APPENDIX S

STRUCTURAL DESIGN

SECTION AS101 GENERAL

AS101.1 Scope. The provisions of this chapter contain the structural design alternatives to the prescriptive requirements of Part III – Building Planning in this code. The structural design provisions for the design of portions shall be subject to the provisions of Sections R301.1.2 and R301.1.3. As an alternative to the provisions of this chapter, an engineered design in accordance with the *Oregon Structural Specialty Code* is permitted.

SECTION AS102 MINIMUM LOADS

AS102.1 General. Minimum loads shall be in accordance with allowable stress design (ASD) or load and resistance factor (strength) design (LRFD) as recommend herein for structures covered by this code or ASCE Standard 7. The individual loads used in the load combinations of Table AS101.2(1) shall be determined in accordance with Sections AS101.2.1 through AS101.2.7.

AS102.1.1 Climatic and geographic criteria. Structures shall be constructed to comply with climatic and geographic conditions criteria as set forth in Table R301.2(1).

AS102.1.2 Dead load. Dead loads shall include permanent construction material loads comprising the roof, floor, wall and foundation systems, including claddings, finishes, and fixed equipment. See Tables AS101.2(2) and AS101.2(3) for weights and densities of commonly used materials and construction in dwelling structures.

AS102.1.3 Live loads. The minimum uniformly distributed live load shall be as provided in Table R301.4.

AS102.1.4 Snow loads. The minimum roof snow load shall be 25 pounds per square feet below elevations per county as shown in Table R301.1(1). For elevations above those shown in this table, see *Snow Load Analysis of Oregon*, published by the Structural Engineers of Oregon, revised 2/78. The value of roof (or other member) snow load, *Pf*, is permitted to be adjusted where the ground snow load is greater than 25 pounds per square feet in accordance with the following formula, which includes consideration of snow drifts:

$p = 0.8\ C_e C_s p_g$

where,

p = roof snow load (psf)

p_g = ground snow load (psf)

C_e = exposure factor
= 0.8 for windy areas with open exposure
= 1.0 for typical suburban areas
= 1.2 for sheltered or wooded areas

C_s = roof slope factor
= 1.0 for slopes = 6:12
= 0.9 for 7:12 up to 8:12 slopes
= 0.8 for 8:12 up to 9:12 slopes
= 0.7 for 9:12 up to 10:12 slopes
= 0.6 for 10:12 up to 11:12 slopes
= 0.5 for 11:12 up to 12:12 slopes
= 0.4 for 12:12 slope

TABLE AS101.2(1)
LOAD COMBINATIONS TYPICLLY USED FOR THE DESIGN OF RESIDENTIAL BUILDING COMPONENTS AND SYSTEMS[1]

COMPONENT OR SYSTEM	ASD LOAD COMBINATIONS	LRFD LOAD COMBINATIONS
Foundation Wall Gravity & Soil Lateral Loads	D + H D + H + L + 0.3(L_r or S) D + H + (L_r or S) + 0.3L	1.2D + 1.6H 1.2D + 1.6H + 1.6L + 0.5(L_r or S) 1.2D + 1.6H + 1.6(L_r or S) + 0.5L
Headers, Girders, Joists, Interior Load Bearing Walls, Footings (Gravity Loads)	D + L + 0.3 (L_r or S) D + (L_r or S) + 0.3L	1.2D + 1.6L + 0.5(L_r or S) 12D + 1.6(L_r or S) + 0.5L
Exterior Load-Bearing Walls (Gravity and Wind Lateral Load)	Same as immediately above plus, D + W D + 0.7E + 0.5L + 0.2S	Same as immediately above plus, 1.2D + 1.6W 1.2D + 1.0E + 0.5L + 0.2S
Roof Rafters, Trusses, and Beams; Roof and Wall Sheathing (Gravity and Wind Loads)[3]	D + (L_r or S) 0.6D + W_u D + W[2]	1.2D + 1.6(L_r or S) 0.9D + 1.6 W_u 1.2D + 1.6W
Floor Diaphragms and Shear Walls (Lateral and Overturning Loads)	0.6E + W 0.6D + 0.7E	0.9D + 1.6W 0.9D + 1.0E

1. Symbols are as follows: D (dead); H (soil); L (floor live); S (roof snow); L_r (roof live); W (wind); and E (earthquake).
2. When the live load on an element or assembly includes live loads (i.e., attic or floor) from more than one story, the combination of live loads may be multiplied by 0.75. The adjusted live load combination shall not produce a load less than that of the single largest live load.
3. W_u is for wind uplift loads only whereas W refers to wind lateral building loads as well as positive or negative surface pressures on components.

