JOHNS HOPKINS UNIVERSITY

Overstrength in Cold-Formed Steel Framing Seismic Design

Ω_E

Report for AISI

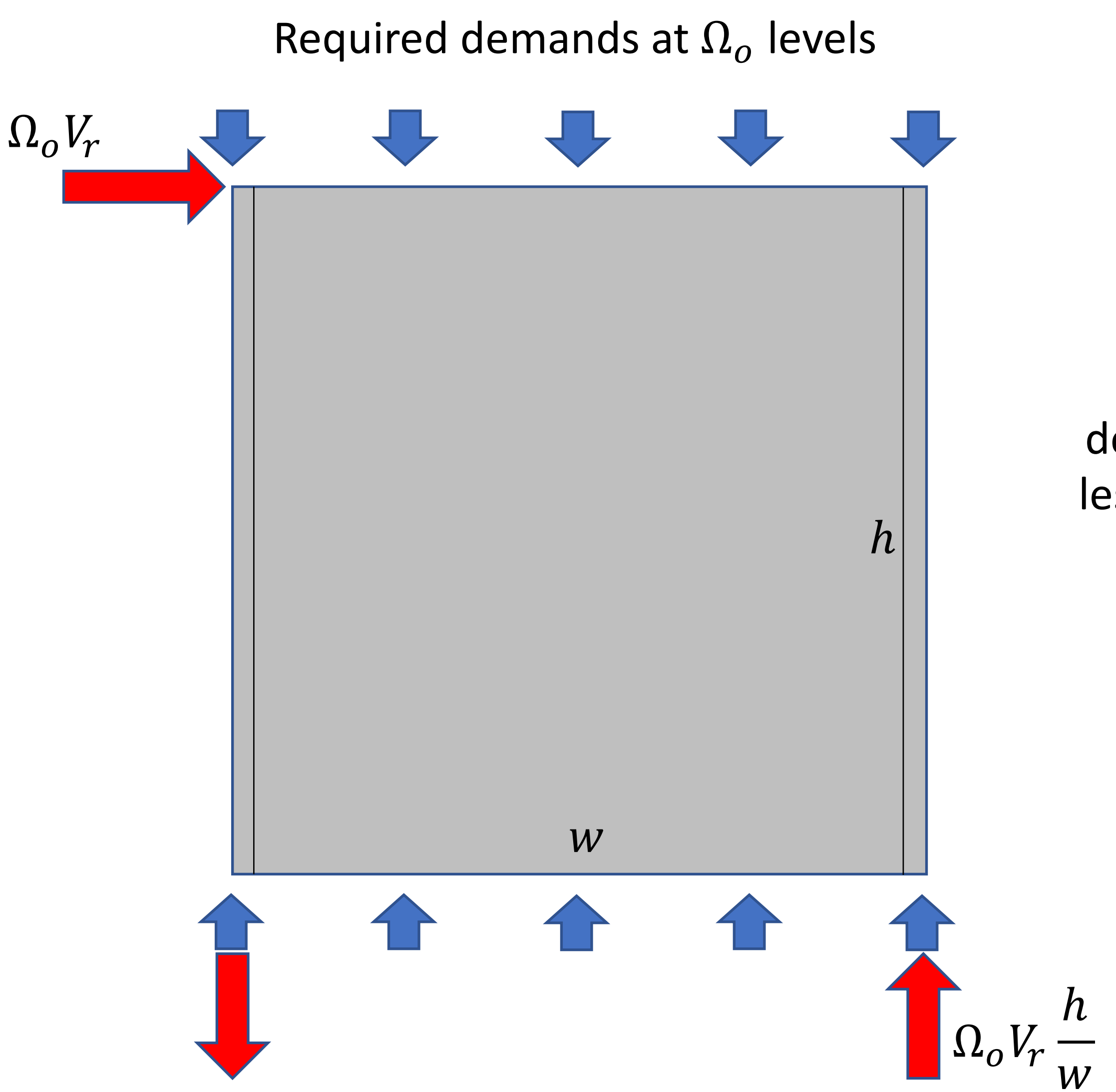
30 June 2020

C_d

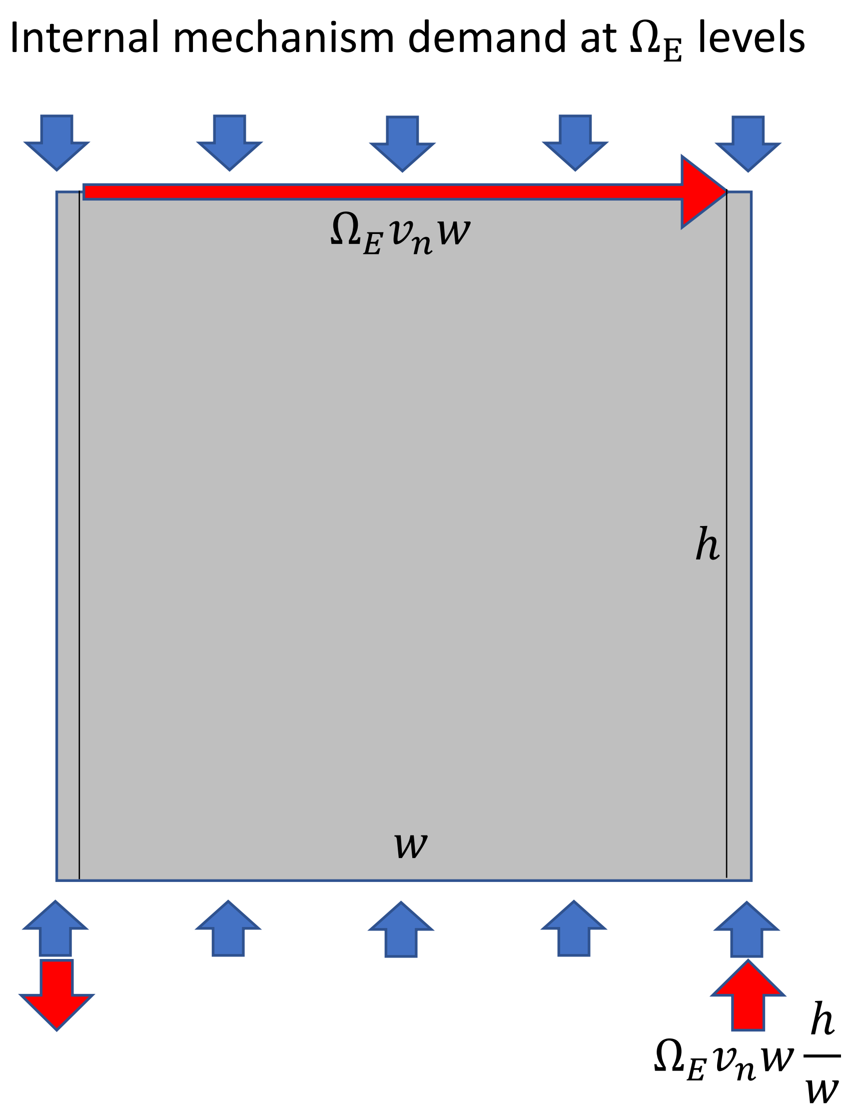
American Iron and Steel Institute

SFIA STEEL FRAMING INDUSTRY ASSOCIATION

Chord Stud Design and Expected Strength, Ω_E



design for the lesser of these two cases



AISI S400 Ballot MS20-20A – Passed Ballot!

$$\Omega_E = \frac{\Omega_b v_n + v_{finish}}{v_n} \leq \max(\phi\Omega_o, 2 - \phi)$$

System	Ω_b	v_n	v_{finish}	ϕ	Ω_o
WSP	1.1	Table E1.3-1	Mean shear strength/unit length of finish, not less than $0.1v_n$	0.6	3
SS	1.1	Table E2.3-1 or Section E2.3.1.1.1	Mean shear strength/unit length of finish, not less than $0.1v_n$	0.6	3
Strap-braced	R_y	Eq. E3.3.1-1/w	Mean shear strength/unit length of finish, not less than $0.2v_n$	0.9	1.8

AISI S400 Ballot MS20-20A – Passed Ballot

bias in mean tested strength over nominal specified strength (from database)

additive model for finish systems, borne out in the data

lateral strength of finish, guidance provided in commentary

$$\Omega_E = \frac{\Omega_b v_n + v_{finish}}{v_n} \leq \max(\phi\Omega_o, 2 - \phi)$$

same upperbounds as AISI S400-15 supplement and result in 1.8

Nearly always some finish, so don't let engineer just set to zero, lots of scatter on bias anyway.

