Equivalent Lateral Loads using UBC-97

General Terms

- **BASE** is the level at which the earthquake motions are considered to be imparted to the structure or the level at which the structure as a dynamic vibrator is supported.

- **BASE SHEAR**, is the total design lateral force or shear at the base of a structure.

- **BRACED FRAME** is an essentially vertical truss system of the concentric or eccentric type that is provided to resist lateral forces.

- **BUILDING FRAME SYSTEM** is an essentially complete space frame that provides support for gravity loads.

General Terms

- **CANTILEVERED COLUMN ELEMENT** is a column element in a lateral-force-resisting system that cantilevers from a fixed base and has minimal moment capacity at the top, with lateral forces applied essentially at the top.

- **COLLECTOR** is a member or element provided to transfer lateral forces from a portion of a structure to vertical elements of the lateral-force-resisting system.

- **COMPONENT** is a part or element of an architectural, electrical, mechanical or structural system.

General Terms

- **DESIGN BASIS GROUND MOTION** is that ground motion that has a 10 percent chance of being exceeded in 50 years as determined by a site-specific hazard analysis or may be determined from a hazard map. A suite of ground motion time histories with dynamic properties representative of the site characteristics shall be used to represent this ground motion. The dynamic effects of the Design Basis Ground Motion may be represented by the Design Response Spectrum.

General Terms

- **DIAPHRAGM** is a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical-resisting elements. The term “diaphragm” includes horizontal bracing systems.

- **LATERAL-FORCE-RESISTING SYSTEM** is that part of the structural system designed to resist the Design Seismic Forces.

- **MOMENT-RESISTING FRAME** is a frame in which members and joints are capable of resisting forces primarily by flexure.

- **MOMENT-RESISTING WALL FRAME (MRWF)** is a masonry wall frame especially detailed to provide ductile behavior and designed in conformance with Section 2108.2.5.

- **ORDINARY BRACED FRAME (OBF)** is a steel-braced frame designed in accordance With the provisions of Section 2-9

General Terms

STORY is the space between levels. Story x is the story below Level x.

STORY DRIFT is the lateral displacement of one level relative to the level above or below.

STORY DRIFT RATIO is the story drift divided by the story height.

STORY SHEAR, is the summation of design lateral forces above the story under consideration.

STRENGTH is the capacity of an element or a member to resist factored load as specified in Chapters 16, 18, 19, 21 and 22.

STRUCTURE is an assemblage of framing members designed to support gravity loads and resist lateral forces. Structures may be categorized as building structures or non-building structures.

CRITERIA SELECTION

1629.1 Basis for Design

The procedures and the limitations for the design of structures shall be determined considering

1) seismic zoning
2) site characteristics
3) occupancy configuration,
4) structural system and
5) height in accordance with this section

CRITERIA SELECTION

1629.1 Basis for Design (contd)

Structures shall be designed with adequate strength to withstand the lateral displacements induced by the Design Basis Ground Motion, considering the inelastic response of the structure and the inherent redundancy, over-strength and ductility of the lateral-force- resisting system.

The minimum design strength shall be based on the Design Seismic Forces determined in accordance with the static lateral force procedure of Section 1630, except as modified by Section 1631.5.4.

1. Occupancy Category

<u>1629.2 Occupancy Categories</u>.

For purposes of earthquake resistant design, each structure shall be placed in one of the occupancy categories listed in Table 16-K.

1. Occupancy Category

TABLE 16-K—OCCUPANCY CATEGORY

OCCUPANCY CATEGORY	OCCUPANCY OR FUNCTIONS OF STRUCTURE	SEISMIC IMPORTANCE FACTOR, I
1. Essential facilities[2]	Group I, Division 1 Occupancies having surgery and emergency treatment areas Fire and police stations Garages and shelters for emergency vehicles and emergency aircraft Structures and shelters in emergency-preparedness centers Aviation control towers Structures and equipment in government communication centers and other facilities required for emergency response Standby power-generating equipment for Category 1 facilities Tanks or other structures containing housing or supporting water or other fire-suppression material or equipment required for the protection of Category 1, 2 or 3 structures	1.25
2. Hazardous facilities	Group H, Divisions 1, 2, 6 and 7 Occupancies and structures therein housing or supporting toxic or explosive chemicals or substances Nonbuilding structures housing, supporting or containing quantities of toxic or explosive substances that, if contained within a building, would cause that building to be classified as a Group H, Division 1, 2 or 7 Occupancy	1.25
3. Special occupancy structures[3]	Group A, Divisions 1, 2 and 2.1 Occupancies Buildings housing Group E, Divisions 1 and 3 Occupancies with a capacity greater than 300 students Buildings housing Group B Occupancies used for college or adult education with a capacity greater than 500 students Group I, Divisions 1 and 2 Occupancies with 50 or more resident incapacitated patients, but not included in Category 1 Group I, Division 3 Occupancies All structures with an occupancy greater than 5,000 persons Structures and equipment in power-generating stations, and other public utility facilities not included in Category 1 or Category 2 above, and required for continued operation	1.00
4. Standard occupancy structures[3]	All structures housing occupancies or having functions not listed in Category 1, 2 or 3 and Group U Occupancy towers	1.00
5. Miscellaneous structures	Group U Occupancies except for towers	1.00

