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INFLUENCE OF STIFFENER GAPS ON ULTIMATE BEHAVIOUR OF PLATES UNDER BENDING

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1 Introduction

Modified structural details of horizontal and vertical stiffeners to meet the requirements of robotic welding are needed in steel bridge fabrication. Purpose of the ongoing numerical study is to analyze the effect of increased stiffener gaps on the ultimate behaviour of stiffened plates and plate girders. This paper presents the details of the applied computational method and the results of the parametric study on stiffened plates under bending.

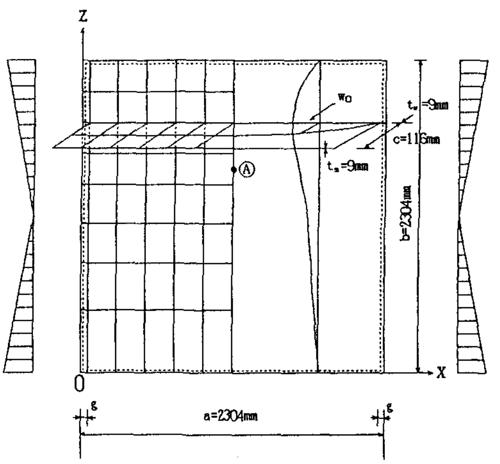
2 Computational Method

Geometrically and physically nonlinear finite element program is developed and applied for the analysis of the interaction between strength and stability phenomena of steel plated structures [1]. A general 3D plate/shell finite element is adopted in the FE program (isoparametric, 8-node Serendipity element, with connecting line definition between elements in different planes). Features of the applied elasto-plastic material models are as follows: a, monotonic plasticity model: von Mises yield criterion, linear isotropic hardening; b, cyclic plasticity model: multi-surface extended Mroz model with combined isotropic and kinematic hardening. In the geometric nonlinearity the Total Lagrangian Approach and the von Karman's hypothesis are used. Combined Newton-Raphson techniques are applied for the solution of the nonlinear equation system.

3 Analyses and Results

Numerical studies are carried out to analyze the effects of stiffener gaps on the ultimate behaviour of square stiffened plates under bending. Geometry and material properties of the stiffened plate are shown in Fig. 1. The analyzed cases - concerning to g stiffener gap size - are as follows :

- full length horizontal stiffener welded to the vertical stiffener, g=0,
- full length horizontal stiffener without welding to the vertical stiffener, g=0,
- partial length stiffener with gap sizes g= 35, 55, 70, 85, 100, 140, 192, 384 and 768 mm,
- plate without horizontal stiffener, g= 1152 mm.



Steel material: SS 400

E= 210000 MPa ν= 0.3 σ_y = 240 MPa

a / b = 1.0

$$w_0(x,z)=\frac{b}{250}\sin(\pi x/a)\frac{f(z)}{f(0.8b)}$$

$$f(z)=\frac{495z^8(b-z)^2}{b^{11}}$$

Fig. 1 Analytical model

Due to the symmetry of the geometry, loading, and boundary conditions, one half of the plate is modelled. All edges of the plate are simply supported in the out-of-plane direction. The edges of z=0 and 2304 are free to move in the in-plane direction. Bending load is applied by the prescribed rotation of the x=0 vertical edge. The material model is elastic - perfectly plastic. The maximum value and the shape of the initial out-of-plane deflection of the plate are shown in Fig.1. For the unstiffened plate, the first buckling mode of plates in pure bending is used for the shape of initial imperfection.

The nonlinear computations are controlled by the Euclidean norm of the unbalanced forces, using convergence tolerance Δ=0.001, and by the negative eigenvalues of the tangent stiffness matrix. The calculations are carried out up to the ultimate strength level.

The relationships between the non-dimensional moment and out-of-plane deflection at the point A and the relationship between the normalized moment and rotation are plotted in Figs. 2 and 3, respectively. The plate with horizontal stiffener welded to the vertical stiffener has the largest ultimate moment. The nonlinear behaviour and ultimate moment in the cases of the full length horizontal stiffener without welding to the vertical stiffener and partial length stiffener with gap sizes g=35 and 50 mm are very close to each other. The relationship between ultimate moment and gap size and the relationship between additional out-of-plane deflection at the service load level of M/M_Y=0.6 and gap size are shown in Figs. 4 and 5, respectively. The ultimate moment takes almost the same magnitude for gap size range 0 < g < 55 mm, and sharply decreases for 55 mm < g < 100 mm. The additional out-of-plane deflection increases linearly for gap size range 55 mm < g < 384 mm. Further studies on different loading conditions and plate girder models are in progress.

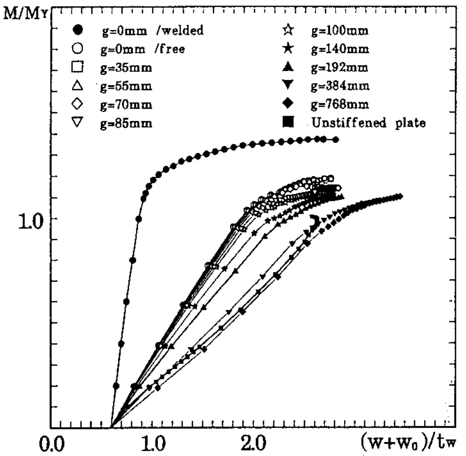


Fig. 2 Moment - out-of-plane deflection curves

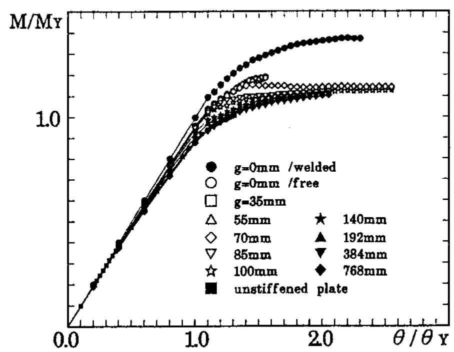


Fig. 3 Moment - rotation curves

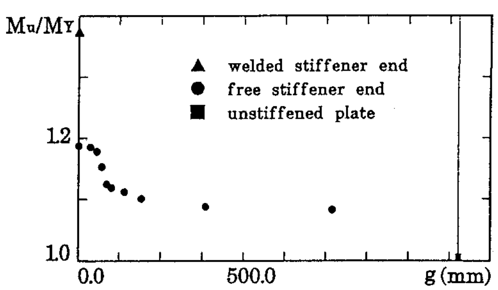


Fig. 4 Ultimate moment - gap size relationship

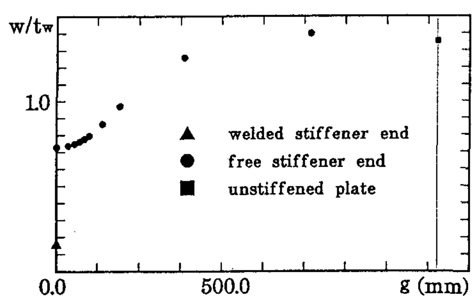


Fig. 5 Deflection - gap size relationship, M/M_Y=0.6

Reference

[1] Dunai L.: "Nonlinear Finite Element Analysis of Steel Plated Structures," University Doctoral Thesis, Technical University of Budapest, 1987, (in Hungarian)