System	Ω_b	v_n	v_{finish}	ϕ	Ω_o
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strap-braced walls have more bias than just yielding of the strap, captured here with larger minimum value.

Bias factor from data

WSP and SS

	V_{test}/V_n		
Sheathing	mean	COV	n
Wood Structural Panel (WSP)	1.14	0.15	62
Steel Sheet (SS)	1.16	0.20	60

Strap-braced

	V_{test}/V_n		
	mean	COV	n
Strap braced wall (F_{yn}=33ksi, 228MPa)	1.51	0.16	26
Strap braced wall (F_{yn}=50ksi, 345MPa)	1.38	0.21	14
	F_{yn}/F_{ya}		
	mean	COV	n
Strap from wall (F_{yn}=33ksi, 228MPa) R_y=1.5	1.39	0.08	22
Strap from wall (F_{yn}=50ksi, 345MPa) R_y=1.1	1.11	0.05	13
	$V_{test}/(R_y V_n)$		
	mean	COV	n
Strap braced wall (F_{yn}=33ksi, 228MPa)	1.01	0.23	26
Strap braced wall (F_{yn}=50ksi, 345MPa)	1.25	0.22	14

Additive model

$v_E = \Omega_b v_n + v_{finish}$

$v_{finish} = v_{gyp} = 520 - 25s$ (plf), where s = perimeter fastener spacing (in.)

Comparison to data in shear wall database

	V_{test}/V_e		
Sheathing	mean	COV	n
Oriented Strand Board (OSB) + Gypsum Board	1.00	0.08	8
Strap braced wall[1] + 1 layer Gypsum Board	0.93	0.02	4
Strap braced wall[1] + 2 layer Gypsum Board	1.02	0.03	12
Strap braced wall[1] + Gypsum (All cases)	1.00	0.05	16

1. strap F_{yn}=50ksi (345MPa), R_y=1.1

Strength of finish systems (gypsum board)

Developed from available data:

Assembly	Max aspect ratio	Perimeter fastener spacing (in.)					Stud and track (mils)	Screw
		12	8	7	6	4		
½ in. gypsum; studs max. 24 in. o.c.	2:1	220	320	345	370	420	33	#6

Assembly	Max aspect ratio	Perimeter fastener spacing (mm)					Stud and track (mils)	Screw
		300	200	175	150	100		
12.5 mm. gypsum; studs max. 600 mm o.c.	2:1	3.2	4.7	5.0	5.4	6.1	33	#6

$$v_{gyp} = 520 - 25s \text{ (lbf/ft)}$$

s = perimeter fastener spacing (in.)

$$v_{gyp} = 0.0146[520 - 25(s/25.4)] \text{ (kN/m)}$$

s = perimeter fastener spacing (mm)

- For multiple layers simply add them up
- If unblocked used 0.35 reduction as already in AISI S400
- If attached to resilient channel assume no contribution
- OK to extend from 1/2 to 5/8 in. board

Strength of finish systems (other)

Type	strength	source
EIFS	746 lbf/ft	CFS-NHERI wall line tests
Plaster on metal lath over CFS framing	150 lbf/ft	ASCE 41-17 Chapter 9
Stucco*	350 lbf/ft	ASCE 41-17 Table 12-1
Wood siding*	70-500 lbf/ft	ASCE 41-17 Table 12-1
Gypsum plaster*	80-400 lbf/ft	ASCE 41-17 Table 12-1

*values reported for finish over wood framing

Example

<u>Example (Imperial Units only)</u>

Consider a 12 ft long single-sided steel sheet sheathed shear wall with 0.030 in. sheet fastened at 4 in. on its perimeter. Relevant finish for the well is ½ in. gypsum fastened at 12/12 to both sides. On the interior face, without the steel sheet, the gypsum board is run perpendicular to the studs and unblocked. Determine the expected strength factor Ω_E for capacity-based design.

$$\Omega_E = \frac{\Omega_b v_n + v_{finish}}{v_n} \leq \max\left(\phi\Omega_o, 2 - \phi\right) \quad (5)$$

