Effects of Initial Geometric Imperfection on Ultimate Strength of Stiffened Plate System

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Abstract
As ultimate compressive strengths of stiffened plates are governed by plate local buckling or global buckling, the magnitude and shapes of initial geometric imperfection significantly influence on the strength. In order to evaluate effects of initial imperfections on in-plane compressive strengths, two different types of initial geometric imperfection were considered in this study. One is the global buckling mode shape and the other is the local plate buckling mode shape. In order to investigate the effects of the shape of initial imperfection, ultimate strength analysis was performed utilizing nonlinear finite element package program.

Keywords: Compressive Strength, Stiffened Plate, Geometric Imperfection, Buckling.

1. Introduction

The stiffened plate systems are widely adopted as main supporting members in civil and marine structural applications. They normally consist of a plate with equally spaced stiffeners welded on one side, usually with intermediate transverse stiffeners or diaphragms. Although their cross-sections are properly proportioned to resist the in-plane compressive forces, it is critical to evaluate the ultimate compressive strengths quantitatively. When ultimate behaviors of thin-walled steel plated structures are discussed, it is generally accepted by researchers that both initial geometric imperfections and residual stresses affect ultimate strengths significantly Khedmati et al. 2012; Xu and Soares 2013). Major objective in this study is to investigate effects of shapes of initial geometric imperfections on in-plane compressive strengths of simply supported stiffened plate system with U-shaped stiffeners. Hypothetical models for stiffened panel plate with U-rib were selected and analysed utilizing a commercial finite element program. Effects of initial imperfection and residual stresses were examined based on nonlinear incremental analysis.

2. Ultimate Strength Analysis

Although AASHTO LRFD bridge design specification (2002) offers general provisions for compressive flanges in box girder section, it recommends FHWA specification (Wolchuck and Mayrbourl 1980) for special purpose of design of wide-type box flanges. This specification was based on strut approach which utilizes the concept of stiffener strut consisting of one stiffener and the associated portion of flange plate with equally spaced stiffener spacing. The ultimate compressive strength of stiffened plate, P_u, is calculated as:

$$P_u = F_u A_f \tag{1}$$

$$\frac{P_u}{F_y} = f(\lambda_{pl}, \lambda_{col}) \tag{2}$$

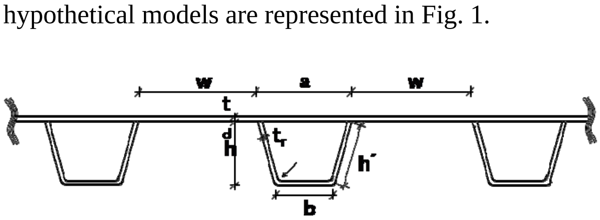
where A_f is the cross sectional area of flange and all longitudinal stiffeners, F_y is the yield stress, F_u is the ultimate compressive strength that is given as a function of the plate slenderness parameter, λ_{pl}, and the column slenderness parameter, λ_{col}, which are given as:

$$\lambda_{pl} = \frac{w/t}{1.9}\sqrt{\frac{F_y}{E}} \tag{3}$$

$$\lambda_{col} = \frac{1}{\pi}\sqrt{\frac{F_y}{E}}\frac{L}{r} \tag{4}$$

where w is the stiffener spacing, t is the thickness of flange plate, transverse stiffener spacing, r is the radius of gyration of stiffener strut, E is the elastic modulus.

After various preliminary numerical studies for U-rib stiffened deck panel systems, it has been identified that failure shapes at ultimate stages can be categorized into two major modes; one is the plate local buckling mode in deck panels and global (overall) buckling mode of panel systems. It has been observed that these two modes of failures are governed by the plate and column slenderness parameters in Eqs. (3) and (4), respectively. The plate local buckling mode occurs when the value of λ_{pl} is relatively high and the global buckling mode occurs when the value of λ_{col} is relatively high. These two different modes were taken into account as shapes of initial imperfections when hypothetical analysis models were set up. The U-ribs considered in this study were checked and set to prevent the stiffener local buckling and/or stiffener tripping. Each parameter was controlled by changing the deck panel plate thickness and deck panel spacing between transverse stiffeners. U-rib shape, thickness, and the spacing in lateral direction were unchanged. Details of hypothetical models are represented in Fig. 1.



