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IPS-1**

Essential Requirements for Reinforced Concrete Buildings

**(For Buildings of Limited Size and Height,
based on ACI 318-02)**

**U. S. Customary Units
2002 Edition**

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Essential Requirements for Reinforced Concrete Buildings

**(For Buildings of Limited Size and Height,
based on ACI 318-02)**

Foreword

Publication of *Essential Requirements for Reinforced Concrete Buildings* is the result of an agreement between the American Concrete Institute and two Colombian Institutions: the Instituto Colombiano de Normas Técnicas y Certificación (Colombian Institute for Technical Standards and Certification) and the Asociación Colombiana de Ingeniería Sísmica (Colombian Association for Earthquake Engineering).

The document was motivated by frequent worldwide criticism that current reinforced concrete codes might be unnecessarily sophisticated for some uses, such as small low-rise structures. The need for guidelines and minimum requirements for the design and construction of structures that fall in these categories is felt throughout the world. The document is expected to be especially useful in the education and training of young engineers in reinforced concrete design.

A useful precedent for the drafting committee was the simplified rules for design and construction of masonry one- and two-story dwellings contained in some building codes. Current knowledge on reinforced concrete behavior obtained through experimentation and experience, and its status and dissemination as a structural material used worldwide, made the task of development of a simplified design and construction document, not only feasible, but challenging.

Among the subjects covered are: aggregate size; allowable soil bearing capacity; analysis and design; beams; bearing strength; columns; combined footings; concrete cover; concrete curing; concrete mixing and transportation; concrete mixture proportions; concrete quality, mixing, and placing; concrete strength evaluation; construction joints; definitions of terms used; design and construction procedures; design for axial load with flexure; design for flexure; design for shear; development length and splicing of reinforcement; drawings and specifications; durability requirements; embedded pipes; flexural and axial loads; floor systems; footings; form removal; formwork; foundation mats; foundations; geotechnical investigation; girders; grade beams; inspection; joists; lateral load resistance; layout of the structural system; limit states; loads (dead, live, rain, snow, wind, earthquake, and soil lateral pressure); materials for reinforced concrete construction; minimum depth for members; one-way and two-way slabs; project specifications; reinforcement details; retaining walls; shear and torsion; shear walls; slab systems; slab-column systems; slabs-on-grade; special provisions for seismic design; spread footings; stairways and ramps; standard hooks; strength and serviceability; structural drawings; wall footings; walls; water tanks.

The following features were the general guidelines for the *Essential Requirements for Reinforced Concrete Buildings*:

- The aim of the document is to provide rules for the design and construction of common, low-rise structures of small to medium floor areas.
- The design rules are based on simplified accepted strength models; other limit states are accounted by specified dimensional requirements. The minimum dimensional requirements contained in the document are intended to replace the need for more-sophisticated analysis and design procedures.
- Material and construction requirements are aimed at available steel grades and concrete of medium strength that could be site mixed.
- The document is self-contained; therefore, loads and simplified analysis procedures are included as well as geotechnical exploration requirements to be used in defining a soil bearing capacity and minimum acceptable construction practice guidelines.
- Earthquake-resistant requirements are based on the use of structural concrete walls (shear walls) that limit the lateral deformations of the structure and provide lateral strength.
- The document is written in mandatory language.
- Where explanatory non-mandatory material was required, this material was included at the appropriate places and a special cursive type font was employed to indicate the non-mandatory character.

Essential Requirements for R/C Buildings

- In a departure from traditional code-related publications, the document contains graphs and graphical explanations.
- Requirements are introduced in the order needed in the course of a design.
- The design can be carried out using solely the document and a hand calculator without need for a computer.
- For international use, SI Metric and US Customary Units versions in English and a SI Metric version in Spanish of the document were produced.

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Essential Requirements for Reinforced Concrete Buildings

INTRODUCTION

The *Essential Requirements for Reinforced Concrete Buildings* (see 1.4) is based on the 2002 “Building Code Requirements for Structural Concrete (ACI 318-02) and Commentary (ACI 318R-02),” developed by the American Concrete Institute, the 1998 “Minimum Design Loads for Buildings and Other Structures (ASCE 7-98),” developed by the American Society of Civil Engineers, and the year 2000 “International Building Code (IBC 2000),” developed by the International Code Council.

The quality and testing of materials used in construction are covered by reference to the appropriate ASTM (American Society for Testing and Materials) standard specifications.

The document is written in mandatory language and the requirements are drawn in such a manner that any structure designed and built following the document will, in principle, meet the Codes and Standards on which the “Essential Requirements for Reinforced Concrete Buildings” was based.

All mandatory material in the *Essential Requirements* has been printed in Helvetica, the same font in which this paragraph is set.

[This paragraph is set in Times New Roman, italic, and all portions of the text corresponding to non-mandatory material are enclosed in brackets and printed in this font.]

The document presents the material in an order that follows the design procedure with the requirements being introduced when the designer will need them in the course of the design.

The *Essential Requirements* uses the load combinations and load factors as presented in Chapter 9 of ACI 318-02. In the 2002 ACI code, the 1999 code load factor combinations and strength reduction factors were revised and moved to Appendix C. The load combinations contained in Chapter 9 of ACI 318-99 were replaced with those of ASCE 7-98 (see 1.4). The strength-reduction factors were replaced with those of the 1999 Appendix C. These new strength-reductions factors are lower than those contained in previous editions of ACI 318, from 1971 to 1999, except for the factor for flexure that was maintained equal. The changes were made to further unify the design profession on one set of load factors and combinations and to facilitate the proportioning of concrete building structures that include members of materials other than concrete.

CHAPTER 1—GENERAL REQUIREMENTS

1.0 — NOTATION

R_n	= nominal strength in terms of flexure, axial load, shear or bearing strength.
S_i	= nominal load effect based on load, i .
U	= required strength to resist factored loads or related internal moments and forces.
ϕ	= strength-reduction factor. See 1.8.3.
γ_i	= load factor for load effect i .

1.1 — SCOPE

The *Essential Requirements* are intended for the planning, design, and construction of reinforced concrete structures to be used in new low-rise buildings of restricted occupancy, number of stories, and area.

1.2 — PURPOSE

The purpose of the *Essential Requirements* is to provide a licensed civil engineer or architect with sufficient information to perform the design of the structural reinforced concrete members that comprise the structural framing of a low-rise building that complies with the limitations established in 1.3. The rules of design as set forth in the present document are simplifications of the more detailed requirements contained in the standards mentioned in 1.4.

1.3 — LIMITATIONS

The *Essential Requirements* shall be used only when the building being designed complies with all the limitations set forth in 1.3.1 to 1.3.10.

1.3.1 — Use and occupancy

1.3.1.1 — Permitted uses and occupancies. Table 1.1 lists occupancy groups and subgroups, indicating for each one of them if the use of the *Essential Requirements* is permitted.

1.3.1.2 — Mixed occupancy. It is permitted to design buildings of mixed occupancy using the *Essential Requirements* when all the types of occupancy in the building are permitted in Table 1.1.

1.3.2 — Maximum number of stories

The maximum number of stories for a building designed using the *Essential Requirements* is five, including the story at the level of the ground, without counting the roof or the basement. The maximum allowable number of basement levels is one.

1.3.3 — Maximum area per floor

The area per floor shall not exceed 10 000 ft².

1.3.4 — Maximum story height

The maximum story height, measured from the floor finish to the floor finish of the story immediately below, shall not be greater than 13 ft.

1.3.5 — Maximum span length

The span length for girders, beams, and slab-column systems, measured center-to-center of the supports, shall not exceed 30 ft.

1.3.6 — Maximum difference in span length

Spans shall be approximately equal, and the shorter of two adjacent spans shall be at least 80% of the larger span, except in elevator and stair cores.

1.3.7 — Minimum number of spans

There shall be at least two spans in each of the two principal directions in plan of the building. Single spans shall be permitted in one- and two-story buildings if the span length does not exceed 15 ft.

1.3.8 — Maximum cantilever span

For cantilevered girders, beams, or slabs, the cantilever span shall not exceed 1/3 of the length of the first interior span of the member.

1.3.9 — Maximum slope for slabs, girders, beams, and joists

When sloping slabs, girders, beams, or joists are used, the slope of the member shall not exceed 15 degrees.

1.3.10 — Maximum slope of the terrain

The slope of the terrain where the building is located shall not exceed, in any direction, a rise of the terrain — in the length of the building in that direction — equivalent to the story height of the first story, without exceeding 30 degrees.

Table 1.1 — Permitted uses and occupancies

Occupancy Group	Occupancy Subgroup		Permitted
Group A — Assembly	A-1	Fixed seating theatres, television, and radio studios	NO
	A-2	Building having an assembly room with capacity less of 100 persons and not having a stage	YES
	A-3		
	A-4	Arenas, skating rings, swimming pools, and tennis courts	NO
	A-5	Amusement parks, bleachers, grandstands, and stadiums	NO
Group B — Business	B	Building for use as offices, or professional services containing eating and drinking establishments with less than 50 occupants	YES
Group E — Educational	E	Use for educational purposes	YES
Group F — Factory	F-1	Light industries not using heavy machinery	YES
	F-2	Heavy industries using heavy machinery	NO
Group H — Hazardous	H	Manufacturing, processing, generation, or storage of materials that constitute a physical or health hazard	NO
Group I — Institutional	I-1	Residential board and care facilities	YES
	I-2	Hospitals	NO
	I-3	Prisons, jails, reformatories, and detention centers	YES
	I-4	Daycare facilities	YES
Group M — Mercantile	M	Display and sale of merchandise	YES
Group R — Residential	R-1	Hotels having an assembly room with capacity less of 100 persons and not having a stage	YES
	R-2	Apartment buildings and dormitories	YES
	R-3	Houses	YES
	R-4	Residential care/assisted-living facilities	YES
Group S — Storage	S-1	Storage of heavy or hazardous materials	NO
	S-2	Storage of light materials	YES
Group U — Utility and Miscellaneous	U	Utilities, water supply systems, and power generating plants	NO
	U	Garages for vehicles with carrying capacity up to 4000 lb	YES
	U	Garages for trucks of more than 4000 lb carrying capacity	NO

1.4 — SUPPORTING CODES AND STANDARDS

When the limitations of 1.3 are met, this document is intended to be a simplification to the corresponding requirements contained in following codes and standards:

- Building Code Requirements for Structural Concrete (ACI 318-02);
- Minimum Design Loads for Buildings and Other Structures (ASCE 7-98); and
- International Building Code (IBC 2000).

1.5 — DEFINITIONS

Terms for general use are presented in Chapter 2, Definitions and Nomenclature.

1.6 — DESIGN AND CONSTRUCTION PROCEDURE

1.6.1 — Procedure

The design procedure comprises the steps listed in Table 1.2. See also Fig. 1.1.