Ω_b=1.1 for SS [Table 7]

v_n=1170 lbf/ft per S400-15/S1-16, Table E2.3-1

v_{finish}=220 lbf/ft + 0.35(220) lbf/ft = 297 lbf/ft (note, OK b/c > 0.1v_n=117 lbf/ft) [Table 8]

$\max(\phi\Omega_o, 2 - \phi) = \max(0.6 \cdot 3, 2 - 0.6) = 1.8$

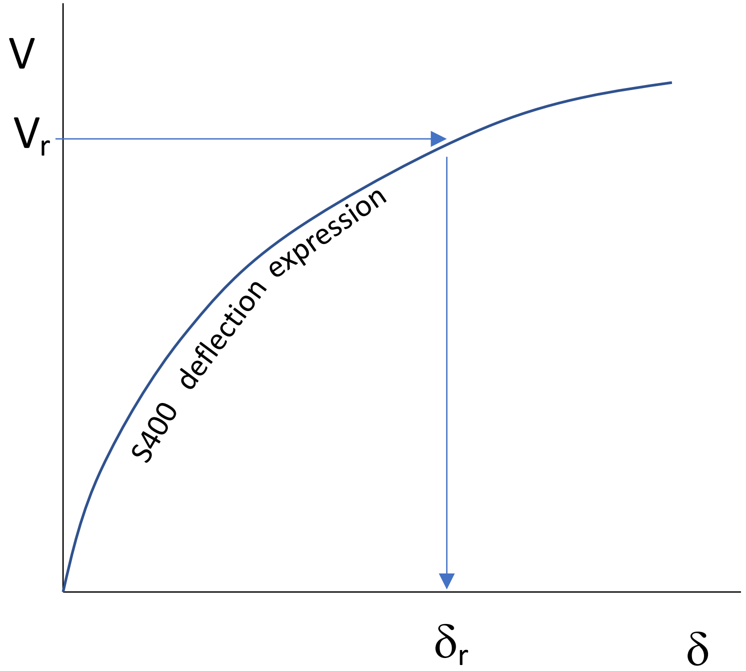
$$\Omega_E = \frac{1.1 \cdot 1170 \frac{lbf}{ft} + 297 \frac{lbf}{ft}}{1170 \frac{lbf}{ft}} \leq 1.8 \quad (6)$$

$$\Omega_E = 1.35 \quad (7)$$

work in progress..

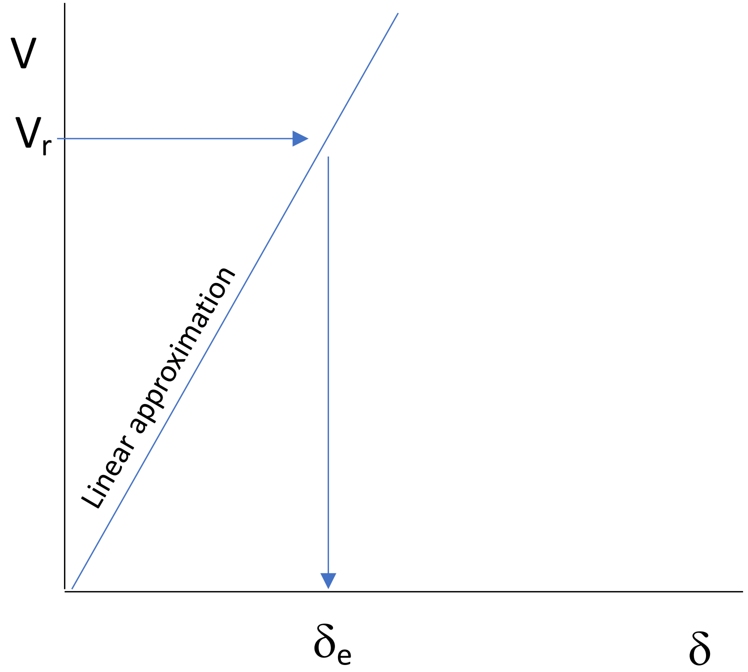
Seismic deflection calculations

What S400 users typically provide:



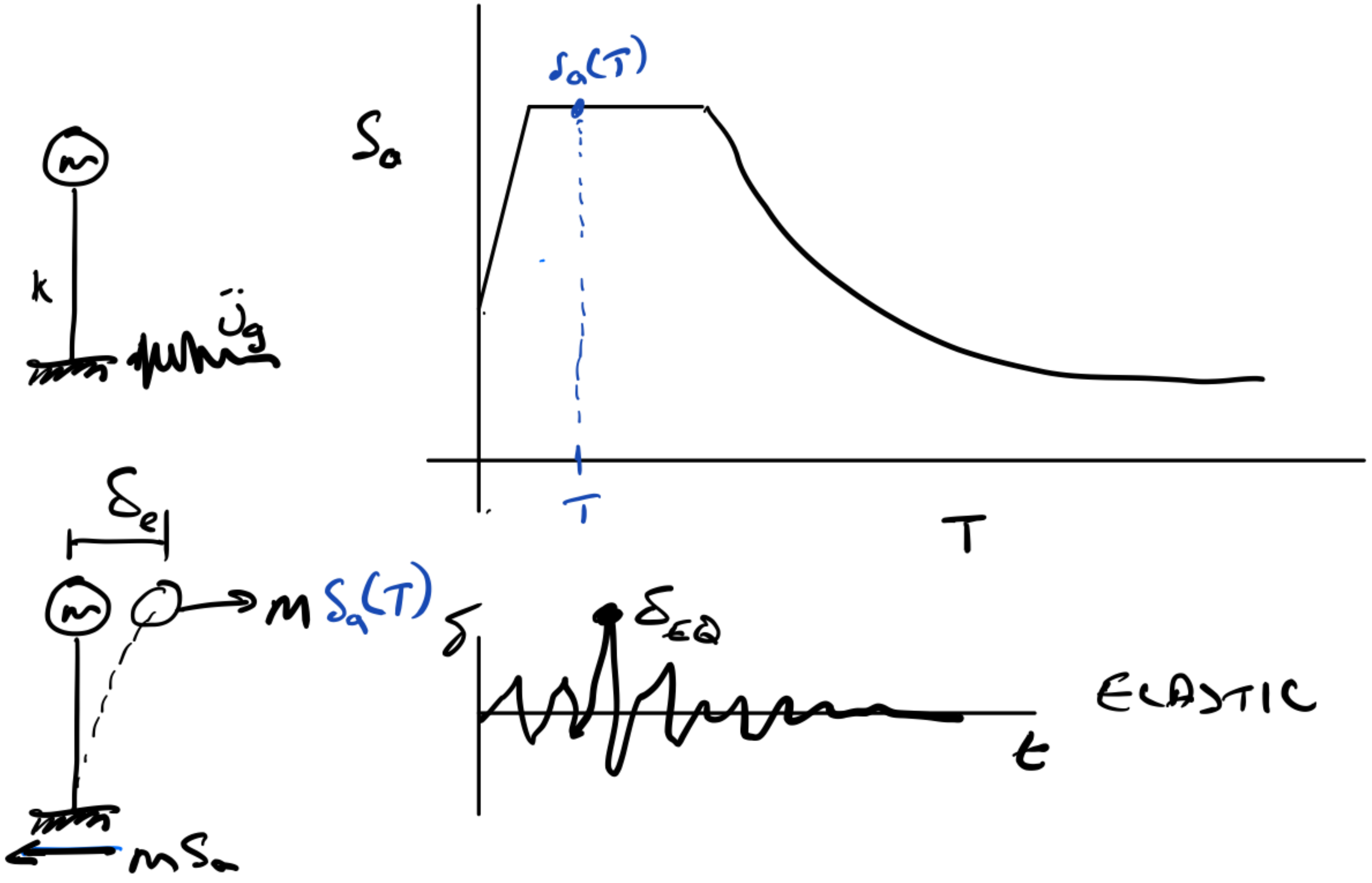
$$\delta_{ASCE7} = C_d \delta_r$$

What ASCE7 expects:



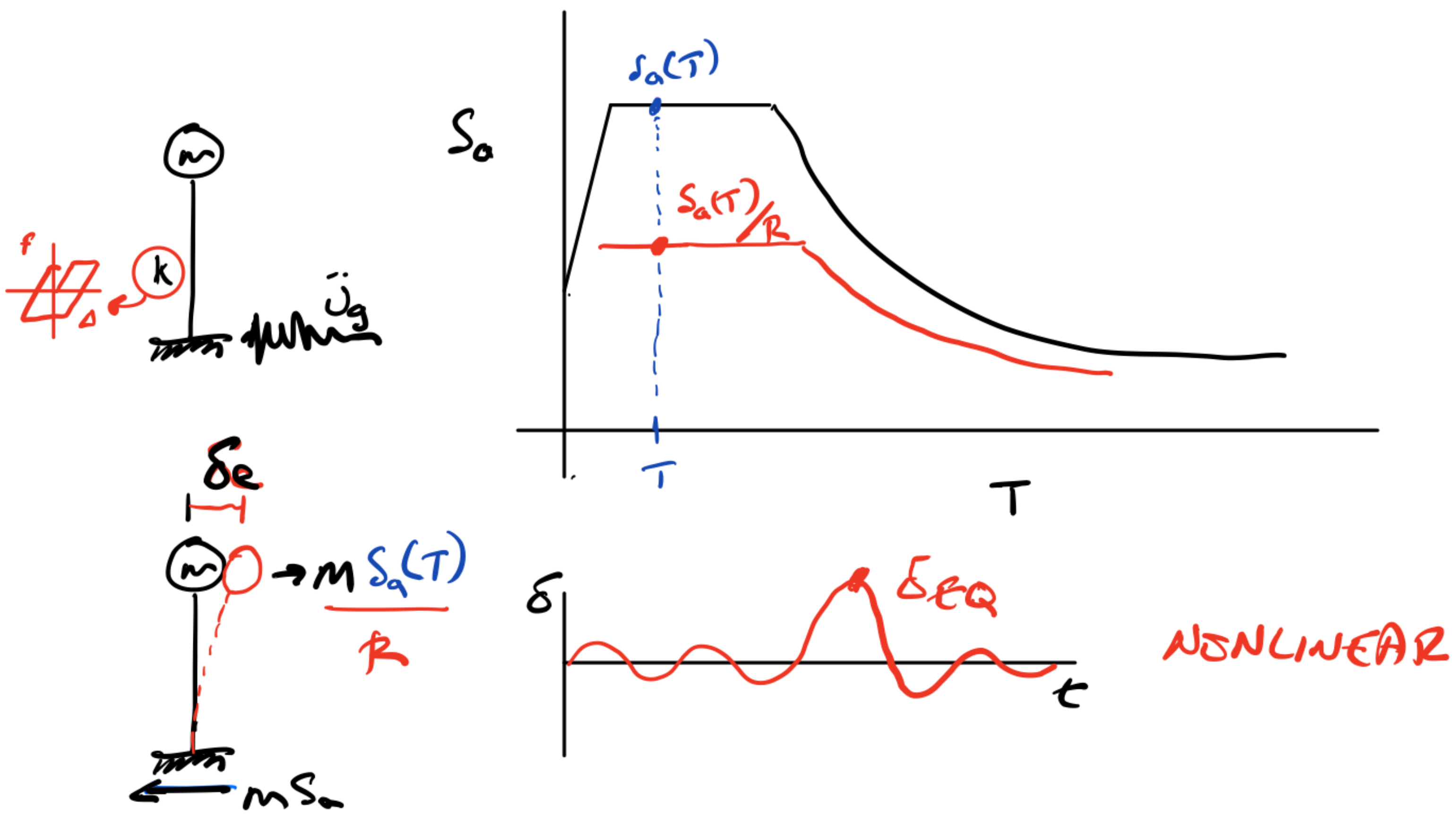
$$\delta_{ASCE7} = C_d \delta_e$$

C_d Background – Elastic Response and ELF



$\delta_e \cong \delta_{EQ}$

C_d Background – Inelastic Response and ELF

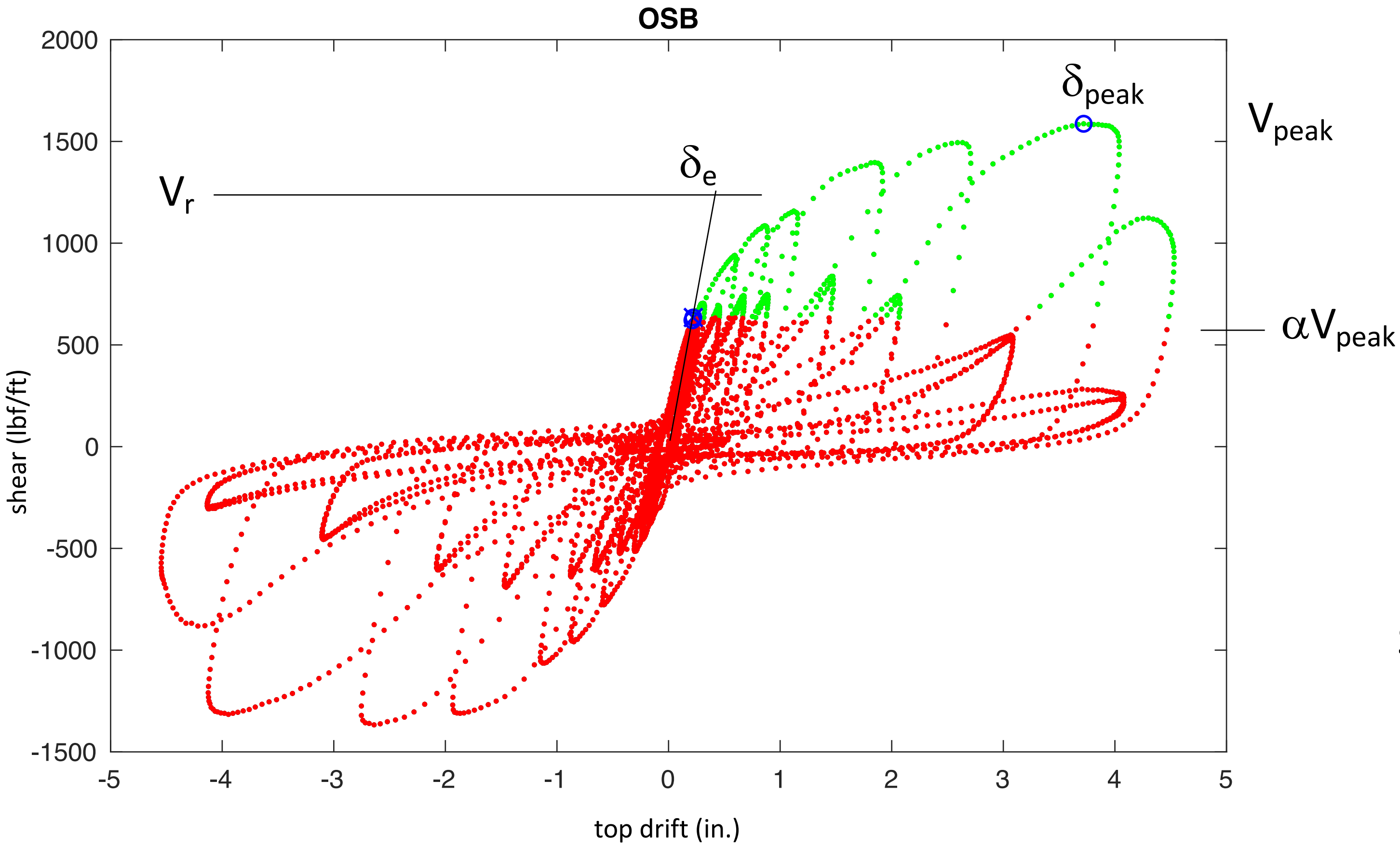


$C_d\,\delta_e \cong \delta_{EQ}$

Objective and discussion

- We want to predict the correct nonlinear drift
- Using the nonlinear response curve and multiplying times C_d is excessively conservative, but what is the correct method?
- Need estimate of the correct nonlinear drift
  - Function of first slope, k
  - Function of shape of the hysteretic response too..
  - Run SDOF time history to establish nonlinear drift
  - Then we can determine appropriate k
- Note, this is improved thinking since February meeting, thanks in part to feedback from C.M. Uang on last presentation; however, work remains in progress.