TABLE AS101.2(2)
TYPICAL DEAD LOADS FOR COMMON RESIDENTIAL CONSTRUCTION

Roof Construction	
Light wood framing, with wood structural panel sheathing & 1/2-inch gypsum board ceiling	12 psf
-with asphalt shingle roofing	15 psf
-with conventional clay tile or slate roofing	27 psf
-with light weight tile or concrete shingles	24 psf
-with metal roofing	14 psf
-with wood shakes or shingle	15 psf
-with tar and gravel	18 psf
Floor Construction	
Light wood framing, with 3/4-inch wood structural panel sheathing & 1/2-inch gypsum board ceiling (without 1/2-inch gypsum board ceiling subtract 2 psf from all values) with carpet vinyl or similar floor covering	10 psf[1]
-with wood flooring	
-with ceramic tile and thin-set or dry-set mortar	12 psf
-with 1/2-inch slate or ceramic tile with 1/2-inch mortar bed	15 psf
	19 psf
Wall Construction	6 psf
Light-frame 2×4 wood wall with 1/2-inch wood structural panel sheathing and 1/2-inch gypsum board finish (for 2×6, add 1 psf to all values)	
-with vinyl or aluminum siding	7 psf
-with lap wood siding	8 psf
-with 7/8-inch Portland cement stucco siding	15 psf
-with thin-coat-stucco on insulation board	9 psf
-with 3 1/2-inch brick veneer	45 psf
Interior partition walls (2×4 with 1/2-inch gypsum board applied to both sides	6 psf

FOUNDATION CONSTRUCTION	MASONRY [2] Hollow	MASONRY [2] Solid or Full Grout	CONCRETE
4-inch-thick wall	22 psf	—	48 psf
6-inch-thick wall	28 psf	60 psf	75 psf
8-inch-thick wall	36 psf	80 psf	100 psf
10-inch-thick wall	44 psf	100 psf	123 psf
12-inch-thick wall	50 psf	125 psf	145 psf
6-inch × 12-inch concrete footing			73 plf
6-inch × 16-inch concrete footing			97 plf
8-inch × 24-inch concrete footing			193 plf

1. Value also used for roof rafter construction (i.e., cathedral ceiling).
2. For partially grouted masonry, interpolate between hollow and solid grout in accordance with the fraction of masonry cores that are grouted.

TABLE AS101.2(3)
DENSITIES FOR COMMON RESIDENTIAL CONSTRUCTION MATERIALS

Aluminum	170 pcf	Water	62.4 pcf
Copper	556 pcf		
Steel	492 pcf	Structural wood panels	
		-plywood	36 pcf
Concrete (normal weight w/reinforcement)	145-150 pcf	-oriented strand board	36 pcf
Masonry, grout	140 pcf		
Masonry, brick	100-130 pcf	Gypsum board	48 pcf
Masonry, concrete	85-135 pcf		
		Stone	
Glass	160 pcf	-granite	96 pcf
		-sandstone	82 pcf
Wood (approximately 10% moisture content)[1]			
-spruce-pine-fir (G = 0.42)	29 pcf	Sand, dry	90 pcf
-spruce-pine-fir (G = 0.36)	25 pcf	Gravel, dry	105 pcf
-southern yellow pine (G = 0.55)	38 pcf		
-Douglas fir-larch (G = 0.5)	34 pcf		
-hem-fir (G = 0.43)	30 pcf		
-mixed oak (G = 0.68)	47 pcf		

1. The equilibrium moisture content of lumber is usually not more than 10 percent in protected building construction. The specific gravity, *G*, is the decimal fraction of dry wood density relative to that of water. Therefore, at a 10 percent moisture content, the density of wood is 1.1(G)(62.4 lbs/ft^3). The values given are representative of average densities and may easily vary by a much as 15 percent depending on lumber grade and other factors.

TABLE AS101.2.4(1)
CLASSIFICATION OF BUILDING ENCLOSURE CONDITION

PARTIALLY-ENCLOSED BUILDING	ENCLOSED BUILDING
All buildings with intentional openings in the exterior envelop exceeding the lesser of 4 ft^2 or 1% of the total projected wall or roof area on any building side (such as attached carports).	All buildings not classified as 'partially enclosed.'

For SI: 1 square foot = $0.0929m^2$.

Notes:

1. Building enclosure condition affects internal pressures experienced within the building. Because internal pressure acts inward or outward on all exterior building surfaces simultaneously, the net effect on lateral building loads is zero. Therefore, building enclosure condition does not affect determination of lateral building loads in Section AS101.2.4.5.1.
2. Open buildings are not addressed; refer to ASCE 7 for appropriate wind loads. Open buildings have openings in each wall which exceed 80 percent of the wall area.