Table 1.2 — Design procedure steps

Step A	Verification that the limitations for using the <i>Essential Requirements</i> are met. Definition of the layout in plan and height of the structure.	Chapters 1 and 3
Step B	Calculation of all gravity loads that act on the structure, excluding the selfweight of the structural members.	Chapter 4
Step C	Definition of an appropriate floor system, depending on the span lengths and the magnitude of the gravity loads.	Chapter 6
Step D	Trial dimensions for the slab of the floor system. Calculation of the selfweight of the system and design of the members that comprise it, correcting the dimension as required by the strength and serviceability limit states, complying with the requirements for slab systems with beams, or slab-column systems.	Chapters 6, 7, and 9
Step E	Trial dimensions for the beams and girders (if needed.) Calculation of the selfweight of girders, beams, and joists. Flexural and shear design of the beams and girders, correcting the dimensions as required by the strength and serviceability limit states.	Chapters 6 and 8
Step F	Trial dimensions for the columns. Verification of column slenderness through the use of minimum dimensions. Calculation of the selfweight of the columns. Design of the columns for combination of axial load and moment and shear. Correcting the dimension as required by the strength and serviceability limit states.	Chapter 10
Step G	If lateral loads such as earthquake, wind, or lateral earth pressure exist, their magnitude and point of application to be established; otherwise the designer may proceed to Step I.	Chapter 4
Step H	Preliminary location and trial dimensions for reinforced concrete walls capable of resisting the lateral loads. For earthquake forces, the influence of the walls selfweight is evaluated. Flexure and shear design of the reinforced concrete walls.	Chapters 11 and 12
Step I	Design of the stairways, ramps, tanks, and retaining walls.	Chapter 13
Step J	Loads at the foundation level are determined. Definition of the foundation system is performed. Design of the structural members of the foundation.	Chapter 14
Step K	Production of the structural drawings and specifications.	Chapter 15
Step L	The structure is built complying with the construction and inspection requirements.	Chapter 16

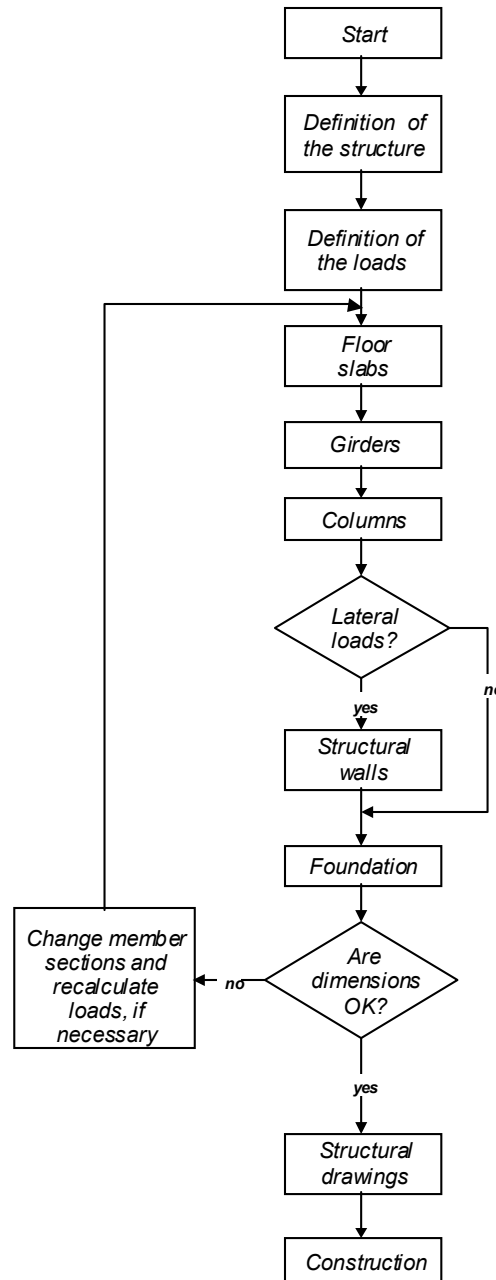


Fig. 1.1 — Design procedure

1.6.2 — Design documentation

The design steps shall be fully recorded in the following documents:

1.6.2.1 — Calculation record. The structural designer shall document all design steps in a calculation record. This record shall contain, as a minimum, the following:

- The general structural requirements of the project, as defined in Chapter 3;
- A description of the structural system used;
- Loads used;
- Characteristics, strength, and fabrication standards for all structural materials;
- Justification of all design computations; and
- Sketches of the reinforcement layout for all structural members.

1.6.2.2 — Geotechnical report. The geotechnical report shall record, as a minimum, the soil investigation performed, the allowable bearing capacity of the soil, the lateral soil pressures required for design of any soil-retaining structures, and all other information required in Chapter 14.

1.6.2.3 — Structural drawings. The structural drawings shall include all the plans required by Chapter 15 for construction of the building.

1.6.2.4 — Project specifications. The project specifications shall include all the construction specifications described in Chapter 15.

1.6.3 — Precast concrete components

It shall be permitted to use precast concrete components, including prestressed concrete, manufactured in off-site facilities. Such components shall be designed by a licensed professional in accordance with the codes and standards listed in 1.4. Calculations shall be reviewed by the designer of record (see 1.2), and included in the *Calculation record* (see 1.6.2.1). Detailing and placing drawings conforming to 15.2.2 shall be furnished and included as part of the *Structural drawings* (see 1.6.2.3). Manufacture of precast components shall be done in a facility with demonstrated capability of producing quality products.

1.7 — LIMIT STATES

The design approach of the *Essential Requirements* is based on limit states, where a limit state is a condition beyond which a structure or member becomes unfit for service and is judged either to be unsafe or no longer useful for its intended function. The designer shall verify that the following limit states are accounted for in the resulting structure:

- (a) Strength limit state; and
- (b) Serviceability limit state.

The following are considered implicitly in the design procedure:

- (a) Structural integrity;
- (b) Lateral load story drift;
- (c) Durability; and
- (d) Fire resistance.

1.8 — STRENGTH LIMIT STATE DESIGN

1.8.1 — General

In the strength limit state design, the structure and the structural members are dimensioned to have design strength at all sections at least equal to the required strength calculated for the factored loads and forces, using the load combinations as described in Chapter 4.

The basic requirement for strength limit state is:

$$\text{Resistances} \geq \text{Load effects} \quad (1-1)$$

To allow for the possibility that the resistances may be less than computed, and the load effects could be larger than computed, strength-reduction factors, ϕ , less than one, and load factors, γ , generally greater than one, are used:

$$\phi \cdot R_n \geq \gamma_1 \cdot S_1 + \gamma_2 \cdot S_2 + \dots \quad (1-2)$$

R_n stands for nominal strength and S stands for load effects based on the loads described in Chapter 4. Therefore, the strength limit state design format requires that:

$$\text{Design Strength} \geq \text{Required Strength} \quad (1-3)$$

$$\phi \cdot (\text{Nominal Strength}) \geq U \quad (1-4)$$

where the required strength is $U = \gamma_1 \cdot S_1 + \gamma_2 \cdot S_2 + \dots$

1.8.2 — Required strength

The required strength, U , shall be computed by multiplying service loads or forces by load factors, using the load factors and load combinations in 4.2.

1.8.3 — Design strength

The design strength provided by a member; its connections to other members; and its cross sections, in terms of flexure, axial load, and shear; shall be taken as the nominal strength multiplied by a strength-reduction factor, ϕ . The nominal strength shall be calculated for each particular force effect in each of the member types at the defined critical sections. The following strength-reduction factors, ϕ , shall be used:

- (a) Flexure, without axial load $\phi = 0.90$
- (b) Axial tension and axial tension with flexure $\phi = 0.90$
- (c) Axial compression and axial compression with flexure
 - Columns with ties and reinforced concrete walls $\phi = 0.65$
 - Columns with spiral reinforcement $\phi = 0.70$
- (d) Shear and torsion $\phi = 0.75$
- (e) Bearing of concrete $\phi = 0.65$

1.9 — SERVICEABILITY LIMIT STATE DESIGN

Serviceability limit states correspond to conditions beyond which specified performance requirements for the structure, or the structural members, are no longer met. The compliance with the serviceability limit state is obtained indirectly through the observance of the limiting dimensions, cover, detailing, and construction requirements. These serviceability conditions include effects such as:

- (a) Long-term environmental effects, including exposure to aggressive environment or corrosion of the reinforcement;
- (b) Dimensional changes due to variations in temperature, relative humidity, and other effects;
- (c) Excessive cracking of the concrete;
- (d) Excessive vertical deflections; and
- (e) Excessive vibration.

1.10 — APPLICABLE STANDARDS

1.10.1 — General

The American Society for Testing and Materials (ASTM) standards cited in the *Essential Requirements* are listed below with their serial designation and are declared part of the *Essential Requirements*.

1.10.2 — ASTM Standards

ASTM A 82-97a Standard Specification for Steel Wire, Plain, for Concrete Reinforcement

ASTM A 184 / A 184M-96 Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement

ASTM A 185-97 Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement

ASTM A 242 / A242M-00a Standard Specification for High-Strength Low-Alloy Structural Steel

ASTM A 496-97a Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement

ASTM A 497-99 Standard Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement

ASTM A 615 / A 615M-00 Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

ASTM A 706 Standard Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement

ASTM A 767 / A 767M-00b Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement

ASTM A 775 / A 775M-00 Standard Specification for Epoxy-Coated Reinforcing Steel Bars

ASTM A 884 / A 884M-99 Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Fabric for Reinforcement

ASTM A 934 / A 934M-00 Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars

ASTM A 996 / A 996M-00 Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement

ASTM C 31/C 31M-98 Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C 33-99a Standard Specifications for Concrete Aggregates

ASTM C 39 / C 39M-99 Standard Method of Compressive Strength of Cylindrical Concrete Specimens

ASTM C 42 / C 42M-99 Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

ASTM C 94 / C 94M-00 Standard Specifications for Ready-Mixed Concrete

ASTM C 109/C 109M-99 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)

ASTM C 143 / C 143M-98 Standard Test Method for Slump of Hydraulic Cement Concrete

ASTM C 144-99 Standard Specification for Aggregate for Masonry Mortar

ASTM C 150-99a Standard Specification for Portland Cement

ASTM C 172-99 Standard Method of Sampling Freshly Mixed Concrete

ASTM C 192/C 192M-98 Standard Method of Making and Curing Concrete Test Specimens in the Laboratory

ASTM C 260-00 Standard Specification for Air-Entraining Admixtures for Concrete

ASTM C 494 / C 494M-99a Standard Specification for Chemical Admixtures for Concrete

ASTM C 496-96 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

ASTM C 567-99a Standard Test Method for Unit Weight of Structural Lightweight Concrete

ASTM C 595-00 Standard Specification for Blended Hydraulic Cements

ASTM C 618-99 Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete

ASTM C 685-98a Standard Specifications for Concrete Made by Volumetric Batching and Continuous Mixing

ASTM C 845-96 Standard Specification for Expansive Hydraulic Cement

ASTM C 989-99 Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

ASTM C 1017 / C 1017M-98 Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete

ASTM C 1218/C 1218M-99 Standard Test Method for Water-Soluble Chloride in Mortar and Concrete

ASTM C 1240-00 Standard Specification for Silica Fume for Use in Hydraulic-Cement Concrete and Mortar

1.11 — A WORD OF CAUTION

Although the requirements contained in the *Essential Requirements* were developed to produce, when properly used, a reinforced concrete structure with an appropriate margin of safety, these requirements are not a replacement for experienced engineering. For the structure designed by the *Essential Requirements* to attain the intended margin of safety, the document must be used as a whole, and alternative procedures shall be used only when explicitly permitted in the document. The minimum dimensioning requirements as prescribed in the *Essential Requirements* replace, in most cases, more detailed procedures prescribed in the supporting codes and standards listed in 1.4.

The licensed professional designing a structure by the *Essential Requirements* shall have training and a minimum appropriate knowledge of: structural mechanics, statics, strength of materials, structural analysis, and reinforced concrete design and construction.

CHAPTER 2 — DEFINITIONS AND NOMENCLATURE

2.1 — DEFINITIONS

The following terms are defined for general use.

Admixture — Material other than water, aggregate, or hydraulic cement, used as an ingredient of concrete and added to concrete before or during its mixing to modify its properties.

Aggregate — Granular material, such as sand, gravel, crushed stone, and iron blast-furnace slag, used with a cementing medium to form a hydraulic cement concrete or mortar.

Aggregate, lightweight — Aggregate with a dry, loose weight of 70 lb/ft³ or less. Concrete manufactured using lightweight aggregate is not covered by the *Essential Requirements*.