a	w	b	h	h′	R	t_r	L
400	500	250	240	521.4	40	8	3,000

Unit: mm

Figure 1. Dimension for u-rib stiffened plates

As ultimate compressive strengths of stiffened plates are governed by plate local buckling or global buckling, the magnitude and types of initial imperfection may significantly influence on the ultimate strengths. In order to evaluate effects of initial imperfections on in-plane compressive strengths, two different shapes of initial geometric imperfection were considered in this study. Fig. 2 shows the first eigenmode of stiffened deck panel system with relatively law width-to-thickness ratio for deck plates while Fig.5 shows the system with relatively high values of width-to-thickness ratio. The thickness of deck panel was varied from 8 mm to 40 mm, respectively. According to Sheikh's study (Sheikh et al. 2002), the global buckling mode shown in Fig.4 is in accord with stiffener induced global buckling mode. Both the global buckling mode and plate local buckling mode were considered in the present analysis for initial imperfections. In the nonlinear incremental ultimate strength analysis, shapes of initial imperfections were incorporated as independent analysis result files using a commercial finite element package program. For the reason that global buckling type is similar to column behaviour, the magnitude of maximum deflection (scaling factor) for initial imperfection, δ_{max}, for global buckling type was assumed to be L/1000. For the plate local buckling type, the magnitude of maximum deflection was taken as w/120. Elastic modulus and Poison's ratio were assumed 355 MPa and 0.3, respectively. Fig. 4 relatively shows the effects of different initial imperfection modeshapes on ultimate in-plane strengths with respect to width-to-thickness ratio of stiffened deck panels.

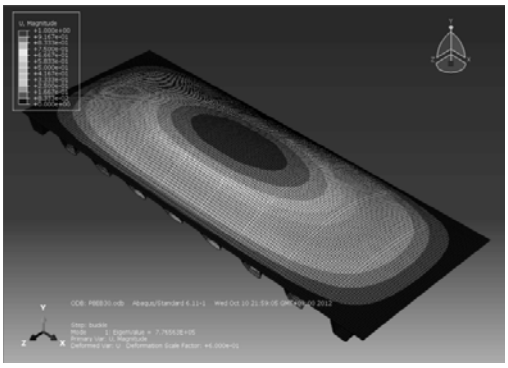


Figure 2. Global buckling (GB) mode

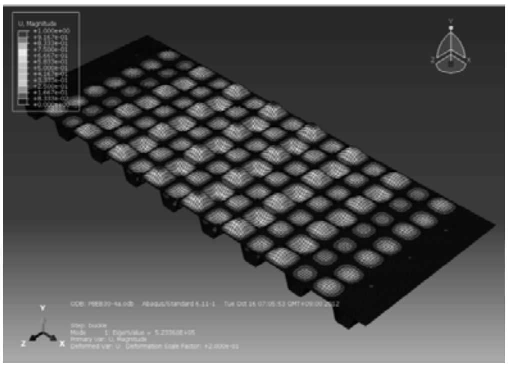


Figure 3. Plate local buckling (PB) mode

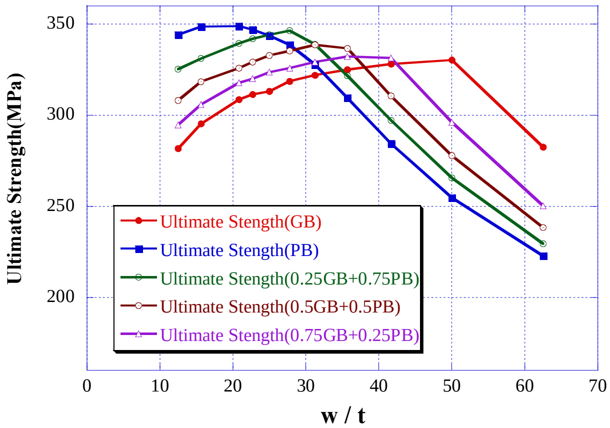


Figure 4. Effects of different initial imperfections on ultimate in-plane compressive strengths

3. Conclusions (Times New Roman, 10 Point, Bold)

Stiffened plates by U-rib were modelled and analysed using finite element software, ABAQUS. Two different mode-shapes of initial imperfections were considered in the analyses. They are the global buckling modeshape and the plate local buckling modeshape, respectively. It has been found that the mode- shapes as well as the magnitudes of initial geometric imperfection affect the ultimate in-plane strengths significantly. Although the possible initial mode-shapes may be reflected from the first mode of the elastic buckling analysis, this procedure may lead to unconservative strength evaluation.

4. Acknowledgement

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