Direct Design Software for Masonry Structural Analysis

Ground Rules…

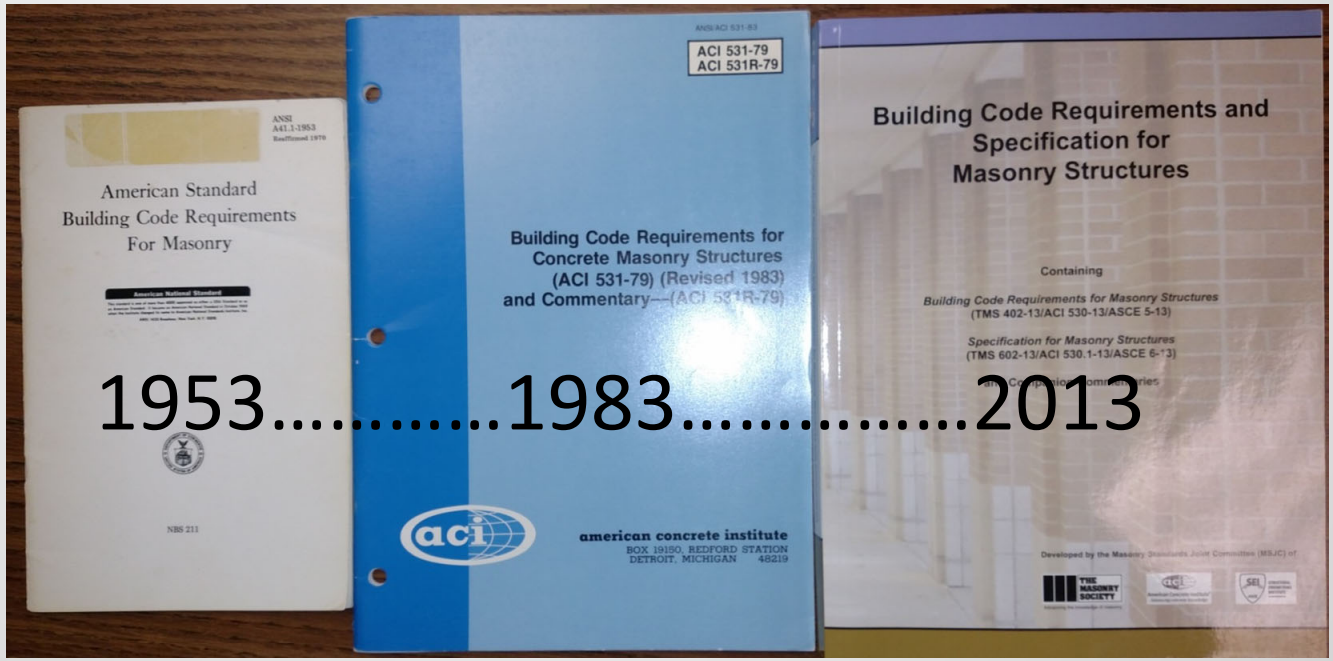
Ask questions any time or use the chat…

Or shoot me an email if you forget…

Jason Thompson
jthompson@ncma.org
703-713-1900

Why was Direct Design Created?

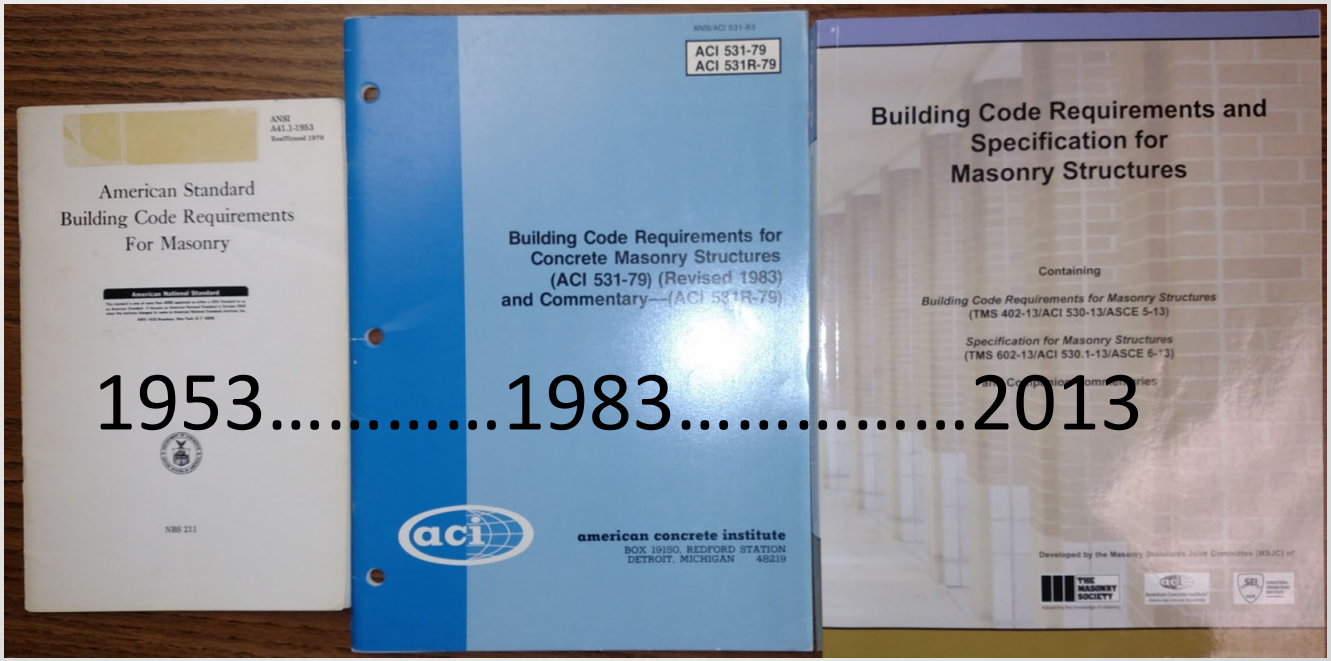
Code complexity…



1953……1983……2013

Why was Direct Design Created?