Allowable stress design — A method of proportioning structural members such that elastically computed stresses produced in the members by nominal loads do not exceed specified allowable stresses (also called working stress design).

Anchorage — Device used to connect a non-structural element to the structural framing.

Bar diameter, nominal — For deformed bars, it shall be taken as the diameter of a plain bar having the same area.

Base of structure — Level at which seismic motions are assumed to be imparted to a building. This level does not necessarily coincide with the ground level.

Beam — A horizontal, or nearly horizontal, structural member supported at one point (such as a cantilever) or more points, but not throughout its length, transversely supporting a load, and subjected primarily to flexure. See also *girder*.

Bearing capacity of the underlying soil — Maximum permissible working stress on the foundation soil that provides adequate safety against bearing failure of the soil or foundation settlement of such magnitude as to impair the structure.

Bending moment — The bending effect at any section of a structural element; it is equal to the algebraic sum of the moments of the vertical and horizontal forces, with respect to the centroidal axis of a member, acting on a free body of the member.

Boundary elements — portions along wall edges strengthened by longitudinal and transverse reinforcement. Boundary elements do not necessarily require an increase in thickness of the wall.

Cement — Materials, specified in the corresponding referenced ASTM standards, that have cementing value when used in concrete either by themselves, such as portland cement, blended hydraulic cements, and expansive cement, or such materials in combination with fly ash, other raw or calcined natural pozzolans, silica fume, ground granulated blast-furnace slag, or all three.

Column — Vertical member with a ratio of height-to-least lateral dimension exceeding three, used primarily to support axial compressive load.

Collector elements — Elements that serve to transmit the seismic inertia forces within the diaphragm to members of the lateral-force resisting system.

Combined footing — Footing that transmits to the supporting soil the load carried by several columns or walls. See also *footing*.

Concrete — Mixture of portland cement and any other hydraulic cement, fine aggregate, coarse aggregate, and water, with or without admixtures.

Concrete mixture proportioning — The proportions of ingredients that make the most economical use of available materials to produce mortar or concrete of the required properties.

Concrete, specified compressive strength of, f'_c — Compressive cylinder strength of concrete used in design and evaluated in accordance with the appropriate ASTM standards, expressed in pounds per square inch (psi). Whenever the quantity f'_c is under a radical sign ($\sqrt{f'_c}$), square root of numerical value only is intended, and result has units of psi.

Concrete, lightweight — Concrete containing lightweight aggregate. This type of concrete is not covered by the *Essential Requirements*.

Compression reinforcement — Reinforcement provided to resist compression stresses induced by flexural moments acting on the member section.

Confinement stirrup or tie — See *hoop*.

Construction documents — The written, graphic, electronic, and pictorial documents describing the design, locations, and physical characteristics of the project required to verify compliance with the standard.

Contract documents — Documents comprising aspects of the required work and the results and products thereof, including plans, specifications, and project drawings.

Contraction joint — Formed, sawed, or tooled groove in a concrete structure to create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure.

Corrosion — Destruction of metal by a chemical, electrochemical, or electrolytic reaction within its environment.

Cover, concrete — The least distance between the surface of embedded reinforcement and the outer surface of the concrete.

Crosstie — Continuous reinforcing bar having a 135° seismic hook at one end and a hook not less than 90° with at least a six-diameter extension at the other end. The hooks shall engage peripheral longitudinal bars. The 90° hooks of two successive crossties engaging the same longitudinal bars shall be alternated end for end.

Curing — Action taken to maintain moisture and temperature conditions in a freshly placed cementitious mixture to allow hydraulic cement hydration and (if applicable) pozzolanic reactions to occur so that the potential properties of the mixture may develop. Curing is performed by keeping the concrete damp for a period of time, usually several days, starting from the moment it is cast, in order for the cement to be provided with enough water to harden and attain the intended strength. Appropriate curing will greatly reduce shrinkage, increase concrete strength, and reduce surface cracking. Curing time will depend on temperature and relative humidity of surrounding air, the amount of wind, the direct sunlight exposure, the type of concrete mixture used, and other factors.

Curtain wall — Walls that are part of the façade or enclosure of the building. See also *partitions*.

Deformed reinforcement — A reinforcing bar with a manufactured pattern of surface ridges intended to reduce slip and increase pullout resistance of bars embedded in concrete. The following steel reinforcement is considered deformed reinforcement: deformed reinforcing bars, welded plain wire fabric, and welded deformed wire fabric conforming to the appropriate ASTM standards.

Depth of member, h — Distance in a flexural member, measured from extreme compression fiber to the extreme tension fiber.

Design load combinations — Combinations of factored loads and forces.

Design strength — The product of the nominal strength multiplied by a strength reduction factor, ϕ .

Development length — Length of embedded reinforcement required to develop the design strength of reinforcement at a critical section.

Development length for a bar with a standard hook — Shortest distance between the critical section (where the strength of the bar is to be developed) and a tangent to the outer edge of the 90° or 180° hook.

Differential settlement — Due to loads, the lowering in elevation of various parts of a foundation by different amounts.

Effective depth of section, d — Distance measured from extreme compression fiber to centroid of tension reinforcement.

Embedment length — Length of embedded reinforcement provided beyond a critical section.

Engineer/architect — Engineer, architect, engineering firm, architectural firm, or engineering and architectural firm, issuing project drawings and project specifications, or administering work under the contract documents.

Essential facilities — Buildings and other structures that are intended to remain operational during and after an extreme environmental event from wind, snow, or earthquake.

Factored loads and forces — Specified nominal loads and forces multiplied by load factors.

Fire resistance — The property of a material or assembly to withstand fire or give protection from it; as applied to elements of buildings, it is characterized by the ability to confine a fire or, when exposed to fire, to continue to perform a given structural function, or both. The concrete cover is a function of the number of hours of exposure to the fire.

Flange — The widened portion of an I, T, or similar cross-section in the top or bottom part separated by the web. See also *web*.

Flexural reinforcement — Reinforcement provided to resist the tensile stresses induced by flexural moments acting on the member section.

Floor system — Structural members that comprise the floor of a story in a building, including girders, beams, joists, and the slab that spans between them or the slab only where it is directly supported on columns, as in slab-column systems.

Footing — A structural element that transmits loads directly to the soil.

Formwork — Total system of support for freshly placed concrete including the mold or sheathing that contacts the concrete as well as supporting members, hardware, and necessary bracing.

Foundation — The structural elements through which the load of a structure is transmitted to the earth.

Foundation beam (grade beam) — A reinforced concrete beam, usually at ground level, that strengthens or stiffens the foundation or supports overlying construction.

Foundation, mat — A continuous footing supporting an array of columns in several rows in each direction, having a slab-like shape with or without depressions or openings.

Girder — A large beam, usually horizontal, that serves as a main structural member. See also *beam*.

Grade beam — see *foundation beam*.

Grade slab — A slab, continuously supported by ground, that serves either as an internal traffic surface or as part of the foundation.

Gravity loads — Loads that act downward and are caused by the acceleration of gravity acting on the mass of the elements and content that cause the dead and live loads.

Hook — Bend at the end of a reinforcing bar. It is defined by the angle that the bend forms with the bar as 90°, 180°, or 135° hooks.

Hoop — Closed stirrup, tie, or continuously wound spiral. A closed stirrup or tie can be made up of several reinforcement elements, each having seismic hooks at both ends. A continuously wound spiral shall have a seismic hook at both ends.

Isolation joint — A separation between adjoining parts of a concrete structure, usually a vertical plane, at a designed location so as to interfere least with performance of the structure, yet allow relative movement in three directions and avoid formation of cracks elsewhere in the concrete and through which all or part of the bonded reinforcement is interrupted.

Integrity, structural — In the event of damage to a major supporting member or an abnormal loading event, the necessary structural redundancy and ductility to confine the resulting damage to a relatively small area, and to improve the structure's overall stability.

Joist — A comparatively narrow beam used in closely spaced parallel arrangements to support floor or roof slabs.

Lap splice — A connection of reinforcing steel made by lapping the ends of bars.

Lateral-force resisting system — Portion of the structure composed of members proportioned to resist forces related to lateral loads.

Loads — Forces or other actions that result from the weight of all building materials, occupants and other variable or permanent contents, environmental effects, differential movement, and restrained dimensional changes. Permanent loads are those loads in which variations over time are rare or of small magnitude. All other loads are variable loads.

Load effects — Forces and deformations produced in structural members by the applied loads.

Load factor — A factor that accounts for deviations of the actual load from the nominal load, for uncertainties in the analysis that transforms the load into a load effect, and for the probability that more than one extreme load will occur simultaneously. It is the factor by which a service load is multiplied to determine a factored load used in the strength-design method.

Limit state — A condition beyond which a structure or member becomes unfit for service and is judged either to be no longer useful for its intended function (serviceability limit state) or to be unsafe (strength limit state).

Live load — The load superimposed by the use and occupancy of the building not including wind, seismic, or dead load.

Longitudinal reinforcement — Reinforcement parallel to the length of a concrete member.

Modulus of elasticity — Ratio of normal stress to corresponding strain for tensile or compressive stresses below proportional limit of material.

Negative moment — A condition of flexure in which top fibers of a horizontally placed member are subjected to tensile stresses.

Negative reinforcement — Steel reinforcement resisting a negative moment that is placed in the upper part of the section of the member.

Nominal loads — The magnitudes of the loads specified in Chapter 4 (dead, live, soil, wind, snow, rain, flood, and seismic).

Nominal strength — The capacity of a structure or member to resist the effects of loads, as determined by computations using specified material strengths and dimensions and formulas derived from accepted principles of structural mechanics or by field tests or laboratory tests of scaled models, allowing for modeling effects and differences between laboratory and field conditions.

Nonstructural elements — The architectural, mechanical, and electrical components and systems permanently attached to the building.

Occupancy — The purpose for which a building or other structure, or part thereof, is used or intended to be used.

Partitions — A nonstructural interior wall that spans horizontally or vertically from support to support. The supports may be the basic building frame, subsidiary structural members or other portions of the partition system.

Pedestal — Upright compression member with a ratio of unsupported height to average least lateral dimension not exceeding three.

Permanent loads — Loads in which variations over time are rare or of small magnitude. See also *nominal loads*.

Pile — A timber, concrete, or steel structural element, driven, jetted, or otherwise embedded on end in the ground for the purpose of supporting a load or compacting the soil.

Pile cap — A structural member that is placed on top of a group of piles and used to transmit loads from the structure through the pile group into the soil.

Plain concrete — Structural concrete with no reinforcement or with less reinforcement than the minimum amount specified for reinforced concrete. Plain concrete is not covered by the *Essential Requirements*.

Plain reinforcement — Reinforcement that does not conform to the definition of deformed reinforcement.

Positive moment — A condition of flexure in which, for a horizontally placed member, the top fibers are subjected to compression stresses.

Positive reinforcement — Steel reinforcement resisting a positive moment that is placed in the lower part of the section of the member.

Precast concrete — Structural concrete element cast elsewhere than its final position in the structure. Precast concrete is not covered by the *Essential Requirements*, except as described in 1.6.3.

Prestressed concrete — Structural concrete in which internal stresses have been introduced to reduce potential tensile stresses in concrete resulting from loads. Prestressed concrete is not covered by the *Essential Requirements*, except as described in 1.6.3.

Project drawings — Drawings that, along with the project specifications, complete the descriptive information for constructing the work required to in the contract documents.

Project specifications — Written documents that specify requirements for a project in accordance with the service parameters and other specific criteria established by the owner. See also *Specifications*.

Reinforced concrete — Structural concrete reinforced with no less than the minimum amounts of reinforcement

Reinforced concrete walls — Walls proportioned to resist combinations of shear, moments, and axial forces. A shearwall is a reinforced concrete wall.

