International Journal of Offshore and Polar Engineering
Vol. 13, No. 3, September 2003 (ISSN 1053-5381)

ISUM Approach for Collapse Analysis of Double-bottom Structures in Ships

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ABSTRACT

An application of ISUM to analyse the collapse behaviour of large ship structural modules is developed. The system analysis of a double-bottom structure as well as isolated floor and girder models is achieved with models consisting of large plate elements and beam-column elements for the inner and outer bottom plating and of Timoshenko beam elements for the girder web plates. Fundamental collapse modes and localized failures in a double-bottom structure under pressure loads are obtained in a very short time compared to FEM. Local collapse of rectangular plate panels under transverse thrust rapidly spreads from the central area of the double-bottom towards the sides and stool supports, but the structure exhibits considerable reserve strength in the overall bending.

INTRODUCTION

Verification of large ship substructures, such as a double-bottom, under severe loads requires a tool for system analysis. At this scale, the elastoplastic analyses based on the Finite Element Method (FEM) would require too much effort and time, despite the rapid development in computer technology.

The Idealized Structural Unit Method (ISUM) was proposed by Ueda and Rashed (1984); they had initially derived and introduced an ISUM element for plate girders. The key concept of ISUM, i.e. to divide the structure into as large elements as possible while keeping the main features of the nonlinear structural members' behaviours in their formulation, was afterwards employed in the development of various types of plate elements (e.g. Paik, 1995). The common aim was to develop elements significantly larger than in FEM, by way of obtaining a drastic reduction in the calculation time.

An efficient ISUM rectangular plate element, recently developed and proven accurate in predicting the buckling/plastic behaviour of stiffened plate panels, is employed here to model the inner and outer plating. In its original formulation (Masaoka et al., 1998), the intra-element lateral deflection is treated as an additional degree of freedom and approximated by its elastic buckling mode throughout the collapse behaviour.

In this paper, the new ISUM rectangular stiffened plate model proposed by Fujikubo and Kaeding (2002) is used. The ISUM rectangular plate element was improved by new lateral shape functions based on the collapse modes, a new element subdivision technique keeping the continuity of deflection, introduction of plate/stiffener interactions, etc. The stiffeners are modelled with beam-column elements. This new model can cope with the buckling/collapse behaviour of the stiffener and plate panel and is accurate in post-ultimate strength behaviour; thus it is useful for system analysis.

The collapse behaviour of double-bottom structures under lateral loads depends mainly on the behaviour of the inner and outer plating under the large in-plane stress occasioned by the overall bending. The aforementioned ISUM plate elements accurately capture local failures such as buckling and yielding, including the post-buckling and post-ultimate behaviour that is crucial to simulate correct load redistribution.

Another principal failure is that of web plates in shear. The floors and girders are made of stiffened webs with or without perforations of various types. The behaviour of double-bottom girders in shear/bending is known from prior detailed nonlinear Finite Element Analyses (FEA) (Yanagihara et al., 2002). In the present approach, the webs are modelled by Timoshenko beam elements provided with elastoplastic layers in the depth direction. The holes in the web plates can also be considered in this approach. The web buckling in bending is taken into account with the aid of the effective width concept.

The ISUM stiffened plate models for the inner and outer plating and Timoshenko beam elements for floors and girders are connected, assuming that the cross-sections remain plane. The accuracy of this approach is validated for several flange/web combinations using singlespan and multispan girder models under shear and bending.

The combined model of Timoshenko beam and ISUM stiffened plate models is applied to predict the collapse behaviour of the double-bottom structure of a bulk carrier. The longitudinal stiffeners on the inner and outer plating are considered. The uniform pressure load is increased up to the collapse. The ultimate strength and the reserved strength after the initial local failure are discussed.

PRESENTATION OF APPROACH

Fig. 1 shows the double-bottom model for analysis, which represents a quarter of a cargo-hold, the axes x and y being taken in the symmetry vertical planes of centre girder and central floor, respectively. Simply supported conditions are assumed along Floor 4 and Girder 4. A plate panel between 2 floors and 2

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Received September 2, 2002; revised manuscript received by the editors March 10, 2003. The original version was submitted directly to the Journal.
KEY WORDS: System collapse analysis, ultimate strength, ISUM, double-bottom.