Development of Isoparametric ISUM Plate Element

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ABSTRACT.

New non-rectangular quadrilateral ISUM (Idealised Structural Unit Method) element is developed in accordance with the formulation of isoparametric FEM element. Calculated results applying the new element are compared with those by nonlinear FEM analyses and the validity of the proposed ISUM element is discussed.

KEY WORDS: Isoparametric element, Idealised Structural Unit Method (ISUM), Finite Element Method (FEM), Buckling strength, Ultimate strength, Progressive collapse analysis

INTRODUCTION

FEM (Finite Element Method) is in general applied for structural analyses on ship’s hull girder. Although an enormous development has been achieved in the computer technology, the incremental elastoplastic large deflection analysis applying FEM is too much time consuming because larger number of finite elements is necessary to accurately simulate progressive collapse behaviour of ship structures.

On the other hand, more than thirty years ago, Ueda and Rashed (1974) proposed ISUM (Idealised Structural Unit Method) as a simple but efficient method to simulate progressive collapse behaviour of large scaled structures. In ISUM, the elements are much larger than those in the ordinary FEM. Ueda (2000) explained in the official discussion to the report of ISSC 2000 (Yao et al., 2000) that ISUM has developed through three generations.

ISUM of the first generation was proposed by Ueda and Rashed (1984a) to simulate progressive collapse behaviour of a transverse ring of a tanker. The first ISUM element was a beam-column element with two nodal points representing a girder, and the influence of local buckling in web was considered. No lateral deflection was considered explicitly, and the reduction of the in-plane rigidity by buckling was simulated by introducing effective width concept. The buckling and the ultimate strength interaction relationships were used in terms of sectional forces (axial force, shear force and bending moment) and the ultimate strength interaction relationship was considered as a plastic potential when the stiffness matrix beyond the ultimate strength was derived. The detail of this ISUM element is explained by Ueda and Rashed (1984a).

On the basis of a similar concept, a rectangular plate element with four nodal points at its corners was developed by Ueda et al. (1984b), Ueda and Rashed (1993) as well as Paik (1995). A stiffened panel as well as a rectangular panel partitioned by stiffeners was considered as an element. Collapse behaviour under in-plane thrust load was simulated with this element. It should be noticed that special intuition and engineering sense were required to formulate such elements, and the formulation is rather complex and difficult to understand.

ISUM of the second generation employed eigen-functions to represent the deflection in an element (Ueda and Masaoka, 1995). The formulation had become more mathematical and easier to understand. Here, if the panel is accompanied by initial deflection of a buckling mode or completely flat, deflection of a periodical buckling mode develops even beyond the ultimate strength. Such behaviour can be simulated by the assumed eigen-function.

However, panels in a ship structure have initial deflection of a complex mode. In this case, localisation of plastic deformation takes place beyond the ultimate strength, and the deflection is no more periodical (Yao et al., 2001). It should be noticed that such collapse behaviour can not be simulated by the ISUM elements of the second generation.

ISUM of the third generation can simulate the localisation of buckling/yielding deformation. (Fujikubo et al, 2000, Kaeding, 2001, Fujikubo and Kaeding, 2002). Prior to the formulation of this element, a series of the FEM analyses was performed, and the collapse behaviour of rectangular plates under longitudinal and transverse thrust was studied. On the basis of the simulated collapse behaviour, new lateral shape functions were assumed and implemented in the ISUM element. In this case, a long plate is modelled by several elements. This increases the number of nodal points compared to the ISUM elements of the first and the second generations, but enables to simulate the localisation of buckling/yielding deformation which takes place in actual structures. Even if the number of nodal points increases, it is still very few compared to the ordinary FEM modelling.

Here, a progressive collapse analysis has been performed using