Reinforcement — Steel bars, wire, or mesh wire, that are embedded in concrete in such a manner that they and the concrete act together in resisting forces.

Reshores — Shores placed snugly under a concrete slab or other structural member after the original forms and shores have been removed from a larger area, thus requiring the new slab or structural member to deflect and support its own weight and existing construction loads applied before the installation of the reshores. See also *shores*.

Required strength — Strength of a member or cross section required to resist factored loads or related internal moments and forces in specified load combinations.

Retaining wall — Wall built to hold back earth.

Seismic hook — Hook on a stirrup, hoop, or crosstie having a bend not less than 135° with a six-diameter (but not less than 3 in.) extension that engages the longitudinal reinforcement and projects into the interior of the stirrup or hoop.

Selfweight — Weight of the structural member, caused by the material that composes the member.

Service load — All loads, static or transitory, imposed on a structure, or element thereof, during operation of a facility (without load factors.)

Settlement — Downward movement of the supporting soil.

Shear — Internal force acting tangential to the plane where it acts, also called diagonal tension.

Shear reinforcement — Reinforcement designed to resist shear or diagonal tension stresses.

Shell concrete — Concrete outside the transverse reinforcement confining the concrete core.

Shores — Vertical or inclined support members designed to carry the weight of the formwork, concrete, and construction loads above.

Shrinkage and temperature reinforcement — Reinforcement designed to resist shrinkage and temperature stresses in concrete.

Slab — A molded layer of reinforced concrete, flat, horizontal (or nearly so), usually of uniform but sometimes of variable thickness, either on the ground or supported by beams, columns, walls, or other framework.

Solid slab — Slab of uniform thickness.

Span length — Horizontal distance between supports of a horizontal structural member such as a slab, joist, beam, or girder.

Specifications — Written document describing in detail the scope of work, materials to be used, method of installation, and quality of workmanship. See also *Project specifications*.

Specified lateral seismic forces — Lateral forces corresponding to the appropriate distribution of the base shear force, for seismic-resistant design.

Specified wind forces — Nominal pressure of wind to be used in design.

Spiral reinforcement — Continuously wound reinforcement in the form of a cylindrical helix.

Spread footing — A generally rectangular prism of concrete, larger in lateral dimensions than the column or wall it supports, to distribute the load of a column or wall to the subgrade. See also *footing*.

Stirrup — Reinforcement used to resist shear and diagonal tension stresses in a structural member; typically bars, wires, or welded wire fabric (plain or deformed) either single leg or bent into L, U, or rectangular shapes and located perpendicular to or at an angle to the longitudinal reinforcement. (The term “stirrups” is usually applied to lateral reinforcement in flexural members and the term “ties” to those in compression members.) See also *tie*.

Story height — Vertical distance from the floor finish of a story to the floor finish of the story below.

Strength, design — Nominal strength multiplied by a strength-reduction factor, ϕ .

Strength design method - Method of proportioning structural members so that the computed forces produced in the members by the factored loads do not exceed the member design strength (also called load and resistance factor design method or simply LRFD).

Strength-reduction factor, ϕ — Capacity-reduction factor (in structural design); a number less than 1.0 by which the strength of a structural member or element (in terms of load, moment, shear, or stress) is required to be multiplied to determine design strength or capacity.

Stress — Intensity of force per unit area.

Structural concrete — All concrete used for structural purposes including plain and reinforced concrete.

Structural diaphragms — Structural members, such as floor and roof slabs, that transmit inertial forces induced by seismic motions.

Tank — Container for the storage of water or other fluids.

Temporary facilities — Buildings or other structures that are to be in service for a limited time and have a limited exposure period for environmental loadings.

Tie — Loop of reinforcing bar or wire enclosing longitudinal reinforcement. A continuously wound bar or wire in the form of a circle, rectangle, or other polygon shape without re-entrant corners is acceptable. See also *stirrup*.

Tie elements — Elements that serve to transmit inertia forces and prevent separation of building components such as footings and walls.

Transverse reinforcement — Reinforcement located perpendicular to the longitudinal axis of the member, comprising stirrups, ties, and spiral reinforcement.

Wall — Member, usually vertical, used to enclose or separate spaces. See also *reinforced concrete wall*.

Web — Thin vertical portion of an I-shaped section that connects the flanges. See also *flange*.

Wire — Reinforcing bar of small diameter.

Wire mesh — Welded wire fabric reinforcement.

Work — Entire construction or separately identifiable parts thereof that are required to be furnished under the contract documents. Work is the result of performing services, furnishing labor, and furnishing and incorporating materials and equipment into the construction in accordance with the contract documents.

Working stress — Maximum permissible design stress using working-stress design methods.

Yield strength, f_y — Specified minimum yield strength or yield point of reinforcement. Yield strength or yield point shall be determined in tension according to applicable ASTM standards.

2.2 — NOMENCLATURE

a	= depth of equivalent rectangular compressive stress block, in.
a	= distance from edge of wall footing to the resultant of soil reaction in wall footing, in.
A_a	= effective seismic peak ground horizontal acceleration in rock for short periods of vibration, expressed as a fraction of gravity, g
A_b	= area of an individual reinforcement bar or wire, in. ²
A_c	= area of core of spirally reinforced compression member measured to outside diameter of spiral, in. ²
A_c	= bearing area of concrete, in. ²
A_f	= contact area of footing with soil, ft ²
A_g	= gross area of section, or area of concrete only excluding area of voids, in. ²
A_i	= area of additional hanger reinforcement where beams are supported by girders or other beams, in. ²
A_j	= effective cross-sectional shear area within a joint, in. ²
A_p	= component, or cladding, wind exposed surface area, ft ²
A_s	= area of longitudinal tension reinforcement, in. ²
A_s'	= area of longitudinal compression reinforcement, in. ²
A_{se}	= steel area at the extreme face of column or reinforced concrete wall, in. ²
A_{s,min}	= minimum area of longitudinal tension reinforcement, in. ²
A_{ss}	= steel area at the side face of column or reinforced concrete wall, in. ²
A_{st}	= total area of longitudinal reinforcement, in. ²
A_{su}	= wind exposed surface area, ft ²
A_v	= area of shear reinforcement, in. ²
b	= width of member
b	= width of compression flange of member, in.
b₀	= perimeter of critical section for two-way shear (punching shear) in slabs, in.
b_c	= width of column section, in.

b_c	= smallest plan dimension of capital or drop panel, in.
b_f	= width of compression face of member, in.
b_w	= web width of section, or wall width, in.
B	= short horizontal dimension of footing, in.
C_p	= component, or cladding, wind surface pressure coefficient
C_{su}	= wind surface pressure coefficient
C_{vx}	= coefficient defined in 4.11.4
d	= effective depth of section, taken as distance from extreme compression fiber to centroid of tension reinforcement, in.
d_b	= nominal diameter of reinforcing bar or wire, in.
d_c	= distance from extreme tension fiber to centroid of tension reinforcement, in.
d_c	= outside diameter of spiral reinforcement, in.
d'	= distance from extreme compression fiber to centroid of compression reinforcement, in.
D	= dead loads or related internal moments and forces
e_B	= eccentricity of resultant applied to footing in direction parallel to B , in.
e_H	= eccentricity of resultant applied to footing in direction parallel to H , in.
e_x	= eccentricity, measured in x direction, between story center of lateral stiffness and point of application of story lateral forces acting in y direction, in.
e_y	= eccentricity, measured in y direction, between story center of lateral stiffness and point of application of story lateral forces acting in x direction, in.
E	= seismic loads or related internal moments and forces
E_c	= modulus of elasticity of concrete, psi
f'_c	= specified compressive strength of concrete, psi
$\sqrt{f'_c}$	= square root of specified compressive strength of concrete, the result shall have units of psi
f'_{cr}	= required average compressive strength of concrete used as the basis for selection of concrete proportions, psi
f_{cu}	= extreme fiber compressive stress due to factored loads at edges of structural walls, psi
f_y	= specified yield strength of reinforcement, psi
f_{ypr}	= probable specified maximum strength of reinforcement, psi ($f_{ypr} = 1.25 \cdot f_y$).
f_{ys}	= specified yield strength of transverse or spiral reinforcement, psi
F	= loads due to weight and pressure of fluids with well-defined densities and controllable maximum heights or related internal moments and forces
F_0	= total lateral at-rest soil force, lb
F_a	= seismic site coefficient for short periods of vibration
F_{pw}	= equivalent static wind force for components and cladding acting normal to wind exposed surface, lb
F_{ac}	= total lateral active soil force, lb
F_{su}	= equivalent static wind force acting normal to wind exposed surface, lb
F_i, F_x	= wind or seismic force applied at level i or x , respectively, lb
F_{ui}, F_{ux}	= factored lateral force applied to wall at level i or x , respectively, lb
g	= acceleration due to gravity, 386 in./s ²
h	= overall depth or thickness of member, or height of section of member, or outside diameter of circular section, in.
h	= mean roof height for wind design, measured over terrain, in.
h	= depth of soil against retaining wall, in.
h_b	= vertical distance measured from bottom of supporting girder to bottom of supported beam, in.
h_c	= depth of column, or dimension of column in direction parallel to girder span, in.
h_c	= largest plan dimension of capital or drop panel or pedestal, or change of thickness in stepped footings, in.
h_f	= flange thickness, in.
h_i, h_x	= height above base to level i or x , respectively, ft
h_n	= clear vertical distance between lateral supports of columns and walls, in.
h_{pi}	= story height of floor i measured from floor finish of story to floor finish of story immediately below, in.
h_s	= total depth of supporting girder, in.

h_w	= height of wall from base to top, in.
H	= loads due to weight and pressure of soil, water in soil, or other materials, or related internal moments and forces
H	= long horizontal dimension of footing, in.
I_c	= moment of inertia of column section, in. ⁴
k_r	= story total rotational stiffness
k_x, k_y	= wall lateral stiffness in direction x and y , respectively, lb/in. See Eq. (11-6)
K_a	= active soil pressure coefficient
K_p	= passive soil pressure coefficient
K_0	= at-rest soil pressure coefficient
ℓ	= center-to-center span length; shortest distance between adjacent parallel column centerlines, in.
ℓ_0	= column confinement length, in.
ℓ_1	= length of span in direction of moments, measured center-to-center of supports, in.
ℓ_2	= length of span transverse to ℓ_1 , measured center-to-center of supports, in.
ℓ_a	= length of clear span in short direction of two-way slabs or in direction of moments, measured face-to-face of beams or other supports, in.
ℓ_b	= length of clear span in long direction of two-way slabs, measured face-to-face of beams or other supports, in.
ℓ_d	= development length, in.
ℓ_n	= length of clear span measured face-to-face of beams or other supports, in.
ℓ_n	= length of clear span in long direction of two-way systems, measured face-to-face of supports or beams, in.
ℓ_w	= horizontal length of wall, in.
L	= live loads or related internal moments and forces
L_r	= roof live load or related internal moments and forces
M_0	= total factored moment at section, lb·in.
M_{ot}	= unfactored overturning moment due to lateral forces at base of structure, lb·in.
M_{otu}	= factored overturning moment due to lateral forces at base of structure, lb·in.
M_a	= factored moment in short direction in two-way slabs, lb·in. per unit slab width
M_b	= factored moment in long direction in two-way slabs, lb·in. per unit slab width
M_{bn}	= nominal moment strength at section at balanced conditions, lb·in.
M_i, M_x	= unfactored overturning moment due to lateral forces for story i or x , respectively, lb·in.
M_{iu}, M_{xu}	= factored story moment due to lateral forces at story i or x , respectively, lb·in.
M_n	= nominal moment strength at section, lb·in.
M_{pr}	= probable flexural strength of member at joint face, computed using f_{yp} and ϕ of 1.0, lb·in.
M_u	= factored moment at section, lb·in.
M_u^+	= factored positive moment at section, lb·in.
$M_{a, \text{or } b}^+$	= factored positive moment at section, lb·in. per unit slab width
M_u^-	= factored negative moment at section, lb·in.
$M_{a, \text{or } b}^-$	= factored negative moment at section, lb·in. per unit slab width
M_{ux}	= factored moment at section in x direction, lb·in.
M_{uy}	= factored moment at section in y direction, lb·in.
M_{xu}	= factored overturning moment due to lateral forces for story x , lb·in.
n_c	= number of central columns in story in direction under consideration, for the whole structure
n_e	= number of edge columns in story in direction under consideration, for the whole structure
N	= number of blows in standard penetration test (SPT)
$\bar{N}$	= average soil standard penetration test resistance, measured in number of blows per foot of penetration, averaged over upper 100 ft of soil profile
p	= unfactored pressure for braced retaining walls, psi
p_a	= unfactored active pressure, psi
p_d	= unfactored concentrated dead load applied directly to member, lb