2. Site Geology and Soil Chracteristics

1629.3 Site Geology and Soil Characteristics.

Each site shall be assigned a soil profile type based on properly substantiated geotechnical data using the site categorization procedure set forth in Division V, Section 1636 and Table 16-J.

EXCEPTION: When the soil properties are not known in sufficient detail to determine the soil profile type, Type S_D shall be used. Soil Profile Type S_E or S_F need not be assumed unless the building official determines that Type S_E or S_F may be present at the site.

2. Site Geology and Soil Chracteristics

TABLE 16-J—SOIL PROFILE TYPES

SOIL PROFILE TYPE	SOIL PROFILE NAME/GENERIC DESCRIPTION	AVERAGE SOIL PROPERTIES FOR TOP 100 FEET (30 480 mm) OF SOIL PROFILE		
		Shear Wave Velocity, $\bar{v}_s$ feet/second (m/s)	Standard Penetration Test, $\bar{N}$ [or $\bar{N}_{CH}$ for cohesionless soil layers] (blows/foot)	Undrained Shear Strength, $\bar{s}_u$ psf (kPa)
S_A	Hard Rock	> 5,000 (1,500)	—	—
S_B	Rock	2,500 to 5,000 (760 to 1,500)		
S_C	Very Dense Soil and Soft Rock	1,200 to 2,500 (360 to 760)	> 50	> 2,000 (100)
S_D	Stiff Soil Profile	600 to 1,200 (180 to 360)	15 to 50	1,000 to 2,000 (50 to 100)
S_E[1]	Soft Soil Profile	< 600 (180)	< 15	< 1,000 (50)
S_F	Soil Requiring Site-specific Evaluation. See Section 1629.3.1.			

3. Site Seismic Hazard Characteristics and Zones

1629.4 Site Seismic Hazard Characteristics.

Seismic hazard characteristics for the site shall be established based on the seismic zone and proximity of the site to active seismic sources, site soil profile characteristics and the structure's importance factor.

