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Seismic behavior of special truss moment frame with double hollow structural sections as chord members

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ABSTRACT

Research work carried out on steel special truss moment frames (STMFs) with double-angle sections as chord members during the 1990s led to the formulation of design code provisions. Further research results using double-channel specimens resulted in a modified equation for the expected vertical shear strength of the central special segments, V_{ne}, and has been incorporated into the current AISC *Seismic Provisions for Structural Steel Buildings*. Double hollow structural sections (double-HSS) have the advantages of minimizing lateral torsional buckling and maximizing compactness in the flanges as compared to single HSS with the same flexural capacity. In this research, double-HSS members were proposed for the chord and web members of STMFs instead of double-angle, double-channel, or single-HSS. Double-HSS can effectively delay flange local buckling and enhance rotational ductility due to reduced width-to-thickness ratio (b/t) without increasing the wall thickness of the members. A full-scale STMF subassemblage with double-HSS as truss members was tested under large displacement reversals to simulate a severe earthquake ground motion. Testing results indicate that using double-HSS truss members is a viable alternative for STMFs in high seismic regions. Plastic hinge models are also suggested for computer analysis and design of non-yielding members outside of the special segments.

1. Introduction

Research carried out in the 1990s on the seismic behavior of steel special truss moment frames (STMFs) using double-angle sections [13,11,4,5] led to the formulation of design code provisions incorporated into the American Institute of Steel Construction (AISC) *Seismic Provisions for Structural Steel buildings* in 1997 (Eq. (1)) [1]. One of the major advantages of using the STMF system is that truss girders can be economically used over longer spans due to the fact that higher overall structural stiffness can be achieved by using deeper girders. In addition, the open-webs can easily accommodate mechanical and electrical ductwork. As a consequence, this system offers a wide range of structural, architectural, and economical benefits because of its ability to achieve a large column-free floor.

STMFs dissipate earthquake energy through the ductile chord members of special segments located near the mid-span of the truss girders which act as a structural "fuse" as shown in Fig. 1 (a). The members outside of the special segment are easily designed to remain elastic using the free-body diagram of the column tree subjected to design loading and expected vertical shear strength, V_{ne}, based on the capacity of the chord members in the special segment, seen in Fig. 1(b). The ductility of a truss system can also be improved by using dissipative energy devices, for example, using dampers at the ends of the bottom chords of the truss girders as shown by Longo et al. [14].

STMFs located in high seismic zones call for truss member sections stronger than double-angle sections, which led to further research studies on STMFs with double-channel chord members and a revised equation in AISC Seismic Provisions for Structural Steel Buildings (AISC 341-10) in 2010 (Eq. (2)) [15,6,2].

$$V_{ne} = \frac{3.75 R_y M_{nc}}{L_s} + 0.075 EI \frac{(L - L_s)}{L_s^3} + R_y (P_{nt} + 0.3 P_{nc}) \sin \alpha \quad (1)$$

$$V_{ne} = \frac{3.60 R_y M_{nc}}{L_s} + 0.036 EI \frac{L}{L_s^3} + R_y (P_{nt} + 0.3 P_{nc}) \sin \alpha \quad (2)$$

where

E = modulus of elasticity of a chord member of the special segment,
I = moment of inertia of a chord member of the special segment,
L = length of the truss,

