Imperfection sensitivity of plate girder webs subjected to patch loading

C. Graciano *, E. Casanova, J. Martínez

Universidad Simón Bolívar, Departamento de Mecánica, Apdo. 89000, Caracas 1080-A, Venezuela

A R T I C L E   I N F O

Article history:
Received 11 August 2010
Accepted 7 February 2011

Keywords:
Sensitivity analysis
Patch loading
Finite element modeling
Initial geometric imperfection
Longitudinal stiffeners

A B S T R A C T

This paper is aimed at studying the influence of initial geometric imperfections on the postbuckling behavior of longitudinally stiffened plate girder webs subjected to patch loading. A sensitivity analysis is conducted herein using two approaches (deterministic and probabilistic) in order to investigate the effect of varying imperfection shape and amplitude on both, the postbuckling response and ultimate strength of plate girders under patch loading. This sensitivity analysis is performed by means of nonlinear finite element analysis. At first, the initial shape imperfections are modeled using the buckling mode shapes resulting from an eigenvalue buckling analysis. Thereafter, the amplitude of the buckling shapes for the various modes is varied, and then introduced in the nonlinear analysis. The results show the influence of these modes and amplitudes on the resistance to patch loading.

1. Introduction

Plate girders are usually able to carry higher loads over long spans than standard rolled sections. They consist of two flanges welded to a web plate and are mostly designed with very deep webs to minimize the required area of flanges. Application fields for such girders are long-span floor girders in buildings and bridge girders, and crane girders. At the launching stage, patch loading is a common loading case for bridge girders, and the resistance to this kind of load must be properly addressed.

Plate girders are also subjected to small shape deviations such as an out-of-flatness of the web. In fact, the term “geometrical imperfection” has been used to denominate such out-of-flatness and it is clear that both the amplitude and shape of the initial imperfections are strongly dependent on the manufacturing process. For thin-walled structures [1], geometrical imperfections are of random nature and could reduce the load carrying capacity of compressed structural elements.

Upon recognizing the significance of geometrical imperfections, a large amount of research has been conducted to develop models of characteristic imperfections for specific structures and then using these models to gain a better estimate of the ultimate load [2]. Besides, over the years many experimental studies have been conducted to measure imperfections very carefully and then store this information for future use [3].

Regarding plate girders subjected to patch loading, Bergfelt [4] observed various types of initial shape imperfections. In the experiments, Bergfelt [4] recognized that an initial shape deformation which has the same shape as the future buckling mode may decrease the strength more than another shape. On the other hand, an initial deformation that counteracts the buckling mode might increase the strength. It was also found that four factors should be considered when analyzing initial shape imperfections, i.e. magnitude, shape, slenderness of the element and the flange-to-web stiffness.

Most researchers have looked into the influence of the magnitude of the imperfections [5–8]. For unstiffened girder webs subjected to patch loading, Granath [5] investigated numerically the influence of the magnitude of the initial imperfection considering a cosine shape. Later on, Chacon et al. [6] performed a numerical study on the influence of the initial geometric imperfections (shape and amplitude) on the numerical modeling of steel girders under patch loading. In these studies, the results showed a small influence on the patch loading resistance. Afterward, some studies were conducted for longitudinally stiffened girders webs. Using the finite element method, Seitz [7] also investigated the influence of both the magnitude and the shape of the initial imperfections considering the various shapes (sinus shape, first, second and fifth eigenmode) obtained by a linear buckling analysis. The results showed a larger reduction in resistance when increasing the size and the order of the mode. In the numerical study conducted by Davaine [8], it was observed that the shape of the initial imperfection affects significantly the structural behavior, the failure mode and may lead to a reduction in resistance.

In order to get a better insight into the influence of initial geometric imperfections on the patch loading resistance of longitudinally stiffened girder webs, this paper presents a parametric analysis that takes into consideration the effect of: the position of the stiffener; the amplitude, and the shape of the imperfection.