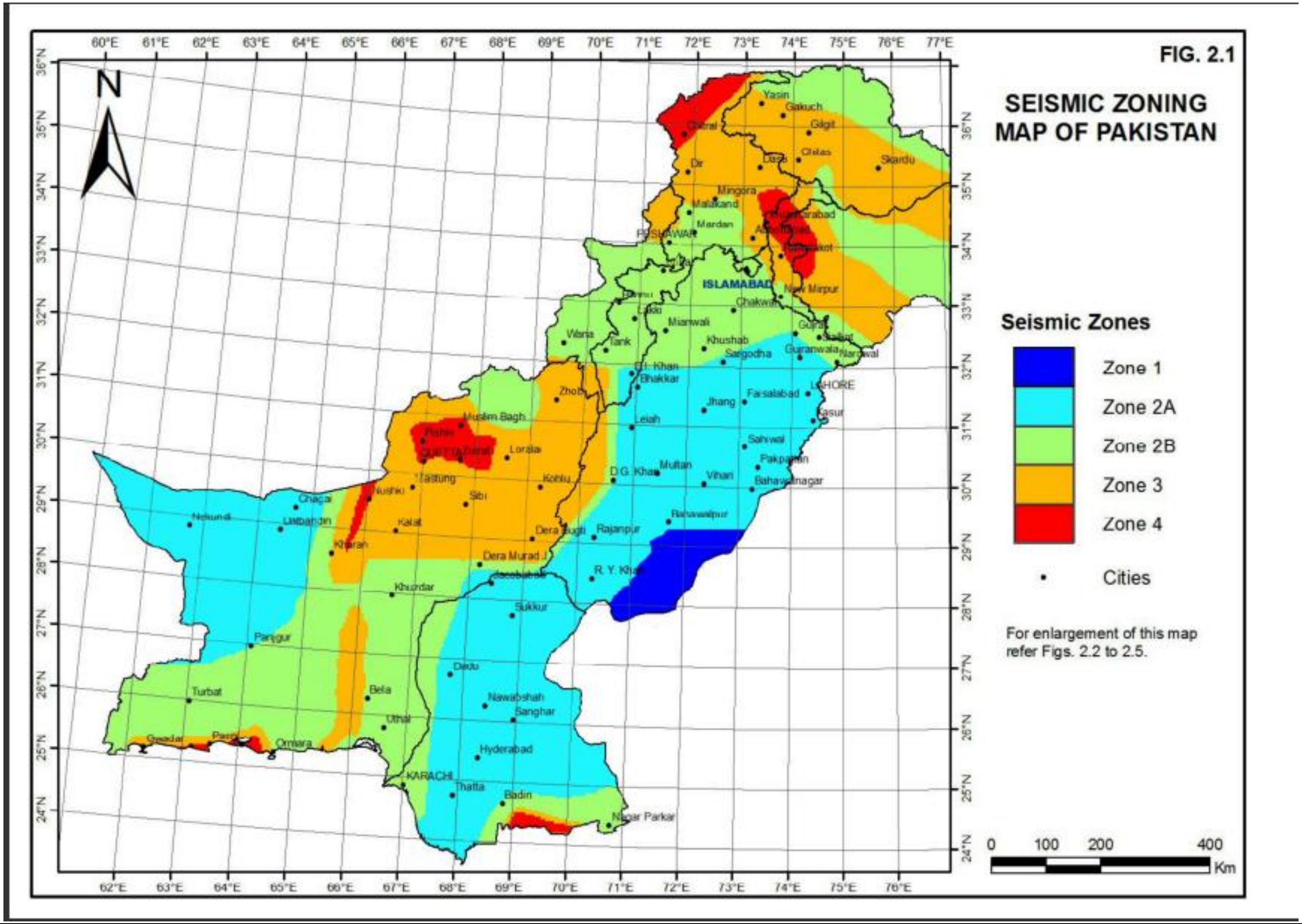
1629.4.1 Seismic zone.

Each site shall be assigned a seismic zone in accordance with Figure 16-2. Each structure shall be assigned a seismic zone factor Z in accordance with Table 16-I.

TABLE 16-I—SEISMIC ZONE FACTOR *Z*

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

1. Occupancy Category



4. Seismic Zone factor

1629.4.2 Seismic Zone 4 near-source factor.

In Seismic Zone 4, each site shall be assigned a near-source factor in accordance with Table 16-S and the Seismic Source Type set forth in Table 16-U.

TABLE 16-U—SEISMIC SOURCE TYPE[1]

SEISMIC SOURCE TYPE	SEISMIC SOURCE DESCRIPTION	SEISMIC SOURCE DEFINITION[2]	
		Maximum Moment Magnitude, M	Slip Rate, SR (mm/year)
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity	$M \geq 7.0$	$SR \geq 5$
B	All faults other than Types A and C	$M \geq 7.0$ $M < 7.0$ $M \geq 6.5$	$SR < 5$ $SR > 2$ $SR < 2$
C	Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity	$M < 6.5$	$SR \leq 2$

4. Near Source Factors

TABLE 16-S—NEAR-SOURCE FACTOR N_a[1]

SEISMIC SOURCE TYPE	CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE[2,3]		
	≤ 2 km	5 km	≥ 10 km
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

[1]The Near-Source Factor may be based on the linear interpolation of values for distances other than those shown in the table.

[2]The location and type of seismic sources to be used for design shall be established based on approved geotechnical data (e.g., most recent mapping of active faults by the United States Geological Survey or the California Division of Mines and Geology).

[3]The closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e., surface projection of fault plane). The surface projection need not include portions of the source at depths of 10 km or greater. The largest value of the Near-Source Factor considering all sources shall be used for design.

TABLE 16-T—NEAR-SOURCE FACTOR N_v[1]

SEISMIC SOURCE TYPE	CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE[2,3]			
	≤ 2 km	5 km	10 km	≥ 15 km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

5. Seismic Response Coefficients

1629.4.3 Seismic response coefficients.

Each structure shall be assigned a seismic coefficient, Ca, in accordance with Table 16-Q and a seismic coefficient, Cv, in accordance with Table 16-R.