p_ℓ	=	unfactored concentrated live load applied directly to member, lb
p_p	=	unfactored passive pressure, lb/ft ²
p_u	=	factored concentrated load applied directly to member, lb
p_u	=	factored design pressure for retaining walls, lb/ft ²
p_z	=	at-rest, or active lateral soil pressure at depth z , lb/ft ²
PI	=	soil plasticity index, equal to difference in percentage of moisture content at liquid limit and at plastic limit
P_{0n}	=	nominal compression, without flexure, or axial load strength at section, lb
P_{cu}	=	factored compression load on wall boundary element, including seismic effects, lb
P_d	=	unfactored dead load axial force at section, lb
P_{bn}	=	nominal compression axial load strength at section at balanced conditions, lb
P_ℓ	=	unfactored live load axial force at section, lb
P_n	=	nominal axial load strength at given eccentricity, lb
$P_{n(max)}$	=	maximum compression nominal axial load strength at section, lb
P_{tn}	=	nominal tension, without flexure, or axial load strength at section, lb
P_{tu}	=	factored tension force on wall boundary element, including seismic effects, lb
P_u	=	factored axial load, lb
P_u	=	factored concentrated load, lb
P_u	=	factored axial load at given eccentricity, lb
P_v	=	maximum vertical load applied to footing not including wind or seismic, lb
P_{ov}	=	maximum vertical load applied to footing including wind or seismic overturning effects, lb
q_o	=	overburden pressure, or unfactored gravity loads applied directly to slab in mat foundations, lb/ft ²
q_a	=	unfactored allowable bearing capacity of soil, lb/ft ²
q_c	=	standard cone penetration resistance in cone penetration test (CPT), lb/ft ²
q_d	=	unfactored dead load per unit area, lb/ft ²
q_h	=	wind velocity pressure at height h over terrain, lb/ft ²
q_ℓ	=	unfactored live load per unit area, lb/ft ²
q_u	=	factored load per unit area, lb/ft ²
q_u	=	unconfined compression strength of soil, lb/ft ²
q_{un}	=	factored net soil reaction pressure on footing, lb/ft ²
r_u	=	factored uniformly distributed reaction from slab on supporting girder, beam, or reinforced concrete wall, lb/ft
R	=	response modification factor related to energy dissipation capacity in inelastic range of seismic resistant structural system
R_a	=	rain load or related internal moments and forces
R_n	=	nominal strength in terms of flexure, axial load, shear or bearing strength
R_{pi}	=	reaction from lateral soil pressure at story i , lb
R_u	=	factored reaction from supported structural member, lb
s	=	spacing of transverse reinforcement measured along axis of member, in.
s	=	spacing between stirrups, in.
s	=	center-to-center spacing of wall reinforcement, in.
s_j	=	center-to-center spacing between parallel joists, in.
s_u	=	shear strength of undrained cohesive soil, lb/ft ²
s_{sk}	=	spacing of skin reinforcement, in.
S	=	snow load or related internal moments and forces
S_a	=	value of elastic acceleration design response spectrum, for damping ratio of 5% of critical, expressed as fraction of acceleration of gravity
S_i	=	nominal load effect based on load, i
t_x, t_y	=	structural vertical member cross-sectional dimension in direction x and y , respectively, in.
T	=	cumulative effect of temperature, creep, shrinkage, differential settlement, and shrinkage-compensating concrete
T_0	=	unfactored story torsional moment due to lateral forces at base of structure, lb·in.
T_{0u}	=	factored story torsional moment due to lateral forces at base of structure, lb·in.
T_i, T_x	=	unfactored story torsional moment due to lateral forces at story i or x , respectively, lb·in.

T_u	=	factored torsional moment at section, lb-in.
T_{xu}, T_{yu}	=	factored story torsional moment due to lateral forces at story i or x , respectively, lb-in.
U	=	required strength to resist factored loads or related internal moments and forces
V	=	basic wind speed, mph, corresponding to 3 s gust speed at 33 ft above ground
V_0	=	unfactored story shear due to lateral forces at base of structure, lb
V_{0u}	=	factored story shear due to lateral forces at base of structure, lb
V_c	=	nominal shear strength provided by concrete, lb
V_i, V_x	=	unfactored story shear due to lateral forces at story i or x , respectively, lb
V_{iu}, V_{xu}	=	factored story shear due to lateral forces at story i or x , respectively, lb
V_n	=	nominal shear strength at section, lb
V_s	=	nominal shear strength at section provided by transverse reinforcement, lb
V_s	=	seismic design base shear, lb
V_u	=	factored shear, lb
V_w	=	wind design base shear, lb
w	=	moisture content of the soil, percentage
w_d	=	unfactored dead load per unit member length applied directly to the member, lb/ft
w_ℓ	=	unfactored live load per unit member length applied directly to the member, lb/ft
w_u	=	factored load per unit member length applied directly to the member, lb/ft
w_i, w_x	=	part of W corresponding to story i or x , respectively, lb
W	=	wind loads or related internal moments and forces
W	=	total building weight for seismic design, lb, see 4.11.3.3
W_u	=	total factored uniformly distributed design load per unit member length, lb/ft
$\bar{x}, \bar{y}$	=	story lateral stiffness center coordinates in directions x and y , respectively, in.
z	=	depth of soil, ft
α	=	parameter of Eq. (5-3)
α	=	factor affecting equivalent shear force due to unbalanced moment at column-slab connection in Eq. (9-3)
α_i	=	horizontal angle between normal to wind exposed surface and wind direction, deg
α_a	=	fraction of load that travels in short direction in two-way slabs-on-girders
α_b	=	fraction of load that travels in long direction in two-way slabs-on-girders
β	=	ratio of clear spans in long to short direction of two-way slabs
β	=	ratio of long side to short side of footing
β_i	=	vertical angle between normal to wind exposed surface and horizontal line, deg
γ	=	unit weight of material, lb/ft ³
γ_i	=	load factor for load effect i
ΔM_u	=	factored unbalanced moment at column-girder joint or wall-girder joint, lb-in.
ΔM_{u-ad}	=	additional factored unbalanced moment at column-slab connection, lb-in.
ΔV_e	=	factored design shear force from development of probable flexural capacity of member at faces of joints, lb
ΔV_u	=	factored shear force due to unbalanced moment at column-slab connection, lb
ΔV_u	=	increase in wall factored shear due to torsional effects, lb
λ	=	factor to calculate punching-shear strength, see 9.5.4.3
ρ	=	ratio of longitudinal tension reinforcement
	=	$A_s/(b \cdot d)$
ρ'	=	ratio of longitudinal compression reinforcement
	=	$A'_s/(b \cdot d)$
ρ_h	=	ratio of horizontal shear reinforcement area to gross concrete area of vertical section
ρ_{max}	=	maximum ratio of longitudinal flexural tension reinforcement
ρ_{min}	=	minimum ratio of longitudinal flexural tension reinforcement
ρ_s	=	ratio of volume of spiral reinforcement to core volume confined by spiral reinforcement (measured out-to-out)
ρ_t	=	ratio of total longitudinal reinforcement area to gross concrete section area
	=	$A_{st}/(b \cdot h)$
ρ_v	=	ratio of vertical reinforcement in reinforced concrete walls

ϕ	= strength-reduction factor, see 1.8.3
ϕ	= angle of internal friction of soil
ΣM_c	= sum of lowest flexural strengths ($\phi \cdot M_n$) of columns framing into joint, lb·in.
ΣM_g	= sum of flexural strengths ($\phi \cdot M_n$) of girders framing into joint, lb·in.
ΣP_u	= sum of factored concentrated loads within span, lb
ΣR_u	= sum of factored reactions from supported structural members at same story, lb

2.3 — ABBREVIATIONS

ACI	American Concrete Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
col.	column
deg	degrees
Eq.	equation
Eqs.	equations
Fig.	figure
ft	feet
in.	inch
lb	pound
long.	longitudinal
max.	maximum
min.	minimum
mph	miles per hour
No.	number
pg.	page
psf	pounds per square foot (lb/ft ²)
psi	pounds per square inch
reinf.	reinforcement
sec.	second
supp.	support
typ.	typical
yd	yard

CHAPTER 3 — STRUCTURAL SYSTEM LAYOUT

3.0 — NOTATION

- h_{pi} = story height of floor i measured from floor finish of story to floor finish of story immediately below, in.
- ℓ = center-to-center span length; shortest distance between adjacent parallel column centerlines, in.

3.1 — DESCRIPTION OF STRUCTURAL COMPONENTS

The building structure shall be divided into components as described by 3.1.1 through 3.1.5:

3.1.1 — Floor system

The floor system consists of the structural members that comprise the floor of a story in a building. In Chapter 6, the different types of floor systems are described. The floor system can include girders, beams, joists, and the slab that spans between them or the slab only, where it is directly supported by columns, as in slab-column systems.

3.1.2 — Vertical supporting members

The vertical supporting members hold up the floor system at each story and carry the accumulated gravity loads down to the foundation of the structure. Vertical supporting members shall be either columns or reinforced concrete walls.

3.1.3 — Foundation

The foundation comprises the structural elements through which the load of a structure is transmitted to the earth. It includes members such as spread footings, combined footings, foundation mats, basement and retaining walls, and grade beams. The foundation members are described in Chapter 14. Deep foundations, such as piles, caissons, pile footings, and caps, are beyond the scope of the *Essential Requirements*.

3.1.4 — Lateral-force resisting system

The lateral-force resisting system comprises the structural members that, acting jointly, support and transmit to the ground the lateral forces arising from seismic motions, wind, and lateral earth pressure. The floor system acts as a diaphragm that carries in its plane the lateral-force from the point of application to the vertical members of the lateral-force resisting system. The vertical members of the lateral-force resisting system, in turn, collect the forces arising from all floors and transmit them down to the foundation and through the foundation to the underlying soil. The main vertical members of the lateral-force resisting system shall be reinforced concrete walls.

3.1.5 — Other structural members

Other structural members that are part of the structure of the building and are covered by the requirements of the *Essential Requirements* are stairways, ramps, water tanks, and slabs on grade.

3.2 — GENERAL REQUIREMENTS

3.2.1 — Architectural requirements

A general architectural program of the building shall be coordinated with the structural designer before the structural design begins. The general architectural program shall include the following items as a minimum:

- (1) Plan geometry and dimensions of all the floors of the building;
- (2) Elevation of the building and the terrain, including the basement, if any;
- (3) Type of roof, its shape and slopes, the type of water-proofing, the means to facilitate the runoff of water from rain and melting snow or hail, and the location of drainage gutters;
- (4) Use of internal spaces of the building, its subdivision, and means of separation, in all stories;
- (5) Minimum architectural clear height in all floors;
- (6) Location and dimensions of stairways, ramps, and elevators;
- (7) Type of building enclosure, internal partitions, architectural and non-structural elements; and
- (8) Locations of ducts and shafts for utilities such as power supply, lighting, thermal control, ventilation, water supply, and wastewater, including enough information to detect interference with the structural members.