Code complexity…

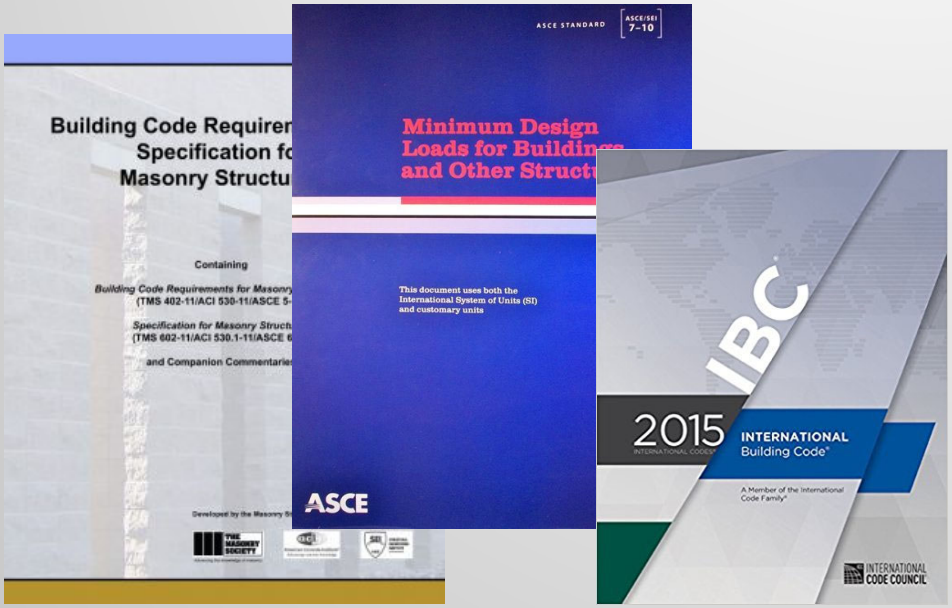


1953……1983……2013

40 pgs……40 pgs……400 pgs

Why was Direct Design Created?

Codes (not just masonry) become more complex with each cycle. The Direct Design Software combines all the relevant structural masonry requirements in one package.



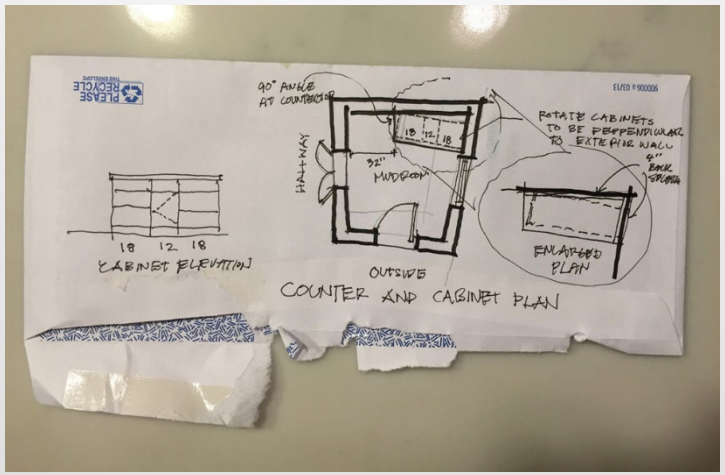
Direct Design

also

Why was Direct Design *Really* Created?

Idea…to concept…to preliminary design

…in minutes

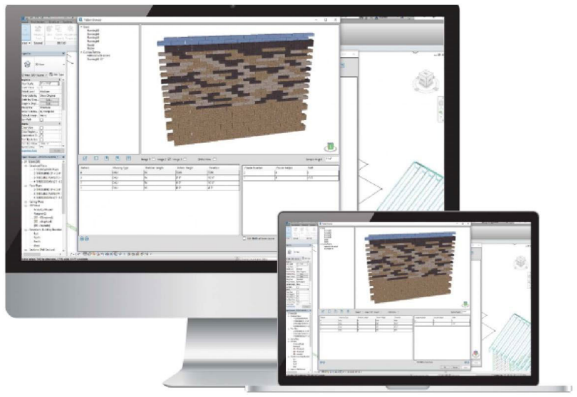


Direct Design

Evolution of Design

With these changes…new tools are needed.