5. Seismic Response Coefficients

TABLE 16-Q—SEISMIC COEFFICIENT C_a

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR, Z				
	$Z = 0.075$	$Z = 0.15$	$Z = 0.2$	$Z = 0.3$	$Z = 0.4$
S_A	0.06	0.12	0.16	0.24	$0.32N_a$
S_B	0.08	0.15	0.20	0.30	$0.40N_a$
S_C	0.09	0.18	0.24	0.33	$0.40N_a$
S_D	0.12	0.22	0.28	0.36	$0.44N_a$
S_E	0.19	0.30	0.34	0.36	$0.36N_a$
S_F	See Footnote 1				

TABLE 16-R—SEISMIC COEFFICIENT C_v

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR, Z				
	$Z = 0.075$	$Z = 0.15$	$Z = 0.2$	$Z = 0.3$	$Z = 0.4$
S_A	0.06	0.12	0.16	0.24	$0.32N_v$
S_B	0.08	0.15	0.20	0.30	$0.40N_v$
S_C	0.13	0.25	0.32	0.45	$0.56N_v$
S_D	0.18	0.32	0.40	0.54	$0.64N_v$
S_E	0.26	0.50	0.64	0.84	$0.96N_v$
S_F	See Footnote 1				

Height Limitations

1629.7 Height Limits.

Height limits for the various structural systems in Seismic Zones 3 and 4 are given in Table 16-N.

Height Limitations

TABLE 16-N—STRUCTURAL SYSTEMS[1]

BASIC STRUCTURAL SYSTEM[2]	LATERAL-FORCE-RESISTING SYSTEM DESCRIPTION	*R*	Ω_o	HEIGHT LIMIT FOR SEISMIC ZONES 3 AND 4 (feet) × 304.8 for mm
1. Bearing wall system	1. Light-framed walls with shear panels			
	a. Wood structural panel walls for structures three stories or less	5.5	2.8	65
	b. All other light-framed walls	4.5	2.8	65
	2. Shear walls			
	a. Concrete	4.5	2.8	160
	b. Masonry	4.5	2.8	160
	3. Light steel-framed bearing walls with tension-only bracing	2.8	2.2	65
	4. Braced frames where bracing carries gravity load			
	a. Steel	4.4	2.2	160
	b. Concrete[3]	2.8	2.2	—
	c. Heavy timber	2.8	2.2	65
2. Building frame system	1. Steel eccentrically braced frame (EBF)	7.0	2.8	240
	2. Light-framed walls with shear panels			
	a. Wood structural panel walls for structures three stories or less	6.5	2.8	65
	b. All other light-framed walls	5.0	2.8	65
	3. Shear walls			
	a. Concrete	5.5	2.8	240
	b. Masonry	5.5	2.8	160
	4. Ordinary braced frames			
	a. Steel	5.6	2.2	160
	b. Concrete[3]	5.6	2.2	—
	c. Heavy timber	5.6	2.2	65
	5. Special concentrically braced frames			
	a. Steel	6.4	2.2	240
3. Moment-resisting frame system	1. Special moment-resisting frame (SMRF)			
	a. Steel	8.5	2.8	N.L.
	b. Concrete[4]	8.5	2.8	N.L.
	2. Masonry moment-resisting wall frame (MMRWF)	6.5	2.8	160
	3. Concrete intermediate moment-resisting frame (IMRF)[5]	5.5	2.8	—
	4. Ordinary moment-resisting frame (OMRF)			
	a. Steel[6]	4.5	2.8	160
	b. Concrete[7]	3.5	2.8	—
	5. Special truss moment frames of steel (STMF)	6.5	2.8	240

Static Lateral Force Procedure

1629.8.3 Static.

The static lateral force procedure of Section 1630 may be used for the following structures:

1. All structures, regular or irregular, in Seismic Zone 1 and in Occupancy Categories 4 and 5 in Seismic Zone 2.

2, Regular structures under 240 feet (73 152 mm) in height with lateral force resistance provided by systems listed in Table 16-N, except where Section 1629.8.4, Item 4, applies.

3. Irregular structures not more than five stories or 65 feet (19 812 mm) in height.

Static Lateral Force Procedure

Seismic dead load, *W*, is the total dead load and applicable portions of other loads listed below.

1. In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.

2. Where a partition load is used in the floor design, a load of not less than 10 psf (0.48 kN/m^2) shall be included.

3. Design snow loads of 30 psf (1.44 kN/m^2) or less need not be included. Where design snow loads exceed 30 psf (1.44 kN/m^2), the design snow load shall be included, but may be reduced up to 75 percent where consideration of siting, configuration and load duration warrant when approved by the building official.