3.2.2 — General structural requirements

Based on the general architectural program information, the structural designer shall define the general structural requirements for the building being designed. The general structural requirements include the following items as a minimum:

- (1) Intended use of the building;
- (2) Nominal loads related to the use of the building;
- (3) Special loads defined by the owner;
- (4) Design seismic motions, if the building is located in a seismic zone;
- (5) Wind forces appropriate for the site;
- (6) Forces from snow, hail, or rain;
- (7) Fire rating requirements;
- (8) Type of roof and associated loads when not built of reinforced concrete;
- (9) Site information related to slopes and site drainage;
- (10) Allowable soil-bearing capacity and recommended foundation system derived from the geotechnical investigation and additional restrictions related to expected settlement;
- (11) Environmental requirements derived from local seasonal and daily temperature variations, humidity, presence of deleterious chemicals, and salts;
- (12) Availability, type, and quality of materials such as reinforcing bars, cement, and aggregates;
- (13) Availability of formwork materials;
- (14) Availability of a testing lab for concrete mixture proportioning and quality control during construction; and
- (15) Availability of qualified workmanship.

3.3 — STRUCTURAL LAYOUT

3.3.1 — General structural layout

The structural designer shall define a general structural layout in plan, including all information that is common to all levels of the structure. See Fig. 3.1. The general structural layout in plan includes:

- (1) A dimensioned axis grid, or centerlines, in both principal directions in plan, located at the intersection of the vertical supporting members (columns and reinforced concrete walls);
- (2) These axes shall intersect at the location of the vertical supporting members (columns and reinforced concrete walls);

- (3) Location in plan of all vertical supporting members, columns and reinforced concrete walls. These vertical-supporting members shall be aligned vertically and be continuous all the way to the foundation. Use of walls that separate spaces built of reinforced concrete as structural walls is permitted if they are continuous all the way to the foundation and have no openings for windows or doors;
- (4) Location of all duct, shafts, elevators, and stairways that are continuous from floor to floor.
- (5) Horizontal distance between centerlines, ℓ , which correspond to the center-to-center span lengths of the floor system; and
- (6) The location and distribution of all reinforced concrete walls.

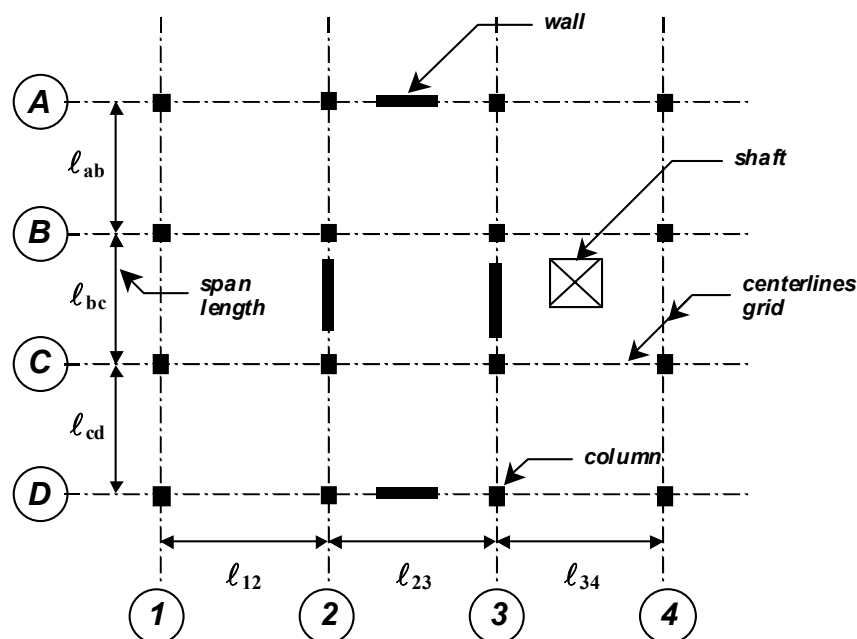


Fig. 3.1 - General structural layout in plan

3.3.2 — Floor layout

For each typical floor, the structural designer shall develop a structural floor layout. See Fig. 3.2. This layout shall contain:

- (1) The superposition of the floor perimeter on the general axis grid;
- (2) Girder and beam locations, or column and middle strips for slab-column systems;
- (3) All substantial architectural openings in the floor; and
- (4) An approximate load path from all floor areas to the supporting beams and girders.

3.3.3 — Vertical layout

The structural designer shall define a general structural layout in elevation. See Fig. 3.3. The general structural layout in elevation includes:

- (1) Number of stories;
- (2) The story height for each floor, defined as the vertical distance from floor finish to floor finish;
- (3) Slope and shape of the roof;
- (4) Architectural clearance from floor finish to ceiling for each floor;

- (5) Space necessary to accommodate power distribution, water supply and drainage, and heating, ventilation, and air conditioning;
- (6) Slope of the terrain and its relationship to the ground floor or basement;
- (7) Supporting soil stratum depth and water-table depth.

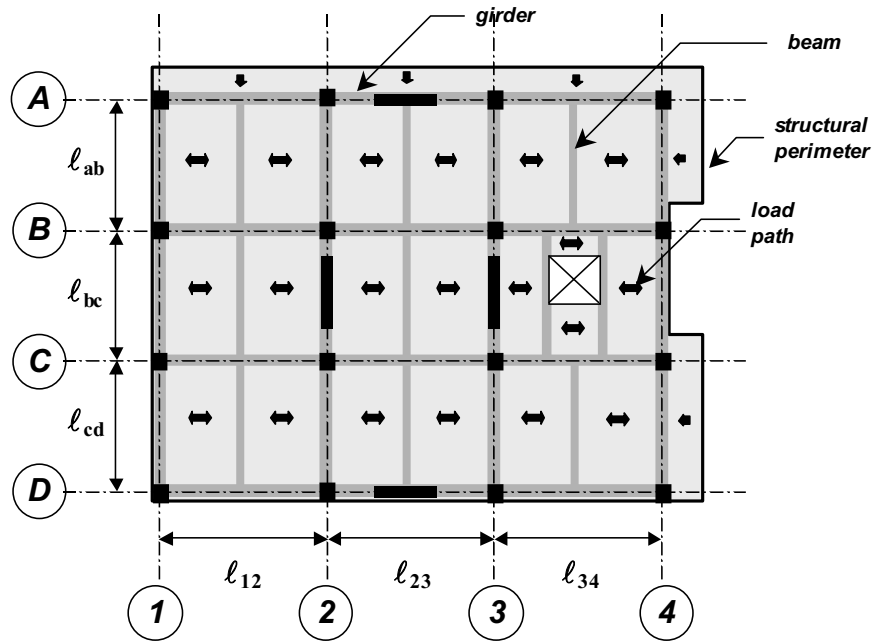


Fig. 3.2 - Typical floor structural layout

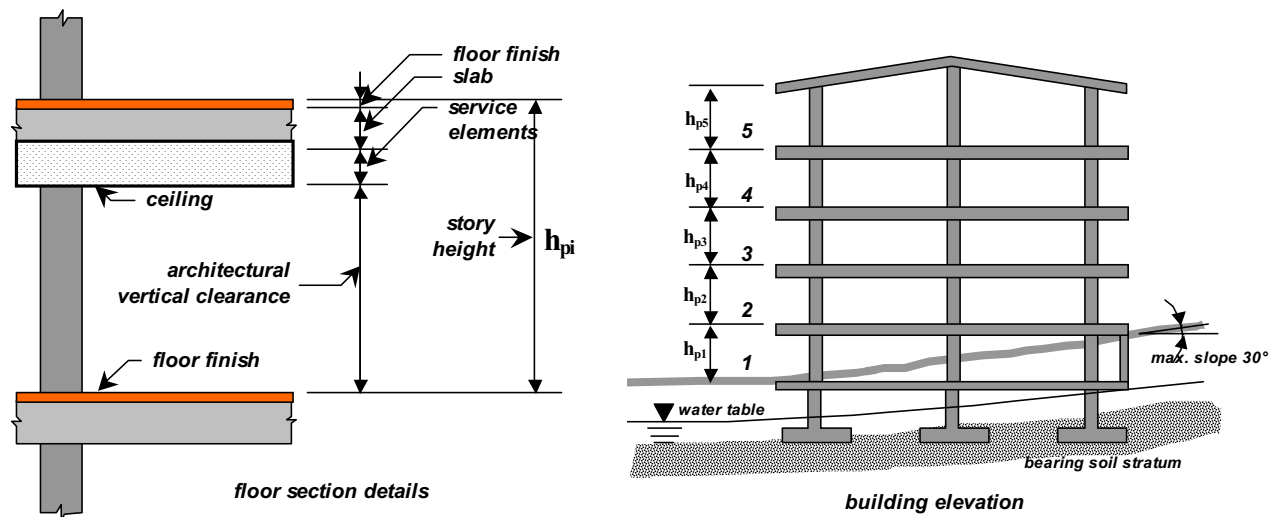


Fig. 3.3 - General structural layout in elevation

3.4 — FEASIBILITY UNDER THE *ESSENTIAL REQUIREMENTS*

Based on the layout information, the structural designer has to verify the feasibility of performing the structural design under the *Essential Requirements*. Compliance with limitations (1) through (10) shall be confirmed:

- (1) The use of the building is within the accepted occupancies of 1.3.1; for mixed use, that all intended occupancies are permitted;
- (2) The number of stories does not exceed the maximum, given in 1.3.2;
- (3) The area of the largest floor does not exceed the maximum area, given in 1.3.3;
- (4) The story heights, measured from finish to finish, do not exceed the maximum story height given in 1.3.4;
- (5) The span lengths do not exceed the maximum span length given in 1.3.5;
- (6) The difference between adjacent spans does not exceed the limit of 1.3.6;
- (7) The number of spans in both directions, and in all floors, meets the requirements of 1.3.7;
- (8) The length of cantilevers does not exceed the limit of 1.3.8;
- (9) The slope of girders, beams, joists, or slabs does not exceed the maximum slope given in 1.3.9; and
- (10) The slope of the terrain at the building site does not exceed the maximum given in 1.3.10.

If any of these conditions are not met, the structural design shall be performed using the supporting codes and standards of 1.4.