Direct Design



3DiQ

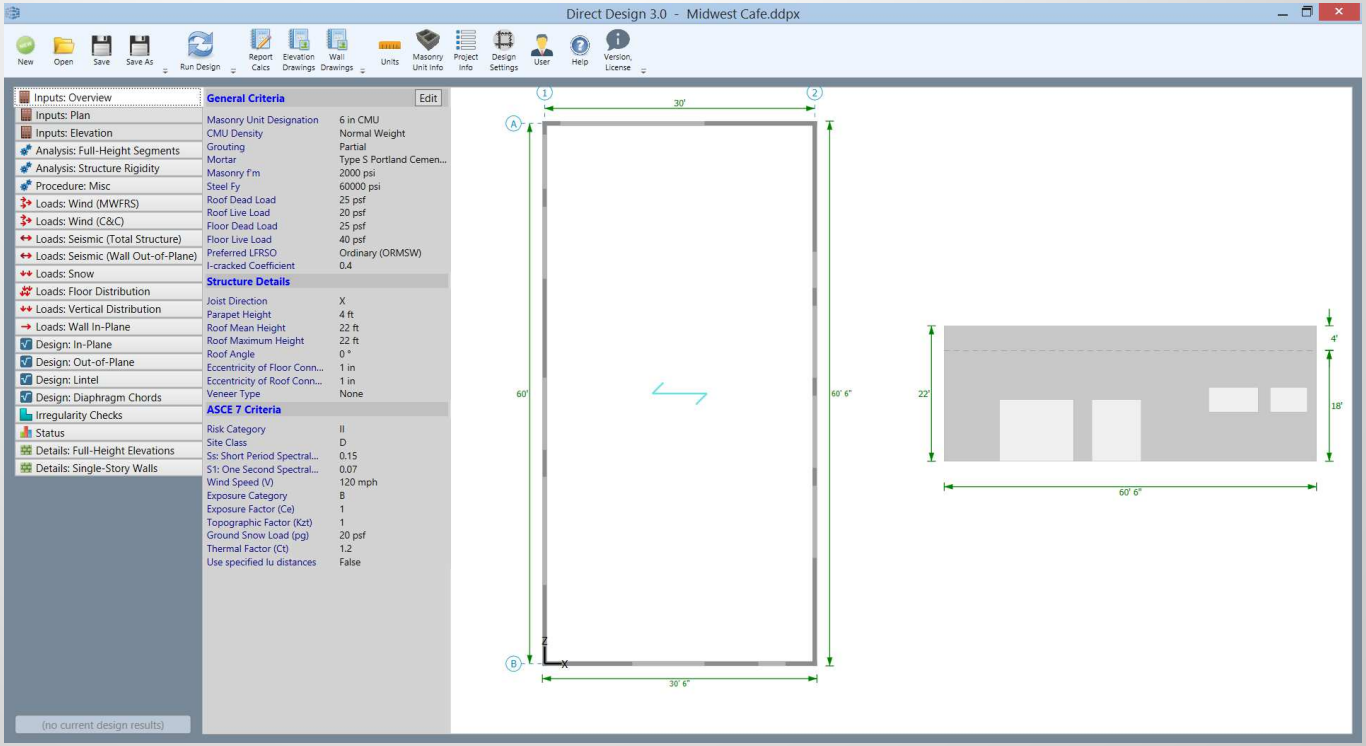
MasonryiQ

Masonry Design Software Plug-In For Revit

Software Inputs

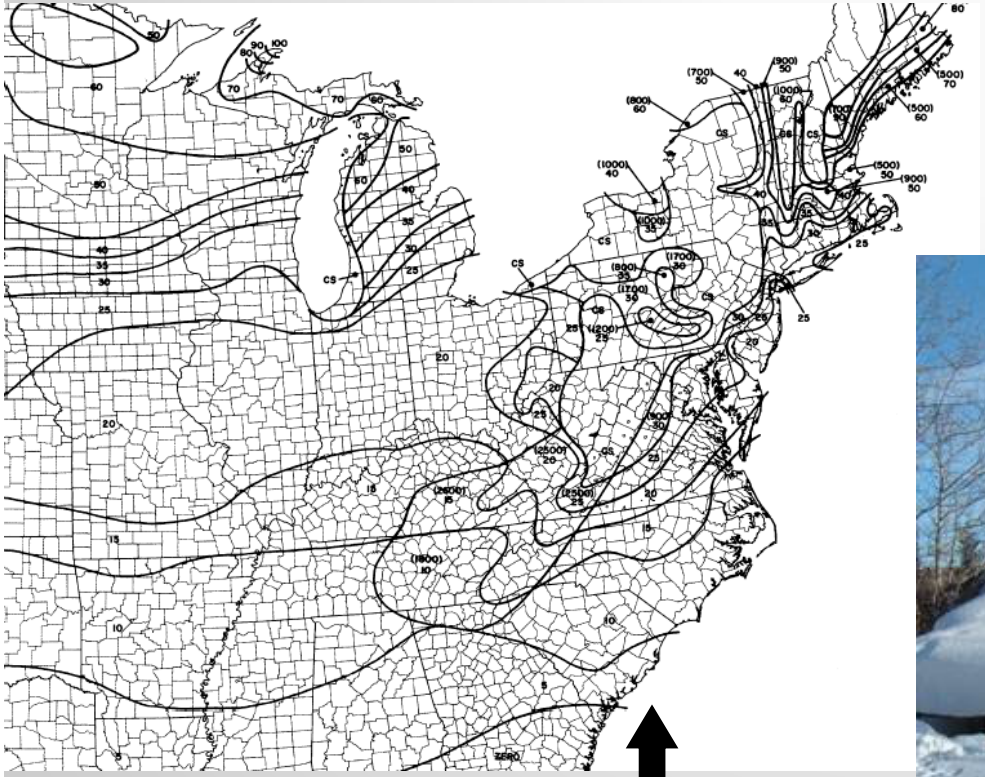
What you need to design a project:

- Building location; and
- Building dimensions



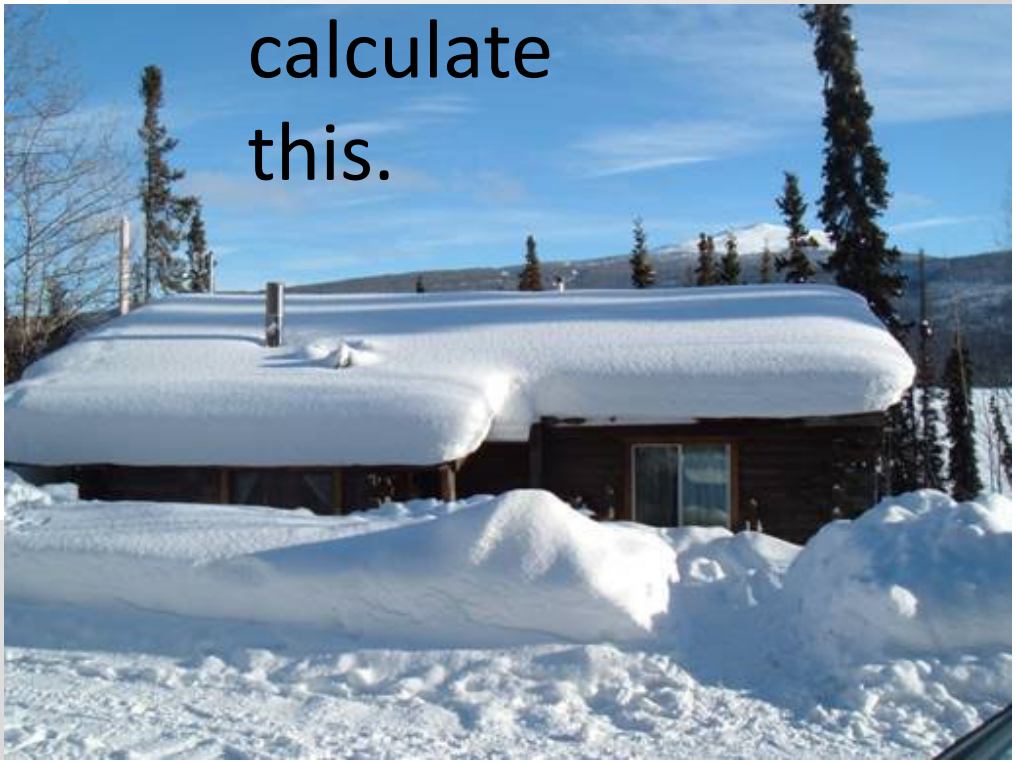
Software Inputs

Mapped Ground Snow Load



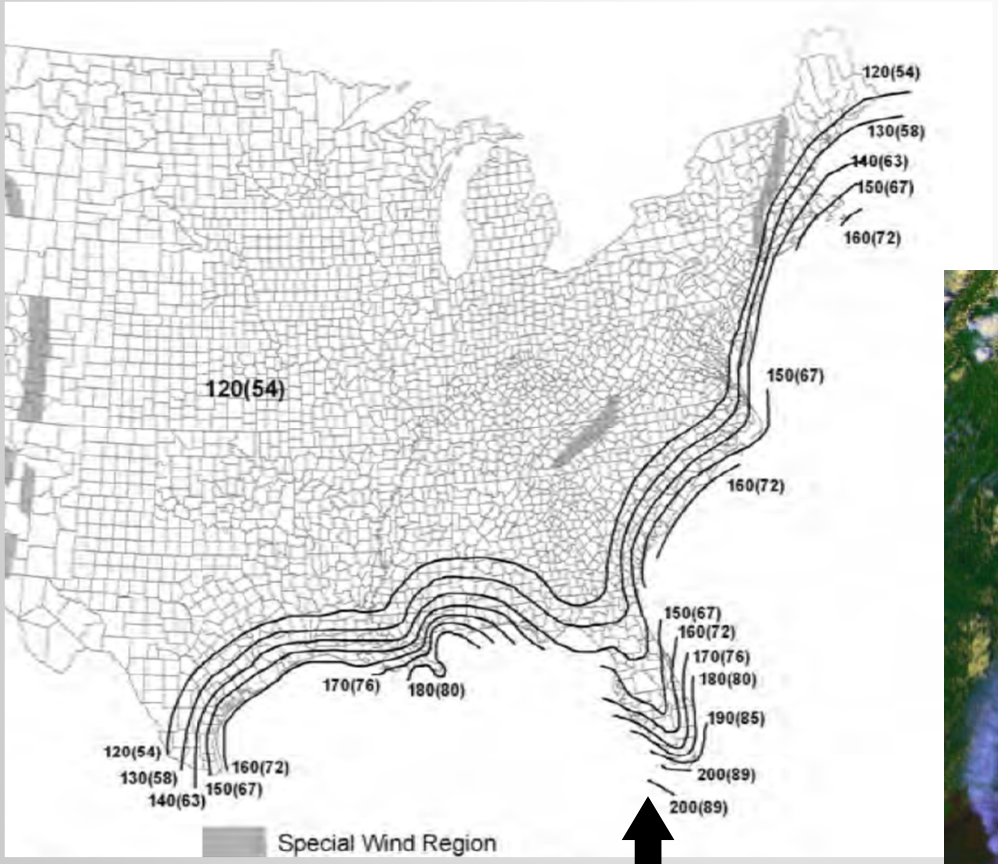
Need to know this.