TABLE AS101.2.4(2)
LATERAL WIND LOADS FOR APPLICATION TO VERTICAL PROJECTED WALL AND ROOF AREA
(EXPOSURE B, MEAN ROOF HEIGHT 30 FEET)

BASIC WIND SPEED (mph)	DESIGN WIND PRESSURE (psf)					
	For Roof VPA by Roof Slope			For Wall VPA by Roof Slope		
	20° (4:12)	25° (5.6:12)	30° (7:12)	10° (2:12)	20° (4:12)	30° (7:12)
85	0	2.4	7.7	10.2	12.5	11.2
90	0	2.7	8.6	11.4	14.0	12.6
100	0	3.3	10.7	14.0	17.3	15.5
110	0	4.0	12.9	17.0	20.9	18.8
120	0	4.8	15.4	20.2	25.3	22.4
130	0	5.6	18.0	23.7	29.2	26.3
140	0	6.5	20.9	27.5	33.6	30.5
150	0	7.4	24.0	31.6	38.9	35.0

For SI: 1 foot = 304.8 mm.

Notes:

1. Table applies to wind Exposure Category B (urban, suburban, or wooded terrain). For Exposure Category C (open or coastal exposure), multiply table values by 1.4.
2. Table applies to a mean roof height of 30 feet. For other mean roof heights from 15 feet to 40 feet, multiply table values by the following factor: $f_h = 0.0087\,(h) + 0.74$ where h is the mean roof height in feet.
3. Interpolation between reported wind speeds and roof slopes shall be permitted. For roof slopes greater than 45 degrees (12:12), use wall VPA value.
4. Extrapolation to wind speeds other than shown shall be permitted by multiplying tabulated values by the ratio of squared wind speeds. For example, a wall VPA pressure of 20.9 psf at 110 mph from the table can be used to determine a pressure for a 170 mph wind speed by multiplying as follows: $(20.9\text{ psf}) \times (170/110)^2 = 49.9$ psf.

TABLE AS101.2.4(3)
WIND UPLIFT LOADS FOR APPLICATION TO ROOF SYSTEM HORIZONTAL PROJECTED AREA
(EXPOSURE B, MEAN ROOF HEIGHT 30 FEET)[1,2,3,4]

BASIC WIND SPEED (mph)	ROOF UPLIFT PRESSURE (psf) BY BUILDING ENCLOSURE CONDITION AND ROOF SLOPE				OVERHANG UPLIFT PRESSURE (psf) BY ROOF SLOPE	
	Partially-Enclosed		Enclosed			
	20° (4:12)	25° (5.6:12)	20° (4:12)	25° (5.6:12)	20° (4:12)	25° (5.6:12)
85	17	11	13	8	19	12
90	19	13	14	9	21	13
100	23	16	17	11	26	17
110	28	19	21	13	32	20
120	33	23	25	16	38	24
130	39	27	29	18	45	28
140	45	31	34	21	52	32
150	52	35	39	24	60	37

For SI: 1 foot = 304.8 mm.

1. Table applies to wind Exposure Category B (urban, suburban, or wooded terrain). For Exposure Category C (open or coastal exposure), multiply table values by 1.4.
2. Table applies to a mean roof height of 30 feet. For other mean roof heights from 15 feet to 40 feet, multiply table values by the following factor: $f_h = 0.0087\,(h) + 0.74$ where h is the mean roof height in feet.
3. For hip roofs, multiply roof uplift pressure by 0.9 for roof slope less than 25 degrees (5.6:12) and 0.8 for roof slope greater than 25 degrees (5.6:12). This adjustment does not apply to overhangs on hip roofs.
4. Apply roof uplift pressure to horizontal projected area bounded by exterior walls. Apply overhang uplift pressure to horizontal projected area of overhangs projecting outward from exterior walls.
5. Interpolation for roof slopes between 20 degrees (4:12) and 25 degrees (5.6:12) and reported wind speeds shall be permitted.
6. Extrapolation of tabulated pressures to wind speeds other than shown shall be done in accordance with note 4 of Table AS101.2.4(2).