4. Total weight of permanent equipment shall be included.

Static Lateral Force Procedure

1630.2 Static Force Procedure.

1630.2.1 Design base shear. The total design base shear in a given direction shall be determined from the following formula:

$$V = \frac{C_v\ I}{R\ T}\ W \qquad (30\text{-}4)$$

The total design base shear need not exceed the following:

$$V = \frac{2.5\ C_a\ I}{R}\ W \qquad (30\text{-}5)$$

The total design base shear shall not be less than the following:

$$V = 0.11\ C_a\ I\ W \qquad (30\text{-}6)$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

Static Lateral Force Procedure

$$V = \frac{0.8 \; Z N_v \; I}{R} W \qquad (30\text{-}7)$$

1630.2.2 Structure period. The value of T shall be determined from one of the following methods:

1. **Method A:** For all buildings, the value T may be approximated from the following formula:

$$T = C_t (h_n)^{3/4} \qquad (30\text{-}8)$$

WHERE:

C_t = 0.035 (0.0853) for steel moment-resisting frames.

C_t = 0.030 (0.0731) for reinforced concrete moment-resisting frames and eccentrically braced frames.

C_t = 0.020 (0.0488) for all other buildings.

Static Lateral Force Procedure

1630.5 Vertical Distribution of Force. The total force shall be distributed over the height of the structure in conformance with Formulas (30-13), (30-14) and (30-15) in the absence of a more rigorous procedure.

$$V = F_t + \sum_{i=1}^{n} F_i \qquad (30\text{-}13)$$

The concentrated force F_t at the top, which is in addition to F_n, shall be determined from the formula:

$$F_t = 0.07\ T\ V \qquad (30\text{-}14)$$

The value of T used for the purpose of calculating F_t shall be the period that corresponds with the design base shear as computed using Formula (30-4). F_t need not exceed $0.25V$ and may be considered as zero where T is 0.7 second or less. The remaining por-

Static Lateral Force Procedure

tion of the base shear shall be distributed over the height of the structure, including Level n, according to the following formula:

$$F_x = \frac{(V - F_t)\, w_x h_x}{\sum_{i=1}^{n} w_i h_i} \qquad (30\text{-}15)$$

At each level designated as x, the force F_x shall be applied over the area of the building in accordance with the mass distribution at that level. Structural displacements and design seismic forces shall be calculated as the effect of forces F_x and F_t applied at the appropriate levels above the base.

Problem-1

Determine the UBC-97 design seismic forces for a three-story concrete shear Wall office building. It is located in Dir District KPK province on rock with a shear Wave velocity of 3000 ft/sec. The story heights are 13 feet for the first floor and 11 feet for the second and third floors. The story dead loads are 2200, 2000 and 1700 kips from the bottom up. The plan dimensions are 180 feet by 120 feet. The Walls in the direction under consideration are 120 feet long and are Without openings. The shear walls do not carry vertical loads.

Problem-1

Level	h_x (ft)	w_x (k)	$w_X h_X$ x10^{-3}	F_i+F_t (k)	V_X (k)	M_x (ft-k)
3	35	1700.	59.5	351.7	351.7	3869.
2	24	2000.	48.0	283.7	635.4	10858
1	13	2200.	28.6	169.1	804.5	21317.
Σ		5900.	136.1	804.5		

Problem-2

Determine the UBC-97 design seismic forces for a nine story ductile moment resisting steel frame office building located in Muzaffarabad on very dense soil and soft rock. The building is located **5km** from a fault capable of large magnitude earthquakes and that has a moderate slip rate (M>7, SR>2mm/yr). The story heights are all thirteen feet. The plan area is 100 feet by 170 feet. The total dead load is 100 pounds per square foot at all levels.

Problem-2

Level	h_x (ft)	w_x (k)	$w_x h_x$ $x10^{-3}$	F_i+F_t (k)	V_x (k)	M_x (ft-k)
9	117	1700.	198.9	260.1	260.1	3381.
8	104	1700.	176.8	156.2	416.6	8793.
7	91	1700.	155.7	137.6	553.9	15994.
6	78	1700.	132.6	117.2	671.1	24718.
5	65	1700.	110.5	97.6	768.7	34711.
4	52	1700.	88.4	78.1	846.8	45720.
3	39	1700.	66.3	58.6	905.4	57490.
2	26	1700.	45.2	39.9	945.3	69779.
1	13	1700.	22.1	19.5	964.8	82321.
Σ		15300.	996.5	964.8		