Software will calculate this.



Software Inputs

Ultimate Wind Speed ≤ 250 mph (ASCE 7-10)

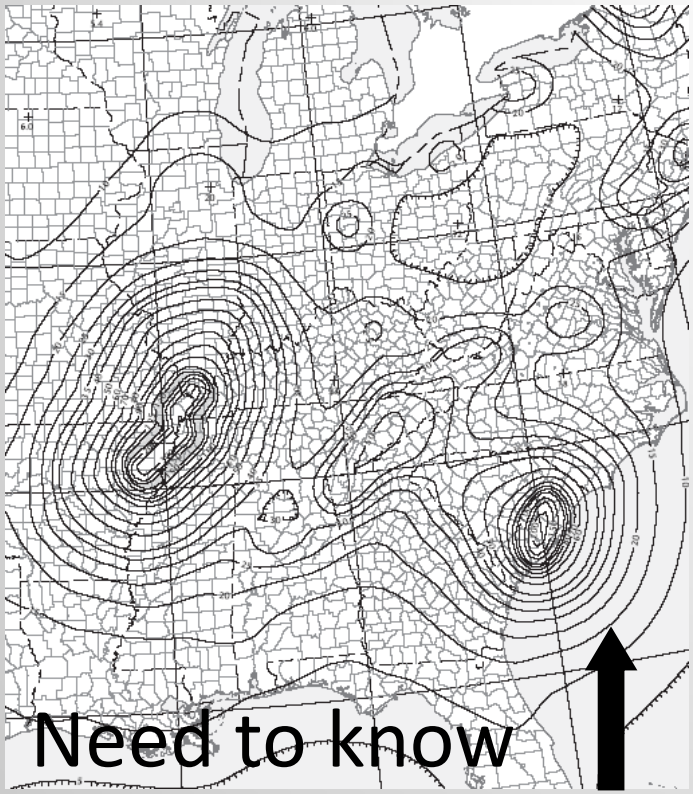


Handbook will calculate this.

Need to know this.

Software Inputs

Mapped Seismic Spectral Accelerations

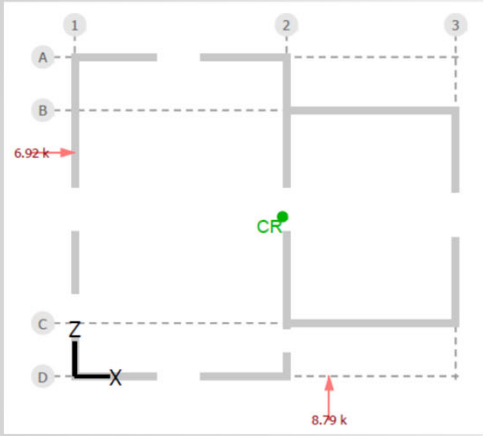


Need to know this.

Handbook will calculate this.

Software Outputs

Entire structural analysis calculations…



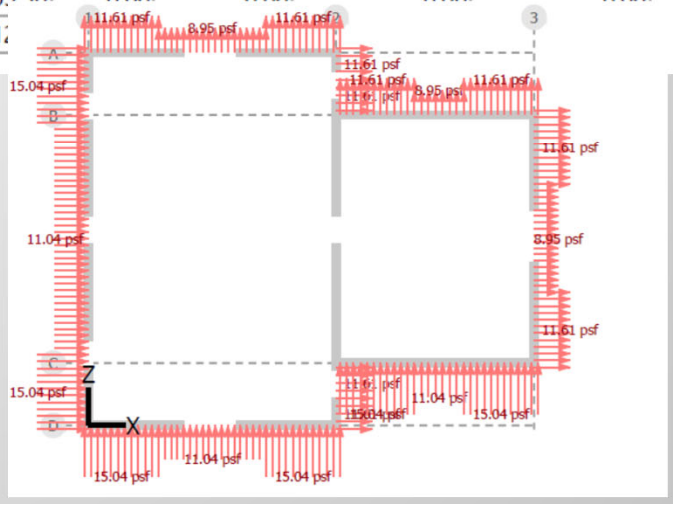
	Reactions at Base of Segment				Relevant Internal Forces			
	Axial Reaction (k)	In-plane Moment Reaction (ft·k)	Distributed Reaction Force Left Value (lb/ft)	Distributed Reaction Force Right Value (lb/ft)	Axial Force At Top (k)	Axial Force At Middle (k)	Out-of-plane Eccentric Moment At top (ft·k)	Out-of-plane Eccentric Moment Middle (ft·k)
Dead	2.76	-0.60	2,283.33	472.22	0.33	1.96	-0.06	-0.03
Snow	0.67	-0.28	750.00	-83.33	0.33	0.67	-0.06	-0.03
$Wind_{C\&C+}$	0.56	-0.23	631.15	-70.82	0.28	0.56	-0.05	-0.02
$Wind_{MWFRS-}$	0.25	-0.10	276.15	-30.68	0.12	0.25	-0.02	-0.01
Seismic	-0.85	0.35	-948.35	102.16	-0.43	-0.85	0.07	0.04
10	0.18	-0.08	207.11	-23.01	0.09	0.18	-0.02	-0.01
11	-0.63	0.26	-711.03	79.00	-0.32	-0.63	0.05	0.03
Rain	0.00	-0.21	309.50	-309.50	0.00	0.00	0.00	0.00
12	0.00	3.74	-5,612.35	5,612				

Vertical distribution factor (C_{v1}), Equation 12.8-12, p. 91:

$$C_{v1} = \frac{w_1 h_1^{\,k}}{\Sigma w_i h_i^{\,k}} = \frac{(333.33\ \text{k})(12.00\ \text{ft})^{1.00}}{22{,}000.00\ \text{ft·k}} = 0.18$$

Lateral seismic force (F_1), Equation 12.8-11, p. 91:

$$F_1 = C_{v1} V = (0.18)(197.33\ \text{k}) = 35.88\ \text{k}$$



Software Outputs

Entire structural analysis calculations…

Segment 1 in Wall along grid C from 2 to 3, Story 3

This segment is 16' 8" long and reinforced with 9 #6 bars.