Shear wall experimental C_d (OSB example)

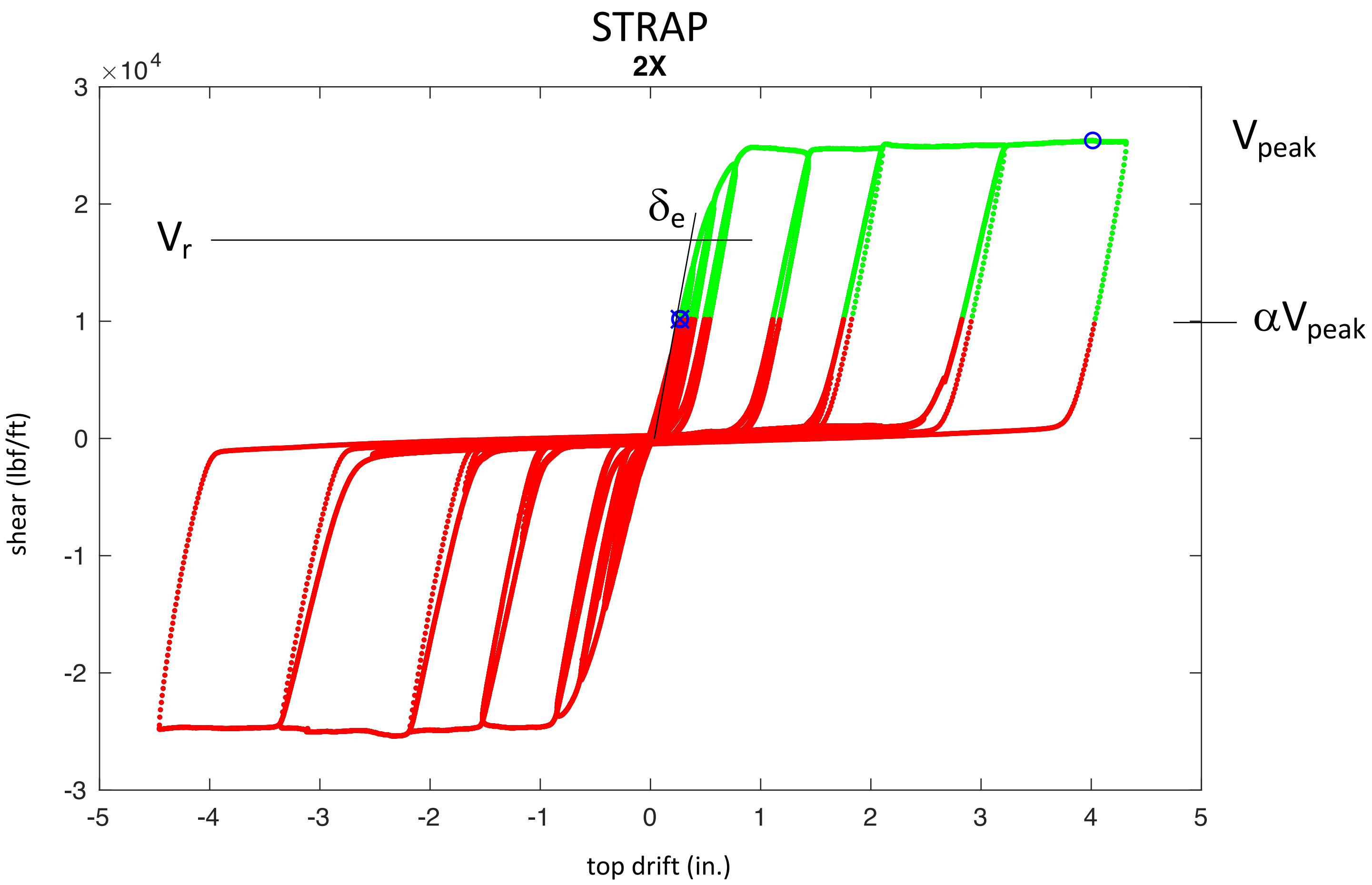


$$\delta_{EQ} \cong C_d \delta_e$$

SDOF time history of actual response to find solution..

At what force level (α) should the linear approximation be set?

Note how different strap wall's appear…



$$\delta_{EQ} \cong C_d \delta_e$$

SDOF time history of actual response to find solution..

Strap walls have longer linear range, but also very pinched…

Conclusions

- Expected strength: we will finalize ballot comments at the meeting in a few weeks and we have a new method that gives realistic “relief” from overstrength provisions and allows engineers some control over the overstrength they are placing into their systems.
- Deflections: we have a clear path forward and have found a PhD student to assist with this part of the calculations. Implementation of deflection provisions does not have to require code change in this cycle, as it is up to the engineer how to use the deflection expressions in AISI S400 in coordination with ASCE 7 – expect that we will simply be able to give better guidance very soon – then we can update Spec. and commentary in time.