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Ultimate strength of longitudinally stiffened I-girder webs subjected to combined patch loading and bending

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Abstract

A numerical study is performed to investigate the ultimate strength of I-girder webs subjected to the combined action of patch loading and bending moment. The study was conducted by means of nonlinear finite element analysis. Initial geometrical imperfections, plastic material behaviour and large deflection effects were considered in the model. The finite element model was validated against experimental results taken from the literature. A parametric study was carried out in order to investigate the influence of the magnitude of the bending moment and the relative location of the stiffener on the ultimate strength to patch loading. Furthermore, diagrams showing the interaction between the aforementioned parameters are presented.

Keywords: Plate girder; Patch loading; Concentrated load; Bending; Longitudinal stiffeners; Ultimate resistance; Finite element analysis

1. Introduction

In general, slender I-girders webs are used in bridge construction. During erection by incremental launching, bridge girders (box and plate) are subjected to a combination

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Nomenclature

a	length of web panel
b_f	width of flange
b_1	position of longitudinal stiffener
b_{st}	width of stiffener
E	Young's modulus
f_u	ultimate strength
f_{yf}	yield stress of flange
f_{yst}	yield stress of stiffener
f_{yw}	yield stress of web
h_w	depth of web panel
F	applied patch load
F_R	patch loading resistance for the longitudinally stiffened plate girder
F_{R0}	patch loading resistance for the unstiffened plate girder
M	applied bending moment
M_R	bending resistance for the longitudinally stiffened plate girder
M_{R0}	bending resistance for the unstiffened plate girder
s_s	length of patch load
t_f	thickness of flange
t_{st}	thickness of stiffener
t_w	thickness of web
w	out-of plane web deflection
ν	Poisson's ratio

of loads such as patch loading, bending and shear [1]. Bending and shear strengths are increased by means of longitudinal stiffening as observed in several investigations [2,3]. For the patch loading case, Graciano [4] demonstrated that the resistance to patch loading is also increased considerably with longitudinal stiffening, particularly when the stiffener is placed rather closed to the loaded flange.

Interaction between patch loading and bending moments in longitudinally stiffened girder webs is often treated as for unstiffened webs [5]. In the last two decades, a number of experimental studies [6–8] have shown that longitudinal stiffening increases the ultimate resistance of plate girder webs to patch loading, in the presence of global bending (Fig. 1). These results have been verified by means of numerical analyses [9–12]. The results reported by Shimizu [11] showed that the best location of the stiffener for combined bending and patch loading is at one fifth of the girder web ($0.2h_w$). Most design codes recommend this location as the optimum to increase the ultimate resistance of plate girders