✔ **Moment check**

ϕM_n = 1,426.40 ft·k, M_u = 4.17 ft·k

✔ **Shear check**

V_m = 203.69 k, V_s = 287.03 k, V_n = 345.55 k, ϕV_n = 276.44 k, $V_{FlexComp}$ = 184.38 k, $V_{FlexTens}$ = 178.30 k, V_u = 20.00 k

✔ **Deflection check**

$\delta_{elastic}$ = 0.01 in, $\delta_{inelastic}$ = 0.01 in, δ_{max} = 1.20 in, I_{gross} = 5,083,333.33 in^4, I_{cells} = 2,660,517.33 in^4, I_{net} = 5,083,333.33 in^4, I_{eff} = 2,033,333.33 in^4

✔ **Rho Max check**

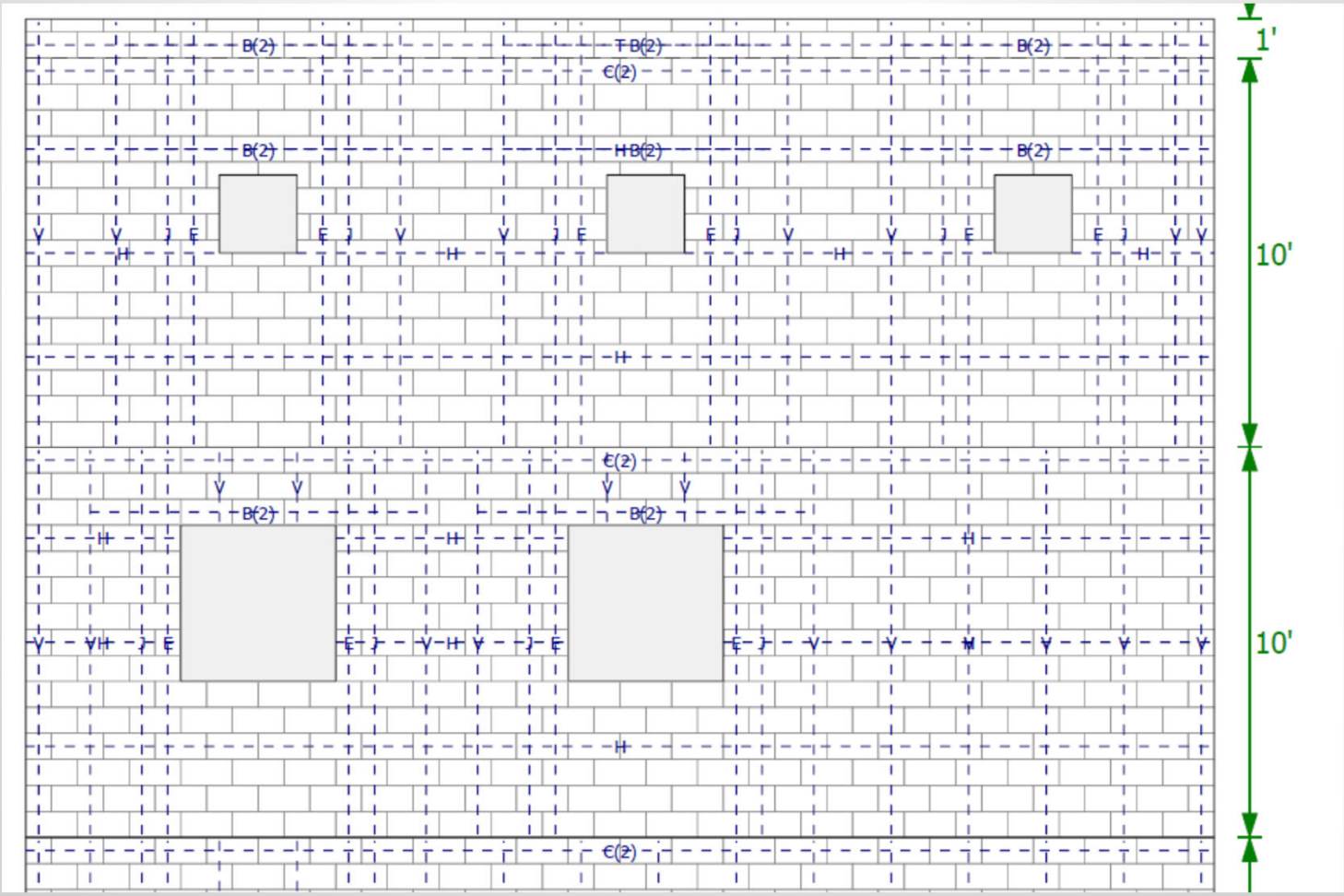
P_u = 10.00 k, $P_{u\_max\_SBE}$ = 305.00 k, SBE condition 1 met = True, $M_u/V_u d_v$ = 0.60, SBE condition 2 met = True, A_{nv} = 1,525.00 in², SBE condition 3 met = True, ρ_{max} check required = False, ε_y = 0.00, ε_{mu} = 0.00, P_{u_RhoMax} = 35.83 k, $A_{s,max}$ = 225.88 in², A_s = 3.96 in²

Step 3 - Structural Irregularities Check

The presence of irregularities impacts the design procedure and the general applicability of Direct Design.

