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Finite element analysis of local shear buckling in corrugated web beams

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ABSTRACT

A corrugated web beam (CWB) is a variation to the universal hot rolled or welded I section. CWBs usually comprise of wide thick plate flanges and a thin corrugated web. Due to the accordion effect shear is carried primarily by the corrugated web while bending moments are resisted by the flanges. Under shear action three different modes of shear buckling may be realised in the web – local, global or interactive.

This paper describes analyses performed to investigate the local shear buckling behaviour of beams with trapezoidal corrugated webs. Finite element models of cantilever beams with different web geometries were prepared and an elastic eigenvalue buckling analysis was performed using the program ABAQUS. The influence of web thickness, panel width and web height on the local shear buckling coefficient k_L was investigated. Values of k_L were compared against existing equations from theory and other research. The effect of these dimensions on the local shear buckling stress was also considered. In total, 90 models were analysed.

Overall, it was found that the value of k_L lies between 5.34 and 8.98. This corresponds to panel boundary conditions that are between simply supported and clamped. The analysis results revealed that k_L increases with stockier panels (large panel width to height ratio) but decreases with thicker webs. When the panel width was decreased, local shear buckling occurred at larger stress values. Similar results were observed when the web height was decreased and the panel thickness was increased. These results are consistent with plate buckling theory. Finally, based on these findings an equation to approximate the local shear buckling coefficient in corrugated web beams is recommended.

1. Introduction

Beams with corrugated webs and flat plate flanges (CWB) have been extensively used in structural applications such as buildings and bridges (Fig. 1). Webs of either trapezoidal or sinusoidal shape are often used. The geometry of a trapezoidal corrugated web profile is shown in Fig. 2. In general, corrugated web beams can be more economical than conventional plate web girders and also help to improve the aesthetics of a structure [20]. The main advantage of corrugated web beams is the increased resistance to shear buckling without the need to weld stiffeners to the web. This results in a decrease in the beam weight without compromise in strength, with reduction in costs of up to 30% being possible [18]. In bridge construction corrugated webs can reduce the requirement for intermediate diaphragms which are used for transverse load transfer. As a result, composite bridges of different cross-sections can be constructed. A notable example is the Maupré viaduct in France which is comprised of box girders with an innovative triangular cross-section shape (Fig. 3).

The Australian equivalent to a corrugated web beam is the industrial light beam (ILB). ILBs feature a corrugated web but have cold-formed Square Hollow Sections or Rectangular Hollow Sections as the flanges. Since 1998 they have seen extensive usage in enclosing large spaces as frames in agricultural, commercial and industrial applications [14].

Although beams with corrugated webs are used extensively throughout the world, no Australian or American design rules currently exist for these types of beams. The aim of this study is to further the research done on the behaviour of corrugated web beams by investigating more closely the geometric parameters that control the local shear buckling. It is hoped that through this investigation, design equations can be developed which will enable more extensive use of these beams in the construction industry.

The specific objectives pertaining to this paper are:

- Construct a finite element model to investigate the local shear buckling behaviour of corrugated web beams.
- Perform an elastic buckling analysis to determine the shear load for local shear buckling to occur.
- Determine the local shear buckling coefficients of corrugated web panels with varying geometries.

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Notation

The following symbols are used in this paper:

b	longitudinal panel width
b_f	flange width
c	inclined panel width
C	a constant
d	horizontal width of inclined panel
D_x	bending stiffness about longitudinal axis
D_y	bending stiffness about vertical axis
E	elastic modulus
f_Y	shear yield stress
h	web height
h_r	corrugation depth
k_G	global shear buckling coefficient
k_L	local shear buckling coefficient
L	beam length
n	exponent
P	applied line load
q	horizontal length of one corrugation wavelength
s	developed length of one corrugation wavelength
t_f	flange thickness
t_w	web thickness
V	shear force
V_L	local shear buckling force
w	larger of b and c
α	corrugation angle
β	ratio of longitudinal panel width to inclined panel width
δ_x	displacement along x axis
δ_y	displacement along y axis
δ_z	displacement along z axis
η	parameter
θ_x	rotation about x axis
θ_y	rotation about y axis
θ_z	rotation about z axis
κ	relative stiffness of longitudinal to inclined web panel
λ	eigenvalue
τ_{cr}	local shear buckling stress from plate buckling theory
τ_{FE}	local shear buckling stress from finite element analysis
τ_G	elastic global shear buckling stress
τ_I	inelastic interaction shear buckling stress
τ_L	elastic local shear buckling stress
τ_Y	shear yield stress
ν	Poisson's ratio

Fig. 1. Application of corrugated web beam in a building [22].

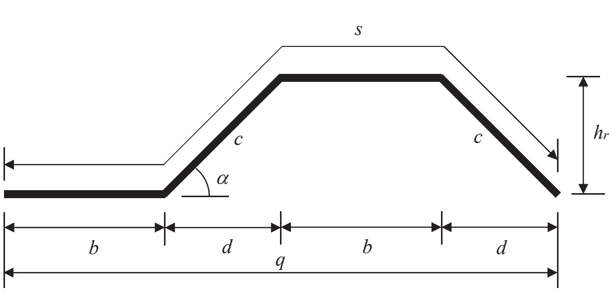

Fig. 2. Profile of trapezoidal corrugated web.

- Understand the effect on the local shear buckling stress by varying specific geometric parameters.
- Compare numerical and theoretical results.
- Recommend an equation to be used to determine the local shear buckling coefficient when designing corrugated web beams.

2. Shear behaviour of beams with corrugated webs

Extensive research has been conducted on the behaviour of beams with corrugated webs. It is widely accepted that the effect of flexure on the strength of the web is negligible [3,20,12]. Therefore in a corrugated web beam the primary purpose of the web is to resist shear forces [8]. Failure under shear load can occur in one of four ways: yielding, local buckling, global buckling or interactive buckling.

2.1. Shear yielding

Elements in pure shear can be modelled as those experiencing compressive stresses along an inclined set of axes. From Von-Mises yield criterion, the amount of shear stress required to cause yielding of the web can then be determined as