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Cold-formed steel flexural member with edge stiffened holes: Behavior, optimization, and design

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ABSTRACT

Circular holes are commonly found on the web of cold-formed steel (CFS) flexural members for piping, electric-wiring, plumbing, or installing lateral bracing, etc. Traditional holes on CFS members are flat bunched without edge lips. A new generation of CFS C-section flexural members with edge stiffened holes was recently developed by the industry. However, research on the new generation C-section members is underdeveloped and available test results are limited. This paper presents finite element analyses to study on the stability of cold-formed steel thin plates and typical C-section members when edge stiffened circular holes are placed on those plates or members. Based on the elastic buckling analyses, the optimized profiles of the holes are obtained and then applied to standard C-section flexural members. The post-buckling finite element analysis is utilized to determine the flexural strength of those members. The results indicate that the stiffened holes can significantly improve the flexural strength of CFS C-sections. New design provisions are proposed to accurately predict the flexural strength of the new generation C-section flexural members with the optimized hole profiles.

1. Introduction

Holes can be seen in cold-formed steel (CFS) flexural members such as joists/beams, studs for piping, electric-wiring, plumbing, bracing, etc. In particular, large openings on the web of floor joists are preferred by the contractors as the mechanical and electrical work becomes more and more complex in today's building industry.

Traditional holes in the CFS members are flat bunched. The sizes of the holes and the distance between holes are greatly restricted due to the weakened flexural strength. To overcome those restrictions, a new generation of profile for the web holes was developed by the industry. Fig. 1 shows one example of a new generation floor joists, the web holes are stiffened by a continuous edge lip around the perimeter of the hole. The new design allows oversize opening to be formed on the web and at the same time the joists still provide satisfied flexural strength.

The presence of the edge stiffener/lip around the holes leads to changes in the boundary conditions of the web element as well as the resultant stress distribution. Thus the elastic and post-buckling behaviors of the whole member will also be potentially altered. In the traditional C-sections, the area where the flat holes are located is usually the weakest zone because the opening splits one stiffened element (the full web) into two unstiffened elements (one edge stiffened and one edge free), as shown in Fig. 2(a). The classical solutions from thin plate theory (e.g. Timoshenko and Gere 1961 [1]) indicate that the stiffened element yields more than 9 time higher elastic buckling stress than the unstiffened element (buckling coefficient 4.0 vs. 0.43) when the element is subject to compression. For the new generation C-section as shown in Fig. 2(b), the edge stiffener acts as edge supporter to the two flat portions of the web therefore the opening splits the whole web element to two stiffened elements. Compared to the traditional C-sections having two unstiffened elements at holes, the new generation C-sections is expected to generate highly improved performance in both flexural and compression strength. This paper focuses on the flexural strength of CFS C-sections with stiffened circular holes.

The current North American Specification for the Design of Cold-Formed Steel Structural Members (AISI S100 2007 [2]) does not provide design provisions for the C-sections with edge stiffened holes. AISI S100 has specific provisions for C-section webs with flat holes under stress gradient (Section B2.4, AISI S100 2007 [2]), the design provisions were developed from 57 simple beam tests conducted at University of Missouri-Rolla (Shan, LaBoube and Yu 1994 [3]), and the specimens were C-sections beams with standard flat holes. However the new generation of C-section joists has shown significantly improved performance due to the edge stiffened holes on the web (NAHB 1999 [4]) and the current specification is no longer applicable for those members. On the other hand, because the new products

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