Software Outputs

To the final design…

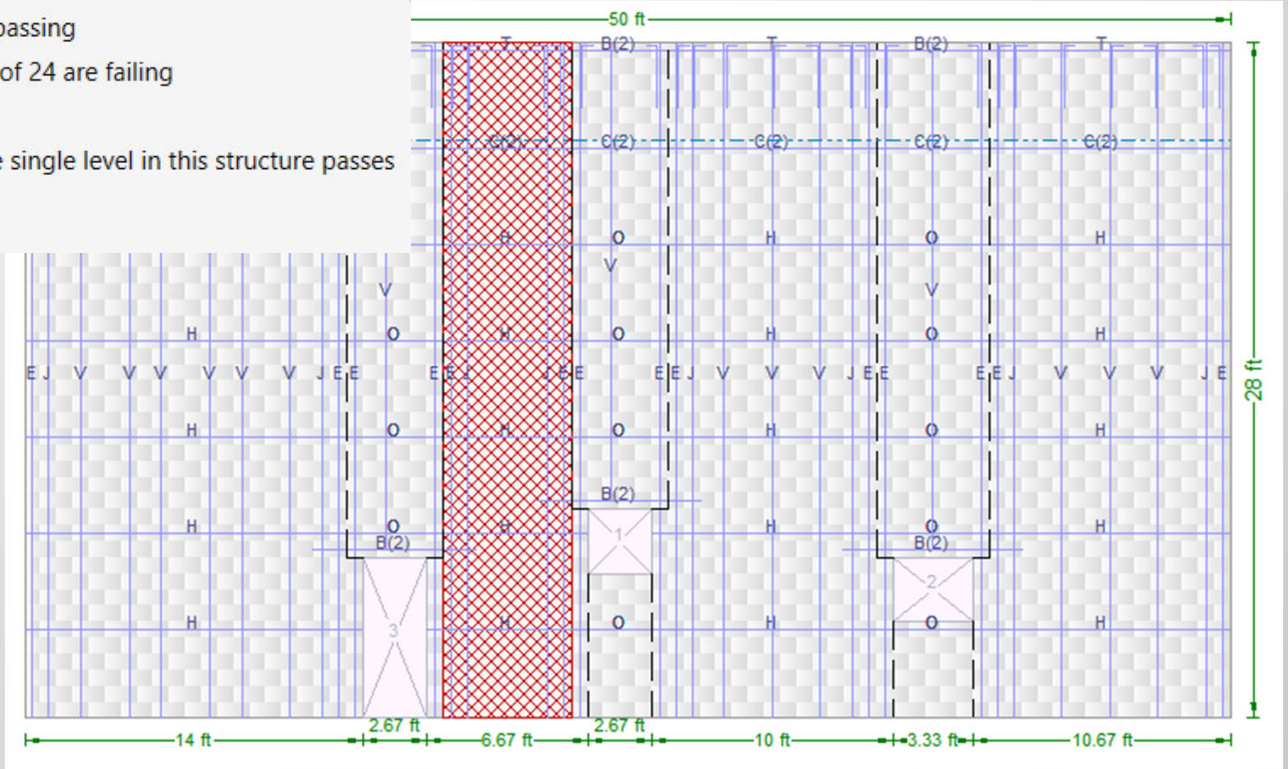


Software Outputs

While flagging sections that the software couldn’t find a solution to.

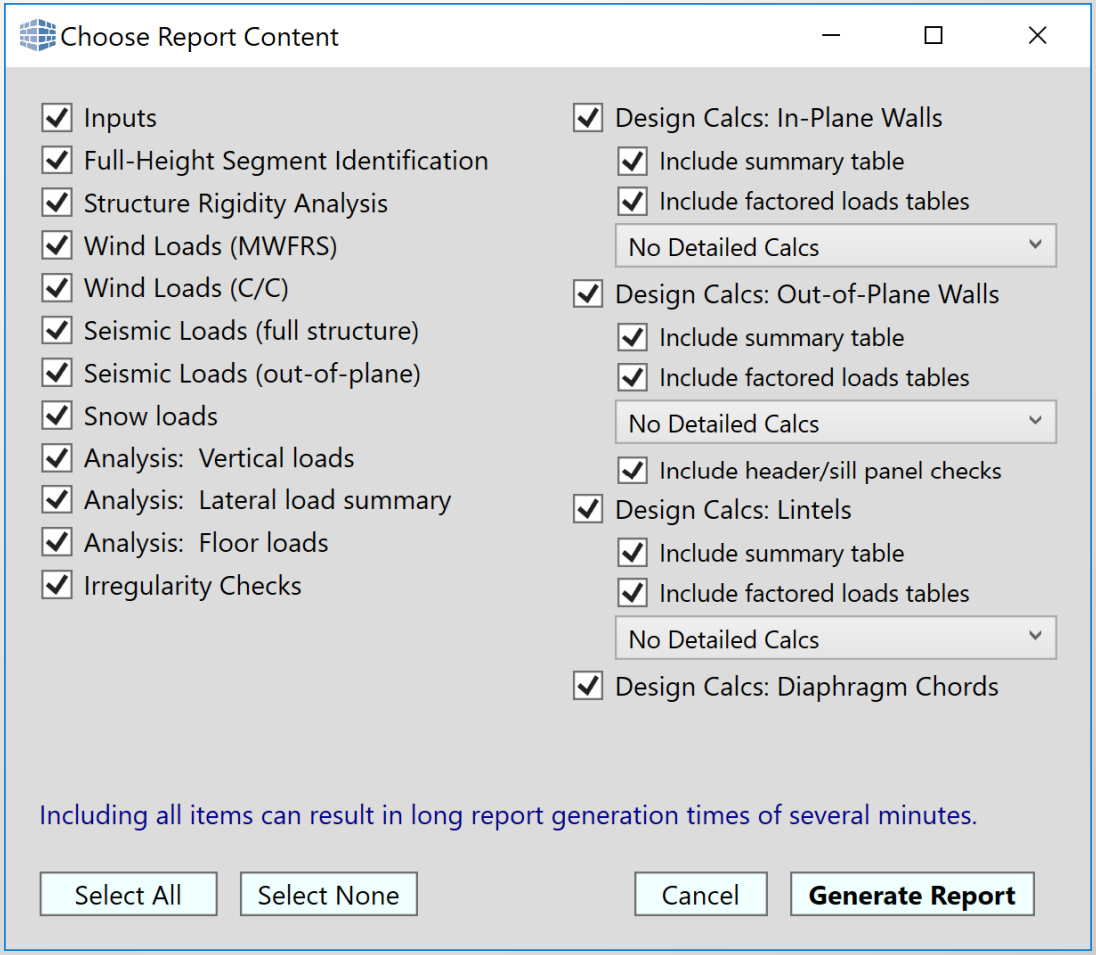
Code Compliance Status

- ✔ Wall Segments (In-Plane Loading): All 24 are passing
- ✖ Wall Segments (Out-of-Plane Loading): 5 out of 24 are failing
- ✔ Lintels: All 10 are passing
- ✔ Diaphragm Levels (Chord Reinforcement): The single level in this structure passes
- ✔ Structure has no irregularities



Software Outputs

Summary or detailed output reports…



What Direct Design Does Not Do.

Does not design the diaphragms (roof/floor).