TABLE AS101.2.4(4)
DESIGN WIND PRESSURES (psf) FOR COMPONENTS AND CLADDING
(ENCLOSED BUILDING, EXPOSURE B, MEAN ROOF HEIGHT 30 FEET)[1,2,3,4]

COMPONENT	85 mph		90 mph		100 mph		110 mph	
	Inward	Outward	Inward	Outward	Inward	Outward	Inward	Outward
Roof Components								
Roof Framing	12	-12	13	-13	17	-17	20	-20
Roof Sheathing, Purlins, etc.	12	-18	13	-20	17	-25	20	-30
Roof Skylights, Glazing, etc.	12	-18	13	-20	17	-25	20	-30
Roofing (nonair permeable)[5]	12	-21	13	-23	17	-29	20	-35
Roof Overhang (framing only)[6]	12	-24	13	-27	17	-33	n/a	-40
Wall Components								
Wall Framing	12	-12	13	-13	17	-17	20	-20
Wall Sheathing (panels, boards, girts)	12	-18	13	-20	17	-25	20	-30
Windows, Doors, Glazing	12	-18	13	-20	17	-25	20	-30
Garage Doors	12	-12	13	-13	17	-17	20	-20
Siding (nonair permeable)[6]	12	-18	13	-20	17	-25	20	-30

COMPONENT	120 mph		130 mph		140 mph		150 mph	
	Inward	Outward	Inward	Outward	Inward	Outward	Inward	Outward
Roof Components								
Roof Framing	24	-24	27	-27	32	-32	37	-37
Roof Sheathing, Purlins, etc.	24	-36	27	-42	32	-49	37	-56
Roof Skylights, Glazing, etc.	24	-36	27	-42	32	-49	37	-56
Roofing (nonair permeable)[5]	24	-42	27	-49	32	-57	37	-65
Roof Overhang (framing only)[6]	n/a	-48	n/a	-56	n/a	-65	n/a	-74
Wall Components								
Wall Framing	24	-24	27	-27	32	-32	37	-37
Wall Sheathing (panels, boards, girts)	24	-36	27	-42	32	-49	37	-56
Windows, Doors, Glazing	24	-36	27	-42	32	-49	37	-56
Garage Doors	24	-24	27	-27	32	-32	37	-37
Siding (nonair permeable)[5]	24	-36	27	-42	32	-49	37	-56

1. Table applies to wind Exposure Category B (urban, suburban, or wooded terrain). For Exposure Category C (open or coastal exposure), multiply table values by 1.4.
2. Table applies to enclosed buildings. For partially enclosed buildings, multiply table values by 1.25.
3. Table applies to a mean roof height of 30 feet or less. For mean roof heights greater than 30 feet and not exceeding 40 feet, multiply table values by the following factor: f_h = 0.0087 (h) + 0.74 where h is the mean roof height in feet.
4. Interpolation between reported wind speeds shall be permitted. Extrapolation of tabulated pressures to wind speeds other than shown shall be done in accordance with Note 4 of Table A2.
5. Nonair permeable claddings (siding and roofing) do not allow venting of air either through the siding or through cavities behind the cladding that lead to vent openings on the same face of the building. Most claddings are air-permeable to some degree and provide some reduction in wind load, provided the supporting wall behind the cladding is relatively nonair permeable. For vinyl cladding, ASTM D 3679 permits a 50 percent reduction in wind load for this reason. Similarly, claddings such as brick veneer (with weeps and vent space) and hardboard lap siding have been reported to experience cladding wind load reductions of 30 percent or more. Wind loads on roofing, such as asphalt shingles, have been reported to experience wind load reductions of as much as 75 percent. Refer to the cladding manufacturer for an appropriate air-permeable cladding reduction factor to use. Consideration should also be given to the dynamic nature of wind pressures (e.g., fluttering) and its potential effect (e.g., fatigue) on some cladding systems and related connections.
6. Roof overhang pressure includes pressure from underside of the overhang as well as on the upper surface. If an “open soffit” is used, the roof overhang pressure should also apply to the roof sheathing (if sheathed) or the roofing (if not sheathed underneath).

AS102.1.5 Wind loads, general. The following wind load requirements provide for simplified wind loads for use by qualified design professionals in the design of buildings meeting the following conditions:

1. Light-frame, concrete, or masonry construction using shear walls and horizontal diaphragms to resist lateral loads.
2. Mean roof height of 40 feet (12 192 mm) or less.
3. One- and two-family dwellings, townhouses, apartments and their accessory structures (wind load importance factor of 1.0)

In this method, a single wind pressure for each roof and wall vertical projected area and the roof horizontal projected area is used to determine main wind force resisting system loads. For components and cladding loads, surface pressures are determined for specific building elements such that multiple pressure zones are not required to be separately evaluated. As an alternative, the simplified wind design based on the 1997 Edition of the *Uniform Building Code* as allowed in the 2004 *Oregon Structural Specialty Code* is permitted to be used.