CHAPTER 4 — LOADS

4.0 — NOTATION

A_a	= effective seismic peak ground horizontal acceleration in rock for short periods of vibration, expressed as a fraction of gravity, g
A_p	= component, or cladding, wind exposed surface area, ft^2
A_{su}	= wind exposed surface area, ft^2
C_p	= component, or cladding, wind surface pressure coefficient
C_{su}	= wind surface pressure coefficient
C_{vx}	= coefficient defined in 4.11.4
D	= dead loads or related internal moments and forces
E	= seismic loads or related internal moments and forces
F	= loads due to weight and pressure of fluids with well-defined densities and controllable maximum heights or related internal moments and forces
F_a	= seismic site coefficient for short periods of vibration
F_{pw}	= equivalent static wind force for components and cladding acting normal to wind exposed surface, lb
F_{su}	= equivalent static wind force acting normal to wind exposed surface, lb
F_i, F_x	= wind or seismic force applied at level i or x , respectively, lb
g	= acceleration due to gravity, 386 in./s^2
H	= loads due to weight and pressure of soil, water in soil, or other materials, or related internal moments and forces
h	= mean roof height for wind design, measured over terrain, $in.$
h_i, h_x	= height above base to level i or x , respectively, ft
L	= live loads or related internal moments and forces
L_r	= roof live load or related internal moments and forces
$\bar{N}$	= average soil standard penetration test resistance, measured in number of blows per foot of penetration, averaged over upper 100 ft of soil profile
PI	= soil plasticity index, equal to difference in percentage of moisture content at liquid limit and at plastic limit
q_h	= wind velocity pressure at height h over terrain, lb/ft^2
R_a	= rain load or related internal moments and forces
R	= response modification factor related to energy dissipation capacity in inelastic range of seismic resistant structural system
S	= snow load or related internal moments and forces
S_a	= value of elastic acceleration design response spectrum, for damping ratio of 5% of critical, expressed as fraction of acceleration of gravity
s_u	= shear strength of undrained cohesive soil, lb/ft^2
T	= cumulative effect of temperature, creep, shrinkage, differential settlement, and shrinkage-compensating concrete
U	= required strength to resist factored loads or related internal moments and forces
V	= basic wind speed, mph , corresponding to 3 s gust speed at 33 ft above ground in exposure Category C
V_s	= seismic design base shear, lb
V_w	= wind design base shear, lb
W	= wind loads or related internal moments and forces
W	= total building weight for seismic design, lb , see 4.11.3.3
w	= moisture content of the soil, percentage
w_i, w_x	= part of W corresponding to story i or x , respectively, lb
α_i	= horizontal angle between normal to wind exposed surface and wind direction, deg
β_i	= vertical angle between normal to wind exposed surface and horizontal line, deg
γ	= unit weight of material, lb/ft^3

4.1 — GENERAL

This Chapter provides minimum load requirements for the design of buildings. Loads and the appropriate load combinations shall be used together.

4.2 — LOAD FACTORS AND LOAD COMBINATIONS

The largest required factored strength, U , as defined in 1.8.1, for the structural member shall be determined using the load factors and load combinations of this section. The following general requirements shall apply:

- (a) Each relevant strength limit state shall be investigated, including effects of one or more loads not acting simultaneously;
- (b) In load combinations where the symbol $\pm$ is used in factoring alternating forces that act in one direction or the opposite, it shall be interpreted as the sign that leads to the maximum (positive) or minimum (negative) value of U ; and
- (c) The most unfavorable effects from both wind and seismic loads shall be investigated, but they need not be considered to act simultaneously.

4.2.1 — Dead and live load

Required factored strength, U , to resist dead load, D , and live load, L , shall be the greater of:

$$U = 1.4 \cdot D \quad (4-1)$$

$$U = 1.2 \cdot D + 1.6 \cdot L \quad (4-2)$$

4.2.2 — Rain load, snow load, and sloping roof live load

Required factored strength, U , to resist rain load, R_a , snow load, S , or sloping roof live load, L_r , shall be evaluated based of the following load combinations:

$$U = 1.2 \cdot D + 1.6 \cdot L + 0.5 \cdot (R_a \text{ or } S \text{ or } L_r) \quad (4-3)$$

$$U = 1.2 \cdot D + 1.0 \cdot L + 1.6 \cdot (R_a \text{ or } S \text{ or } L_r) \quad (4-4)$$

4.2.3 — Wind forces

Required factored strength, U , to resist wind forces, W , shall be evaluated based of the following load combinations:

$$U = 1.2 \cdot D + 1.0 \cdot L \pm 1.6 \cdot W + 0.5 \cdot (R_a \text{ or } S \text{ or } L_r) \quad (4-5)$$

$$U = 1.2 \cdot D + 0.8 \cdot W + 1.6 \cdot (R_a \text{ or } S \text{ or } L_r) \quad (4-6)$$

$$U = 0.9 \cdot D \pm 1.6 \cdot W \quad (4-7)$$

4.2.4 — Seismic forces

Required factored strength, U , to resist seismic forces, E , shall be evaluated based of the following load combinations:

$$U = 1.2 \cdot D + 1.0 \cdot L + 0.2 \cdot S \pm 1.0 \cdot E \quad (4-8)$$

$$U = 0.9 \cdot D \pm 1.0 \cdot E \quad (4-9)$$

4.2.5 — Earth pressure

For members resisting lateral earth pressure, **H**, the required factored strength, **U**, shall be at least equal to

$$U = 1.2 \cdot D + 1.6 \cdot L + 1.6 \cdot H \quad (4-10)$$

When the building structure as a whole resists permanent uncompensated horizontal loads due to lateral soil pressure, $(1.6 \cdot H)$ shall be added to the right side of Eq. (4-7) and Eq. (4-9).

4.2.6 — Weight and pressure of fluids

For members subjected to weight and pressure of fluids with well-defined densities and controllable maximum heights, $(1.4 \cdot F)$ in Eq. (4-1) and $(1.2 \cdot F)$ in Eq. (4-2) shall be added to the right side.

4.2.7 — Other effects

Where structural effects, **T**, of differential settlement, shrinkage, or temperature change are significant in design, the design shall not be performed using the *Essential Requirements*, and the supporting codes and standards listed in 1.4 shall be used.

4.3 — MASS AND WEIGHT

A clear distinction between mass and weight shall be made by the structural designer in all calculations.

4.4 — WEIGHT OF MATERIALS

In determining dead loads, the actual weight of materials and constructions shall be used.

[In the absence of definite information, the approximated values listed in Table 4.1 may be used.]

4.5 — DEAD LOADS

4.5.1 — Definition of dead loads

Dead loads consist of the weight of all material of construction incorporated into the building, including, but not limited to: structure, walls and partitions, floors, roofs, ceilings, stairways, ramps, finishes, cladding, and other incorporated architectural and structural systems, and fixed service equipment. In determining dead loads for purposes of design, the actual weights of materials and constructions shall be used. For purposes of design, the weight of fixed service equipment, such as plumbing stacks and risers, electrical feeders, and heating, ventilating, and air conditioning systems, shall be included with the dead loads.

Table 4.1 — Minimum unit weight, γ , for evaluation of dead and live loads from materials

Material	unit weight γ (lb/ft ³)	Material	unit weight γ (lb/ft ³)
Aluminum	170	Iron	
Bituminous products		Cast	450
Asphalt and tar	81	Wrought	480
Gasoline	42	Lead	710
Graphite	135	Lime	
Paraffin	56	Hydrated, loose	32
Petroleum	53	Hydrated, compacted	45
Brass	526	Masonry, brick (solid portion)	115
Bronze	552	Masonry, concrete (solid portion)	125
Cement, portland, loose	90	Masonry grout	140
Ceramic tile	150	Masonry, stone	162
Charcoal	12	Mortar cement or lime	130
Cinder fill	57	Particleboard	45
Coal, piled	50	Plywood	36
Concrete, plain	144	Sand	
Concrete, reinforced	150	Clean and dry	90
Copper	556	River, dry	106
Cork, compressed	14	Steel	488
Earth		Stone	
Clay, dry	63	Basalt, granite, gneiss	96
Clay, damp	110	Limestone, marble, quartz	95
Clay and gravel, dry	100	Sandstone	82
Silt, moist, packed	96	Shale	92
Silt, moist, loose	78	Terra cotta	
Sand and gravel, dry, loose	100	Voids filled	120
Sand and gravel, dry, packed	110	Voids unfilled	72
Sand and gravel, wet	120	Tin	459
Glass	160	Water	
Gravel, dry	104	Fresh	62
Gypsum, loose	70	Sea	64
Gypsum, wallboard	50	Wood, Seasoned	28-47
Ice	57	Zinc, rolled sheet	449

4.5.2 — Selfweight of the structure

The unit weight of reinforced concrete shall be taken as 150 lb/ft³.

4.5.3 — Dead loads from non-structural elements

Dead load from non-structural elements shall be divided into flat and standing non-structural elements.

4.5.3.1 — Flat non-structural elements. Flat non-structural elements shall include all construction material whose vertical dimension is substantially less than the horizontal dimensions and are either applied, supported, attached, fixed, or hung to the slabs or roof of the building. These elements shall include, but are not to be limited to: permanent slab or joist forms, floor topping, floor fills, floor finishes, roof slope fills, roof coverings, tiles, waterproofing membranes, thermal insulation, skylights, ceilings, furring, and ducts for services. In office buildings or other buildings where partitions will be erected or rearranged, provision for partition weight shall be made, whether or not partitions are shown on the architectural drawings.

[For purposes of design, the dead loads due to flat non-structural elements may be considered as uniform vertical loads per unit area of horizontal surface or horizontal projection, applied to the corresponding zones or areas where the flat non-structural elements are located. In determining the dead loads of flat non-structural elements, the actual weight of materials and constructions and realistic thickness should be used. As a guide, Table 4.1 gives minimum unit weight (the values provided there have to be multiplied by the corresponding thickness in ft to obtain dead loads in lb/ft²). In Tables 4.2 to 4.5, values are given for dead loads of typical flat non-structural element construction materials. The values provided in Tables 4.2 to 4.5 correspond to average minimum values. The

structural designer should take into account the possibility of variation of these values due to different local materials and local construction practices.]

Table 4.2 — Flat non-structural elements minimum dead loads - ceilings

Component	Load (lb/ft ²) ft ² of floor area
Ceilings	
Acoustical fiberboard	1
Gypsum board	0.55 (per 1/8 in. thickness)
Mechanical duct allowance	4
Plaster on tile or concrete	5
Plaster on wood lath	8
Suspended steel channel system	2
Suspended metal lath and cement plaster	15
Suspended metal lath and gypsum plaster	10
Wood furring suspension system	2.5

Table 4.3 — Flat non-structural elements minimum dead loads - floor fills

Component	Load (lb/ft ²) ft ² of floor area
Floor fill	
Cinder concrete	9 (per in. thickness)
Lightweight concrete	8 (per in. thickness)
Sand	8 (per in. thickness)
Stone concrete	12 (per in. thickness)

Table 4.4 — Flat non-structural elements minimum dead loads - floors

Component	Load (lb/ft ²) ft ² of floor area
Floors and floor finishes	
Asphalt block (2 in.), 1/2 in. mortar	30
Cement finish (1 in.) on stone-concrete fill	32
Ceramic or quarry tile (3/4 in.) on 1/2 in. mortar bed	16
Ceramic or quarry tile (3/4 in.) on 1 in. mortar bed	23
Concrete fill finish	12 (per in. thickness)
Hardwood flooring, 7/7 in.	4
Linoleum or asphalt tile, 1/4 in.	1
Marble and mortar on stone-concrete fill	33
Slate	15 (per in. thickness)
Solid flat tile on 1 in. mortar base	23
Sub flooring, 3/4 in.	3
Terrazzo (1-1/2 in.) directly on slab	19
Terrazzo (1 in.) on stone-concrete fill	32
Terrazzo (1 in.), 2 in. stone concrete	32
Wood block (3 in.) on mastic, no fill	10
Wood block (3 in.) on 1/2 in. mortar base	16

Table 4.5 — Flat non-structural elements minimum dead loads - roof coverings

Component	Load (lb/ft²) ft² of floor area
Roof covering	
Asbestos-cement shingles	4
Asphalt shingles	2
Cement tile	16
Clay tile including mortar	25
Copper or tin	1
Corrugated asbestos-cement roofing	4
Deck, metal, 20 gage	2.5
Deck, metal, 18 gage	3
Decking, 2 in. wood	5
Decking, 3 in. wood	8
Fiberboard, 1/2 in.	0.75
Gypsum sheathing, 1/2 in.	2
Insulation, roof boards	
Fibrous or cellular glass	1.0 (per in. thickness)
Fiberboard	1.5 (per in. thickness)
Perlite	0.8 (per in. thickness)
Polystyrene foam	0.2 (per in. thickness)
Urethane foam with skin	0.5 (per in. thickness)
Plywood (per 1/8 in. thickness)	0.4 (per 1/8 in. thickness)
Skylight, metal frame, 3/8 in. wire-glass	8
Waterproofing membranes:	
Bituminous, gravel-covered	5.5
Bituminous, smooth surface	1.5
Liquid applied	1
Single-ply, sheet	0.7
Wood sheathing	3.0 (per in. thickness)
Wood shingles	3

4.5.3.2 — Standing non-structural elements. Standing non-structural elements shall include all construction material whose vertical dimension is substantially greater than the minimum horizontal dimension and are either free standing, supported by the vertical structural members or attached to them, or span vertically from floor to floor. These elements shall include, but are not to be limited to: facades, non-structural walls, partitions, wall coverings, veneer, architectural ornaments, windows, doors, and vertical ducts for services.