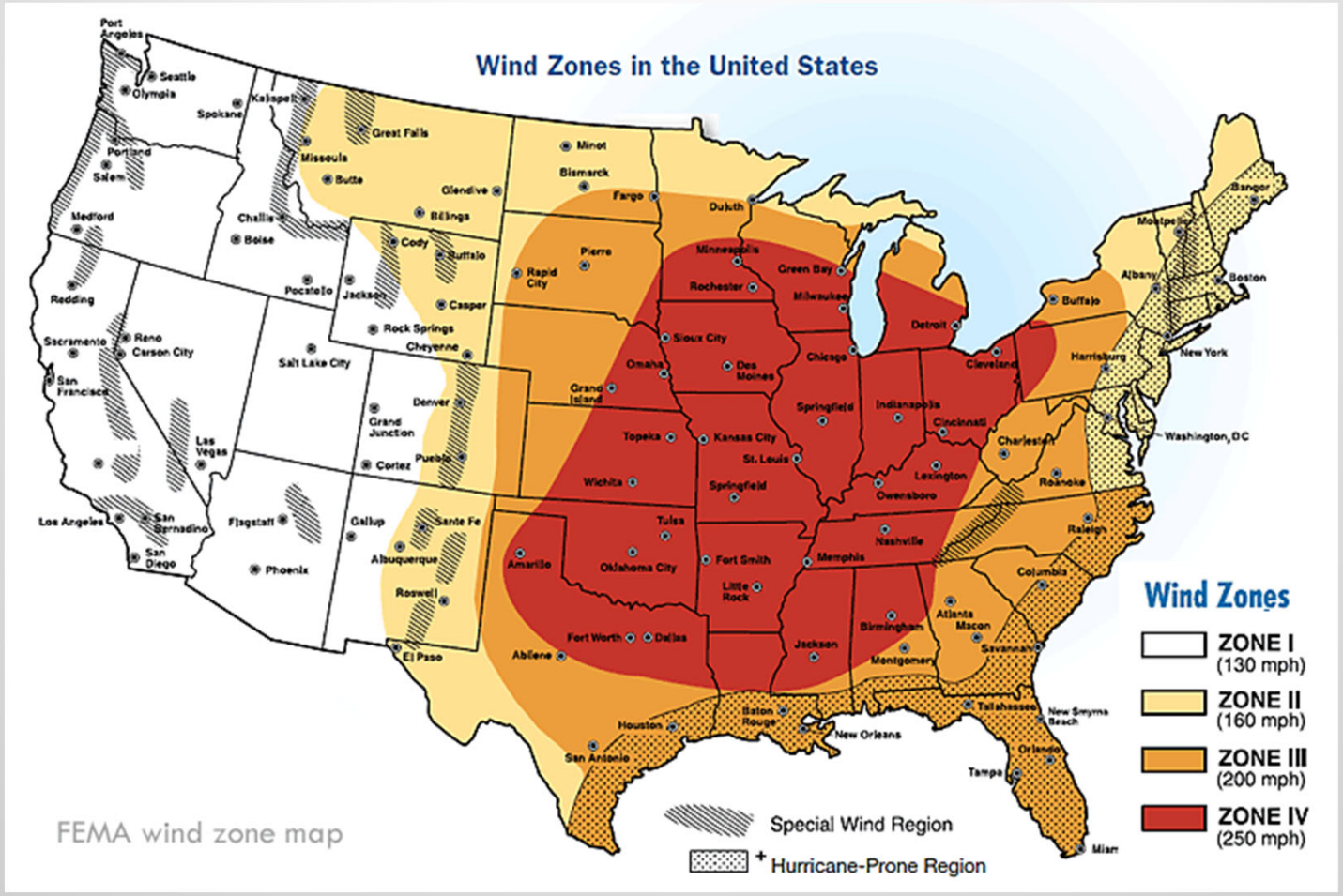
Does not design the foundation.

Does not design the connection system between the masonry and supports.

Limited to the structural and non-structural masonry components.

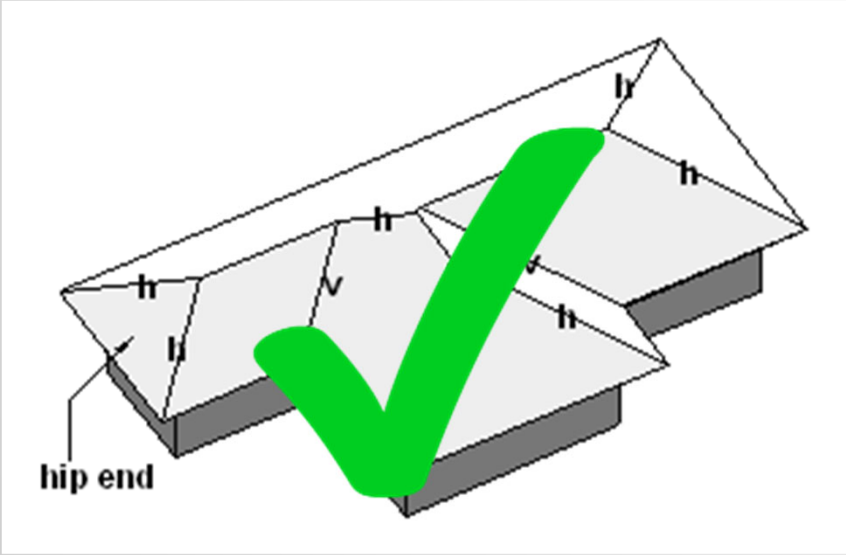
Limitations

- Mapped wind speed ≤ 250 mph



Limitations

- Building height ≤ 60 feet
- No funky roofs



Limitations

- Joist spacing of 10 feet or less.
- Architectural features.

Limitations

- Units must comply with ASTM C90.
- Standard mortar and grout.

2.5.4 *Grout* – Grout shall comply with ASTM C476 and shall have a specified compressive strength, f'_g, that meets or exceeds the specified compressive strength of masonry, f'_m.

Table 2.5.2 – Permitted Mortar Types by Seismic Design Category

SDC A, B, and C	SDC D, E, and F
Type N, S, or M masonry cement mortar	Type S or M mortar cement mortar
Type N, S, or M mortar cement mortar	Type S or M non-air-entrained portland cement-lime mortar
Type N, S, or M portland cement-lime mortar	Type S or M masonry cement mortar used in fully grouted masonry construction

Limitations

- Rebar: No. 4 thru No. 9, Grade 60

Limitations

- Cladding weight $\leq$ 50 psf.

Limitations

- No extreme loading types (e.g., blast).
- Axial load eccentricity t/2 plus 3 inches.

2.4.1 *Load Types* – The provisions outlined in this *Handbook* shall not be applied to the design of structures that include design loads other than roof dead and live loads, floor dead and live loads, snow loads, wind loads, seismic loads, soil loads, and rain loads.

2.4.2 *Eccentricity of Loads* – The maximum eccentricity of applied axial loads shall not exceed half the thickness of the masonry wall plus 3.0 in. (76 mm).

2.4.3 *Concentrated Loads* – Masonry designed in accordance with this *Handbook* shall not support concentrated loads not otherwise permitted by Section 2.3.6.

Limitations

- Diaphragm limits to avoid complex irregularities.

2.3.4 *Diaphragms* – The roof and floor systems shall consist of one or more rigid or flexible diaphragms and meet the following requirements:

- The maximum plan dimension of a single diaphragm shall not exceed 200 ft (61.0 m).

  Each diaphragm shall be rectangular in plan dimensions.

  Diaphragms of a single building shall not be offset in plan.

  The larger plan dimension of a diaphragm shall not exceed four times the shorter plan dimension of the diaphragm.