AS102.1.5.1 Basic wind speed. The site design wind speed (mph, 3-second gust) shall be determined from Figure R301.2(4). If relying on either on the fastest-mile wind speed or older design provisions based on fastest-mile wind speeds, the design shall convert wind speed in accordance with Table R301.2.1.3.

AS102.1.5.2 Wind exposure and topography. The provisions of this appendix are based on wind Exposure Category B (suburban, urban, or wooded terrain) as defined in Section R301.2.4. For buildings located in wind Exposure Category C (open or coastal terrain), tabulated Exposure B wind loads shall be increased by a factor 1.4 [see table notes as applicable in Tables AS101.2.4(2) and AS101.2.4(3)]. Building sited within 10 building heights from the top edge of a prominent topographic feature shall be designed in accordance with the *Oregon Structural Specialty Code* or ASCE 7. A prominent topographic feature has a ground slope of greater than 15 percent and a vertical rise of greater than 50 feet (15 240 mm), and is separated from features of similar or greater height by a distance of more than 100 times the height of the topographic feature.

AS102.1.5.3 Building enclosure condition. Building enclosure condition shall be classified in accordance with Table AS101.2.4(1) for the purpose of determining wind loads in accordance with Section AS101.2.4.

AS102.1.5.4 Wind loads.

AS102.1.5.4.1 Lateral-force-resisting system loads. Wind pressures from Table AS101.2.4(2) shall be applied to building roof and wall vertical projected areas (VPA) corresponding to each of four elevations of the building to determine maximum lateral wind forces (shear) tributary to horizontal diaphragms, shear walls, and related connections.

AS102.1.5.4.2 Roof system uplift loads. Wind pressures from Table AS101.2.4(3) shall be applied to the horizontal projected areas (HPA) of a roof system to determine uplift loads tributary to structural elements, assemblies and connections that experience loads from multiple roof surfaces.

AS102.1.5.4.3 Components and cladding loads. Table AS101.2.4(4) shall be used to determine inward (positive) and outward (negative) acting wind loads tributary to wall and roof components, cladding and related connections. Design wind pressures shall be applied perpendicular to the tributary area of the component, cladding, or connection under consideration.

AS102.1.6 Earthquake loads. The site design ground motion is based on a calculated S_{DS} value (derived from the short period spectral response acceleration, S_s, and value of site coefficient, F_a) is based on a default Site Class D for the determination of the seismic design category in Table R301.2(1). The total seismic shear load (lateral) is determined by the following formula using the S_{DS} values from Table AS101.2.5(1):

$$V = 1.2[(S_{DS})(W)]/R$$

Where, V = seismic story shear or total base shear (lbs)

W = weight of the building (dead load only) supported by the story or shear plane under consideration (lbs)

R = seismic response modifier per Table AS101.2.5(2)

For application of soil conditions other than Site Class D, see Section R301.2.2.1.1.

TABLE AS101.2.5(1)
SDS VALUES FOR SEISMIC SHEAR LOAD

SEISMIC DESIGN CATEGORY	S_{DS} VALUE
C	0.42g
D_1	0.72g
D_2	1.17g

TABLE AS101.2.5(2)
SEISMIC RESPONSE MODIFIERS – *R*

BUILDING SYSTEM	*R*
Wood-frame walls with wood structural panel sheathing	6.5
Masonry Walls -unreinforced -nominally reinforced	 1.5 4.5
Concrete walls -unreinforced -nominally reinforced	 2 5.5

AS102.1.6.1 Distribution of story shear load. The story shear load shall be distributed to share walls in a manner that does not induce unacceptable torsional response or overloading due to differences in stiffness of various structural systems or building configuration. Methods to distribute forces shall consider reasonable engineering judgment and analysis methods. Shear loads shall be considered acting along both major axis of the dwelling.

AS102.1.7 Soil lateral loads. A value of 35 psf shall be permitted to be used as the design lateral soil load for shallow foundations walls which meet the following conditions:

1. A maximum of 9 feet (2743 mm) of unbalanced backfill depth,
2. The backfill is not required to be compacted to optimum density, and
3. Foundation and surface water drainage is provided.

Where other conditions exist, the lateral soil pressure, P, shall be determined using the following formula:

$P = qh$ (psf)

The active soil force, H, (pounds per lineal foot of wall applied at depth, $2/3h$) is:

$H = {}^1/_2 qh^2$ (plf)

The formula above do not apply to foundations subject to hydrostatic pressure, such as may occur in flood hazard zones.