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Shear behavior of partially encased composite I-girder with corrugated steel web: Numerical study

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ABSTRACT

Shear behavior of partially encased composite I-girders with corrugated web has been investigated analytically and numerically in this paper. A 3-D finite element model with geometric and material nonlinearity is established and verified by the experiments. Subsequently, a parametric study is carried out to examine the effects of geometric and material properties on the shear behavior which includes corrugation, height, thickness, connection degree between steel web and concrete encasement. It is found that the ultimate shear strength of steel I-girders is improved with increases in the thickness, height and yield strength of corrugated web, while the ultimate shear strength of partially encased composite I-girders increases with the thickness, yield strength of corrugated web and the thickness, compressive strength of concrete encasement. However, the stud stiffness has little influence on the ultimate shear strength. Moreover, the concrete encasement improves the shear strength of steel I-girders, the degree of improvement increases with the thickness and compressive strength of the concrete, but decreases drastically with the thickness of corrugated web. Therefore, it is suggested that concrete should be poured on the corrugated web with thin thickness or low yield strength to prevent buckling occurrence before yielding of steel web. Finally, shear strength prediction equations are proposed and verified by numerical results. The calculated shear strength agree well with the numerical results for steel I-girders before and after composite with concrete, which indicates that the proposed analytical equations can be applied to predict the shear strength of such partially encased composite girders with corrugated web.

1. Introduction

Prestressed concrete girder with corrugated steel webs is one of the promising steel–concrete hybrid structures applied to highway bridges, which is composed of concrete slabs, corrugated steel webs and internal or external tendons. The way to substitute corrugated steel webs for concrete webs of composite girders will result in no restraint among the upper or lower slab and the webs, which will alleviate influence on the structure due to concrete creep, drying shrinkage and temperature differences. Prestressing can be efficiently introduced into the top and bottom concrete slabs due to the so-called “accordion effect” of corrugated webs. The strength, stability of structures and material efficiency can be improved by concrete slabs combined with corrugated steel webs [1–3].

Corrugated steel plates can ensure higher resistibility against shear buckling, leading to elimination of stiffeners. The shear behavior of corrugated steel plates has been extensively studied: Shimada [4] was the first researcher who studied the shear strength of steel plate girders with folded web plate. Easley [5,6] proposed the global shear buckling equation of corrugated web by treating the corrugated web as an orthotropic flat web. The corrugated steel web is assumed to provide the shear capacity of the girder where the shear strength is controlled by buckling and/or shear yielding of the web [7–11]. Lindner and Aschinger [12] presented test results for the shear strength of steel trapezoidal corrugated webs and suggested using 70% of the shear buckling stress as the nominal shear strength for design. Luo and Edlund [13,14] analyzed the buckling of trapezoidally corrugated panels under in-plane loading by spline finite strip method and finite element method. Elgaaly et al. [15] presented experimental and analytical results of steel beams with trapezoidal corrugated webs loaded predominantly in shear. Yamazaki [16] described some formulas for estimating buckling strength of corrugated steel web in comparison with the test results of 6 full-scale models for bridge girders. Driver et al. [17] tested full-scale corrugated web girders made of HPS 485W steel, assessed the effect of web initial geometric imperfections through measurements of the out-of-plane displacements, and proposed a lower bound equation for design that accounts for both local and global buckling of the web in the elastic and inelastic domains. Watanabe et al. [18,19] presented the test results using four different trapezoidal corrugation configurations to study the shear capacity with and without local heating history. Yi et al. [20] studied the nature of the interactive shear buckling of corrugated web, and concluded that the first order interactive shear buckling equation

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