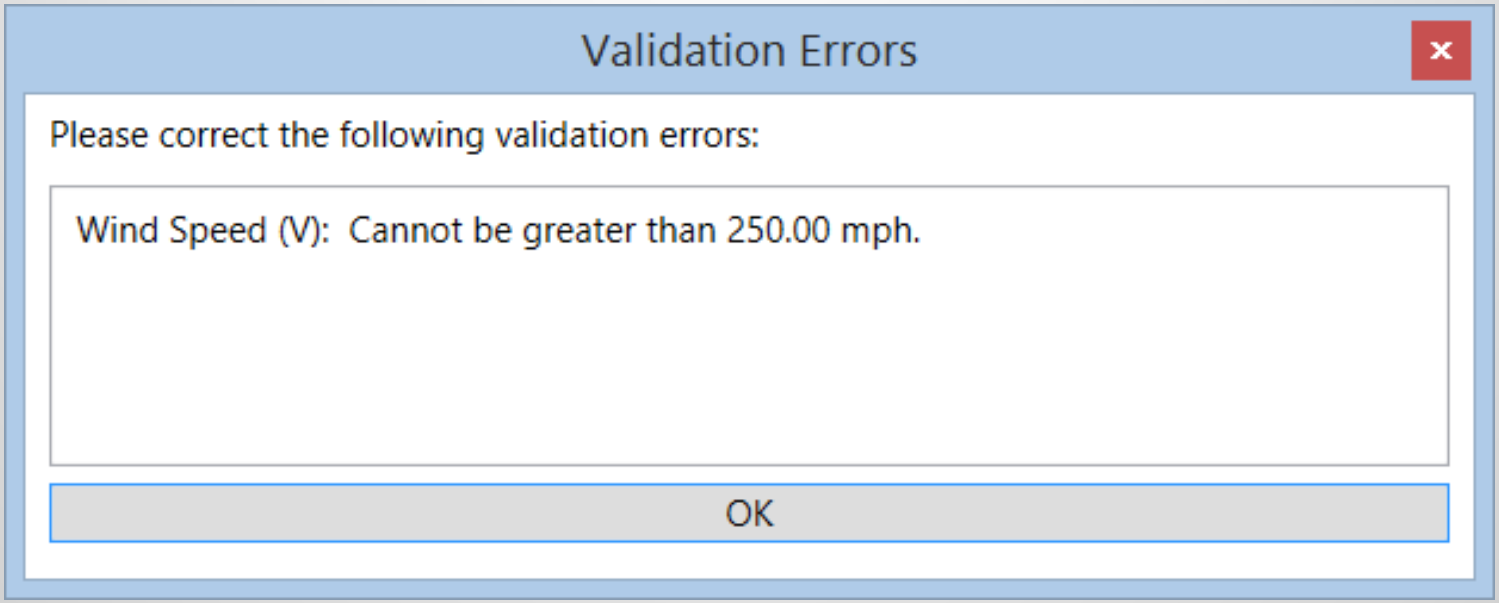
3.2.8.4 *Diaphragm Classification* – Diaphragms shall be classified as either flexible or rigid in accordance with Table 3.2.8.4.

Table 3.2.8.4 – Diaphragm Classification

Diaphragm Construction	Diaphragm Classification
Wood structural panels	Flexible
Untopped steel decking	Flexible
Concrete slab	See Section 3.2.8.4.1
Concrete filled deck	See Section 3.2.8.4.1
Other – flexible diaphragm	Flexible
Other – rigid diaphragm	Rigid

Limitations

If a software input isn't covered by Direct Design, an error message will appear.



Gut-Check

Direct Design targets the design of:

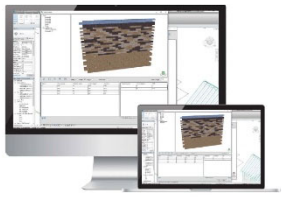
- Common masonry buildings;
- The majority of the masonry in these buildings.

Integration

Few use one software package today…

AUTODESK REVIT

EleMasonry

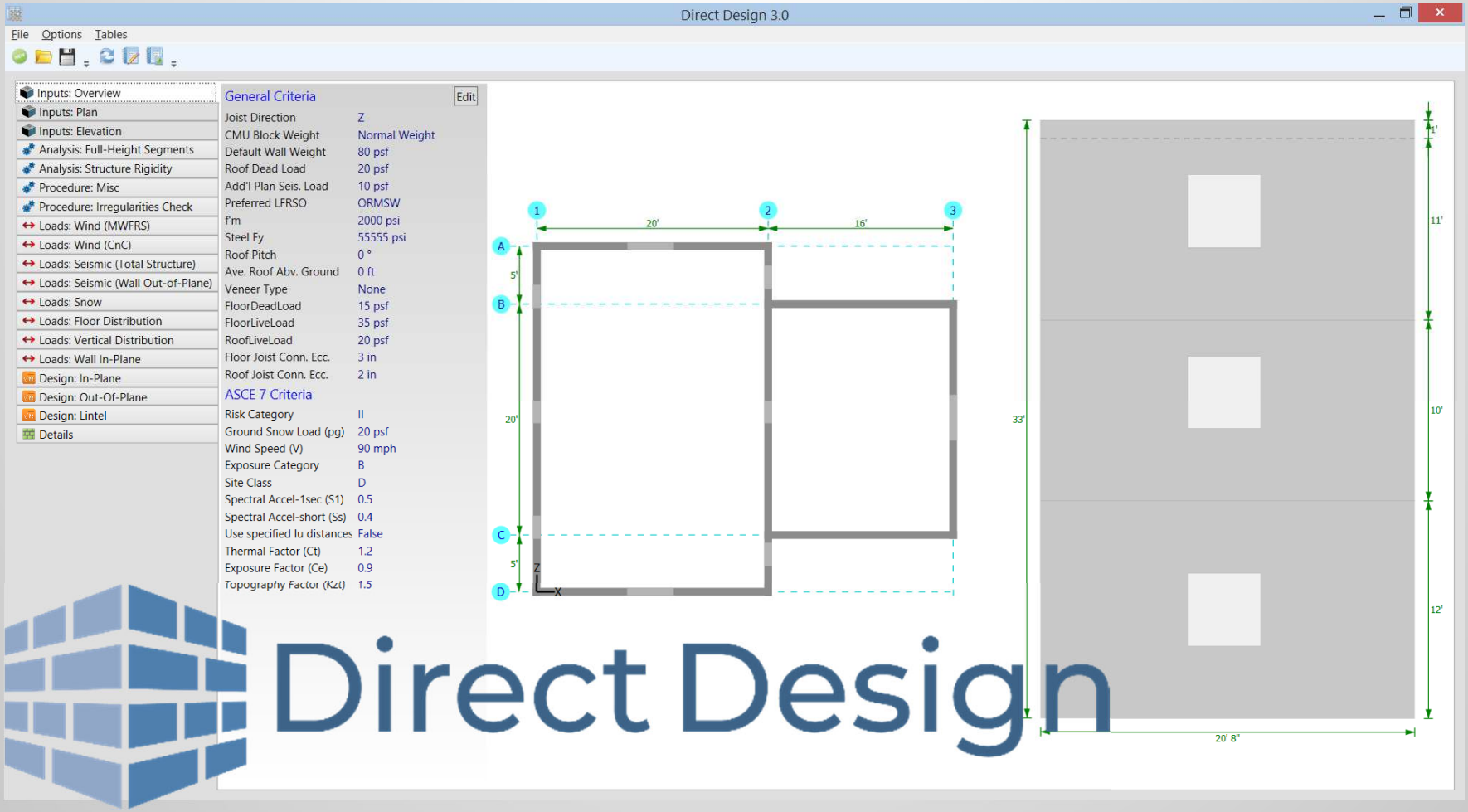


3DiQ
MasonryiQ
Masonry Design Software
Plug-In For Revit

Direct Design

Software Demo

Using the software…



Questions?

Thank you for your time!

13750 Sunrise Valley Drive
Herndon, VA 20171
703.713.1900
jthompson@ncma.org
www.ncma.org