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Nomenclature

α	angle of diagonal members with the horizontal	I	moment of inertia of a chord member of the special segment
β	angle of vertical members at the ends of the special segment with the vertical	L	span length of truss
γ	angle of chord members with the horizontal	L_s	length of special segment
θ_p	plastic hinge rotation of chord members	M_{nc}	nominal flexural strength of a chord member of the special segment
b	width of compression element	M_p	nominal plastic flexural strength
A_f	gross area of the flange	$M_{p,\exp}$	expected plastic flexural strength
D_l	member rotation corresponding to the beginning of strength loss	M_r	residue flexural strength
D_r	member rotation corresponding to the end of strength loss	M_u	required flexural strength, using LRFD load combinations
D_y	member rotation corresponding to expected flexural strength	P_{nc}	nominal compressive strength of the chord member at the ends
D_u	member rotation corresponding to required flexural strength	P_{nt}	nominal axial tensile strength of a diagonal members of the special segment
E	modulus of elasticity of steel	P_u	required axial strength, using LRFD load combinations
F_y	specified minimum yield stress of the type of steel to be used	R_y	ratio of the expected yield stress to the specified minimum yield stress, F_y
$F_{y,actual}$	actual yield stress of steel from a coupon test	t	thickness of element
h	the clear distance between the flanges less the inside corner radius on each side	V_{ne}	expected vertical shear strength of the special segment
		Z	plastic section modulus of a member

L_s = length of the special segment,
M_{nc} = nominal flexural strength of a chord member of the special segment,
P_{nt} = nominal tensile strength of a diagonal member of the special segment (if any),
P_{nc} = nominal compressive strength of a diagonal member of the special segment (if any),
R_y = ratio of the expected yield stress to the specified minimum yield stress,
V_{ne} = expected vertical shear strength of the special segment,
α = angle of diagonal members with the horizontal.

As opposed to moment frames in which the plastic rotational demand in beams is close to the story drift ratio, the plastic rota-

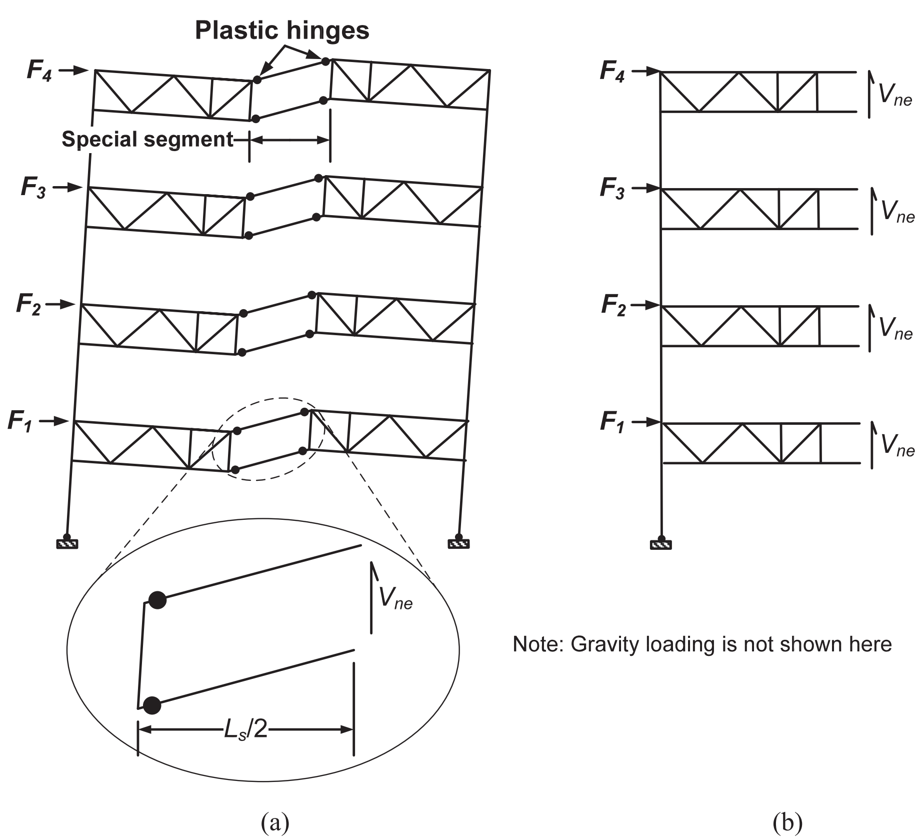

Fig. 1. STMF: (a) yielding mechanism adapted from Goel and Chao [10], (b) free-body diagram of column tree and associated truss girder portions adapted from Goel and Chao [10].

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