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Assessment of AISI-S400 deflection equation for cold-formed steel framed shear walls

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Abstract

In current CFS standards, the AISI-S400 deflection expression is used to find the deflection of different types of cold-formed steel framed shear walls, including: those with steel sheet sheathing, and wood structural panels. In this paper, an assessment of the S400 deflection equation is performed. A total of 118 different cold-formed steel shear walls were investigated, of which 83 utilize steel sheet sheathing and 35 utilize wood structural panels. These 118 cases cover a wide range of parameters including: shear wall type, sheathing thickness, sheathing screw size, fastener spacing at panel edges, and type of holddown used. Exploiting the experimental results of the 118 shear walls, the AISI-S400 deflection equation expression was assessed. The assessment results demonstrated that the S400 equation is conservative for both wood structural panel and steel sheet sheathed shear walls.

1. Introduction

In current cold-formed steel (CFS) design standards, deflection of CFS shear walls is calculated according to AISI S400 [1] depending on the seismic force resisting system (SFRS). For wood structural panel (WSP) sheathed shear walls and steel sheet (SS) sheathed shear walls, the equation is:

$$\delta^e = \frac{2vh^3}{3EA_cb} + \omega_1\omega_2\frac{vh}{\rho G t_{sheathing}} + {\omega_1}^{5/4}\omega_2\omega_3\omega_4\left(\frac{v}{\beta}\right)^2 + \frac{h}{b}\delta_v \qquad (1)$$

where all coefficients are defined in AISI S400 [1]. The first term in the equation accounts for deformation due to chord bending, the second term addresses shear in the sheathing material, the third or "nonlinear" term is empirically formulated depending on experimental studies, and the fourth term gives the contribution from hold-downs or other inter-story joints. Note, the demand V is given per unit length by dividing by the wall length b, i.e. $v = V/b$, and the coefficients for WSP and SS shear walls are different, but the form of the expression remains the same [1]. It is also worth noting that, in the present paper, δ_{S400} refers to the deflection determined by Eq. (1).

Current CFS practice amplifies $\delta_{S400}(V_r)$ by a deflection amplification factor to find peak nonlinear drift according to the following equation:

$$\delta^{peak} = C_d\delta_{S400}(V_r) \qquad (2)$$

where δ^{peak} is peak nonlinear deflection, C_d is deflection amplification factor per ASCE 7 [2], and V_r is the required shear demand.

Hence, to verify the accuracy of peak nonlinear deflection calculations in current CFS practice, it is essential to assess AISI-S400 deflection amplification factor. To this end, this article presents an assessment of the AISI-S400 deflection equation. The experimental data for a total of 118 cold-formed steel shear walls (including steel sheet (SS) and wood structural panel (WSP) shear walls) were employed in the assessment covering a wide range of geometric and material parameters. The assessment results for WSP and SS shear walls were discussed and compared.

2. Parametric study

In the present investigation, all shear walls, in the database of CFSSWs test results [3], complying with AISI-S400 [1] (118 shear walls) were studied, which covers a broad range of geometric and material parameters: shear wall type, thickness of sheathing, size of sheathing screw, spacing of fasteners at panel edges, and utilized holddown. Table 1 provides the main geometric and material parameters studied and the number of investigated cases connected to each parameter.

Using the results of the 118 tests, an assessment of AISI-S400 deflection expression (Eq. (1)) was carried out. For

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each test, the ratio of observed deflection (determined utilizing the backbone curve if it is cyclically-loaded) to that estimated by S400 expression (i.e. $\delta_{exp}/\delta_{S400}$) was determined at four different force levels: $0.4\Phi V_n$, $0.4V_n$, ΦV_n, V_n; where ϕ is the resistance factor (0.60 in AISI S400 [1]) and V_n is the nominal resistance (tabled in S400 as $v_n = \frac{V_n}{wall\ length}$).

Table 1: Key parameters studied

Parameter investigated		# considered cases
Shear wall type	SS	83
	WSP	35
Sheathing thickness (in.)	7/16 in (11.11 mm) WSP	35
	0.018 in (0.46 mm) SS	15
	0.027 in (0.68 mm) SS	19
	0.03 in (0.76 mm) SS	29
	0.033 in (0.84 mm) SS	20
Sheathing screw size	8	107
	10	11
Fastener spacing at panel edges	6 in (152.4 mm)	60
	4 in (101.6 mm)	23
	3 in (76.2 mm)	6
	2 in (50.8 mm)	29
Holddown employed	S/HD10	26
	S/HD10S	70
	S/HDU6	13
	others	9

3. Results and discussion

As the coefficients of AISI-S400 deflection equation differ according to wall type [1], the results of each wall type (i.e. WSP or SS) were independently studied. Mean; standard deviation; and COV of $\delta_{exp}/\delta_{S400}$ are given in Table 2 for tests and Table 3 for SS cases.

Table 2: Main Statistics of $\delta_{exp}/\delta_{S400}$ for the WSP tests

force level	$0.24V_n$	$0.4V_n$	$0.6V_n$	V_n
mean	0.79	0.78	0.73	0.90
Standard Deviation	0.35	0.24	0.15	0.35
COV	0.44	0.31	0.21	0.38

Table 3: Main Statistics of $\delta_{exp}/\delta_{S400}$ for the SS tests

force level	$0.24V_n$	$0.4V_n$	$0.6V_n$	V_n
mean	1.41	1.06	0.64	0.78
Standard Deviation	3.35	2.05	0.37	0.47
COV	2.38	1.94	0.58	0.60

As seen in Tables 2 and 3, it is evident that deflection estimation of AISI-S400 equation is not highly accurate. At a force level of ϕV_n (i.e. $0.6V_n$), the S400 equation is conservative for WSP and SS shear walls. At lower force levels the WSP predicted deflections are more consistent than those of the SS. Ultimately, the assessment of the AISI S400 deflection equation should be done when it is combined with C_d to calculate the peak plastic drift.

4. Conclusions

In the present study, an assessment of the AISI-S400 deflection equation, using the results of 118 tests on cold-formed steel framed wood structural panel (WSP) and steel sheet (SS) sheathed shear walls, was carried out. Comparing AISI-S400 deflection expression with experimental results demonstrated that the S400 expression yields approximate predictions for nonlinear static deflection. At the design level with 100% utilization of the shear wall the S400 equation is conservative for all investigated shear walls (WSP and SS), while at lower force levels the SS results showed less consistency than the WSP results. However, it should be said that the critical assessment of the AISI-S400 deflection equation for seismic design is in its coupling with the deflection amplification factor and its prediction of ultimate plastic drift – a study performed by the same research team and to be published in a separate paper.

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