:

$$d(x,t) = u_e(t)\Phi(x) \quad (2a)$$

$$\kappa(x,t) = u_e(t)\Phi''(x) \quad (2b)$$

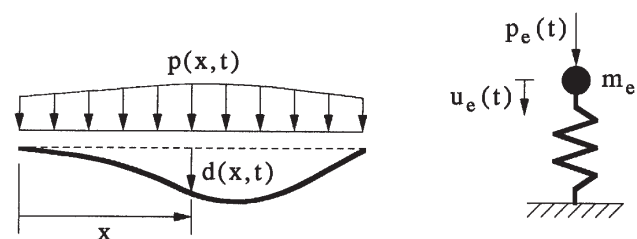


Fig. 1 SDOF idealisation of member subject to blast loading

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