Table 4.6 — Standing non-structural elements minimum dead loads - coverings for walls

Component	Load (lb/ft²) per ft² of vertical surface (multiply by the height of element in ft, to obtain line loads in lb/ft)
Covering for walls	
Cement tile	16
Fiberboard, 1/2 in.	0.75
Gypsum sheathing, 1/2 in.	2
Insulation, wall boards	
Fibrous or cellular glass	1.0 (per in. thickness)
Fiberboard	1.5 (per in. thickness)
Perlite	0.8 (per in. thickness)
Polystyrene foam	0.2 (per in. thickness)
Urethane foam with skin	0.5 (per in. thickness)
Plywood (per 1/8 in. thickness)	0.4 (per 1/8 in. thickness)
Wood sheathing	3.0 (per in. thickness)

Table 4.7 — Standing non-structural elements minimum dead loads - light partitions

Component	Load (lb/ft²) per ft² of vertical surface (multiply by the height of element in ft, to obtain line loads in lb/ft)
Light partitions	
Movable steel partitions (non-full height)	6
Movable steel partitions (full height)	4
Wood or steel studs, 1/2 in. gypsum board each side	8
Wood studs, 2 x 4, unplastered	4
Wood studs, 2 x 4, plastered one side	12
Wood studs, 2 x 4, plastered two sides	20

Table 4.8 — Standing non-structural elements minimum dead loads - veneer

Component	Load (lb/ft²) per ft² of vertical surface (multiply by the height of element in ft, to obtain line loads in lb/ft)
Veneer	
Granite veneer	9 (per in. thickness)
Limestone veneer	8 (per in. thickness)
Sandstone veneer	7 (per in. thickness)
Ceramic veneer	8 (per in. thickness)

Table 4.9 — Standing non-structural elements minimum dead loads - walls

Component	Load (lb/ft²) per ft² of vertical surface (multiply by the height of element in ft, to obtain line loads in lb/ft)
Walls	
Exterior stud walls (steel or wood studs):	
2x4 @ 16 in., 5/8 in. gypsum, insulated, 3/8 in. siding	11
2x6 @ 16 in., 5/8 in. gypsum, insulated, 3/8 in. siding	12
Exterior stud walls with brick veneer	48
Clay solid masonry unit walls:	
Unplastered	wall thickness 4 in. 8 in. 12 in. 16 in. 39 79 115 155
Clay tile masonry unit walls:	
Plaster in both faces	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 37 52 64 79 91
Unplastered	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 27 41 54 68 81
Hollow concrete masonry unit walls:	
No grout	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 29 30 39 47 54
48 in. o. c. grout spacing	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 36 47 57 66 72
40 in. o. c. grout spacing	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 37 48 59 69 78
32 in. o. c. grout spacing	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 38 50 62 72 81
24 in. o. c. grout spacing	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 41 54 67 78 87
16 in. o. c. grout spacing	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 46 61 76 90 105
Full Grout	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 62 83 105 127 155
Solid concrete masonry unit walls:	
Unplastered	wall thickness 4 in. 6 in. 8 in. 10 in. 12 in. 41 64 87 110 133

Table 4.10 — Standing non-structural elements minimum dead loads - windows

Component	Load (lb/ft²) per ft² of vertical surface (multiply by the height of element in ft, to obtain line loads in lb/ft)
Windows	
Glass curtain walls, glass, frame and sash	10
Windows, glass, frame and sash	8

[The dead loads from standing non-structural elements may be considered as concentrated loads or as uniform line loads per unit of length of non-structural element. As a guide, in Table 4.1 minimum unit weights are given (the values are to be multiplied by the corresponding thickness in ft and by the height of the element in ft to obtain uniform line dead loads in lb/ft). In Tables 4.6 to 4.10 values are given for dead loads of typical standing non-structural elements construction materials, in lb per unit vertical area in ft². To obtain uniform line dead loads in lb/ft, the values suggested in Tables 4.6 to 4.10 are multiplied by the height of the standing non-structural element in ft. The values provided in Tables 4.1 and 4.6 to 4.10, correspond to typical average minimum values; the structural designer should take into account the possibility of variation of these values due to local materials and local construction practices.]

[The dead load of internal standing non-structural elements, such as internal walls and partitions, may be considered as uniform vertical dead loads per unit area when the secondary structural members of the floor system are capable of supporting the resulting concentrated or uniform line loads, without impairment to the strength and serviceability of the floor system or the non-structural element. If the standing non-structural elements are more than one story tall, their dead loads should be considered as concentrated loads or line load. The dead load of façades and elements of the building enclosure should be considered as line loads on the edge of the slab.]

4.5.3.3 — Alternative minimum values for dead loads of non-structural elements. For buildings with story heights not exceeding 10 ft, it shall be permitted to use the minimum values in lb/ft² of horizontal floor area given in Table 4.11 for the occupancies listed, instead of a detailed analysis of the dead loads caused by non-structural elements.

Table 4.11 — Alternative minimum values for dead load of non-structural elements when no detailed analysis is performed

Occupancy			Façade and partitions (lb/ft ²) ft ² of floor area	Floor finish and ceiling (lb/ft ²) ft ² of floor area
Group A — Assembly	A-2 A-3	Building having an assembly room with capacity less of 100 persons and not having a stage	20	40
Group B — Business	B	Movable full height partitions	20	40
		Fixed masonry partitions	45	40
Group E — Educational	E	Classrooms	45	35
Group F — Factory	F-1	Light industries	18	35
Group I — Institutional	I-1	Residential board and care facilities	45	35
	I-3	Prisons, jails, reformatories, detention centers	55	40
	I-4	Daycare facilities	45	35
Group M — Mercantile	M	Display and sale of merchandise	35	30
Group R — Residential	R	Masonry façade and partitions	65	35
		Light façade and partitions	45	30
Group S — Storage	S-2	Storage of light materials	35	35
Group U — Utility and Miscellaneous	U	Garages for vehicles with carrying capacity up to 4000 lb	5	20

4.5.4 — Fixed equipment

Fixed equipment dead load shall be provided by the manufacturer of the equipment.

4.6 — LIVE LOADS

Live loads are produced by the use and occupancy of the building and do not include construction or environmental loads such as wind load, snow load, rain load, seismic load, or dead load. The live loads shall be the maximum loads expected by the intended use or occupancy but in no case shall be less than the minimum uniformly distributed unit loads given in Table 4.12 for the occupancies listed.

Table 4.12 — Minimum uniformly distributed live loads

Occupancy or Use		Uniform (lb/ft ²) ft ² of floor area
Group A — Assembly	Balconies	125
	Corridors and stairways	125
	Fixed seats (fastened to floor)	75
	Gymnasiums	125
	Lobbies	125
	Movable seats	125
	Recreational areas	100
	Platforms	125
	Stage floors	160
Group B — Business	Corridors and stairways	115
	Offices	50
	Restaurants	115
Group E — Educational	Classrooms	65
	Corridors and stairways	125
	Libraries	
	Reading rooms	75
	Stack rooms	170
Group F — Factory	Light industries	150
	Heavy industries	275
Group I — Institutional	Operating rooms, laboratories	85
	Wards and private rooms	50
	Corridors and stairways	115
Group M — Mercantile	Retail	115
	Wholesale	150
Group R — Residential	Balconies	115
	Private rooms and corridors serving them	50
	Public rooms and corridors serving them	115
	Stairways	125
Group S — Storage	Light	140
	Heavy	300
Group U — Utility and Miscellaneous	Garages for passenger cars only	60
	Garages for trucks up to 4000 lb capacity	100

4.7 — ROOF LIVE LOADS

Roof live loads shall not be less than the maximum value used for the rest of the building, and when of mixed occupancy, the maximum of the different occupancies. When the roof is a light roof with a slope greater than 15 degrees, supported on a steel or wood structure, it is permitted to use a roof live load of 20 lb/ft².

4.8 — RAIN LOAD

Each portion of the roof shall be designed to sustain the load of all rainwater that will accumulate on it if the drainage system for that portion is blocked.

4.9 — SNOW LOAD

Where snow is expected, the loads caused by its accumulation shall be taken into account in the design of the roof. North of latitude 30°, the minimum snow load in lb/ft² as given in Fig. 4.1 for the latitude and altitude above sea level of the site shall be used. Where records or experience near the site indicate that the value with a 2% annual probability of being exceeded (50 year mean recurrence interval) exceeds the value from Fig. 4.1, the design shall not be preformed using the *Essential Requirements*, and the supporting codes and standards listed in 1.4 shall be used.

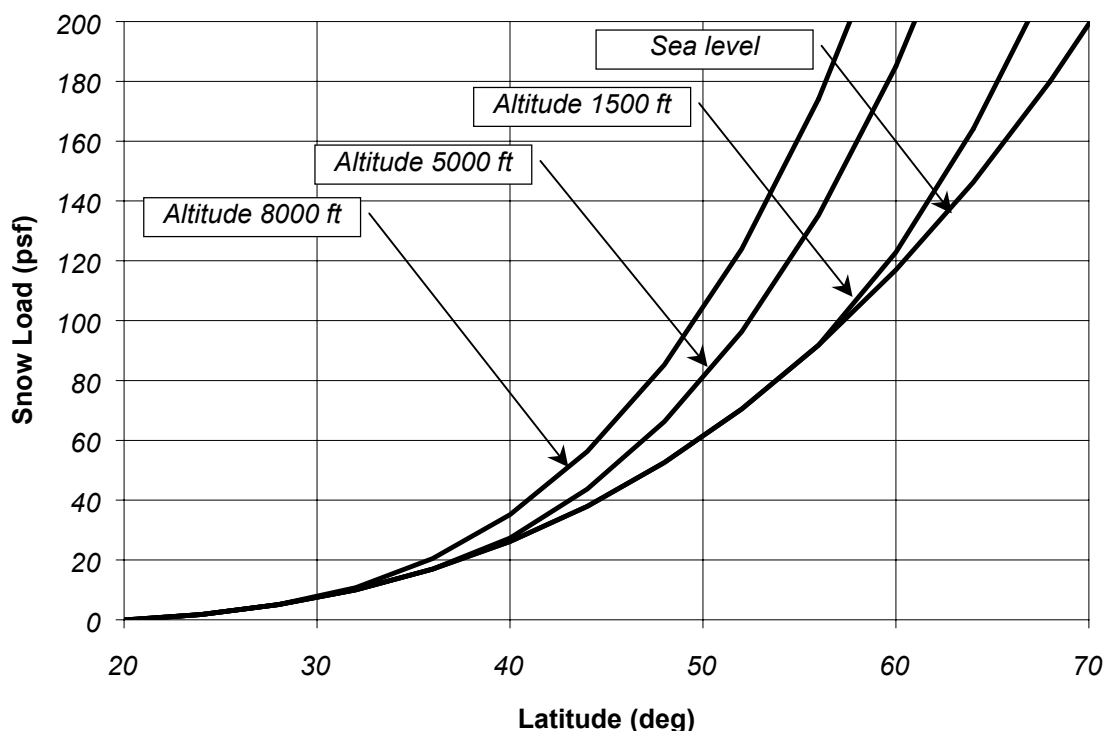


Fig. 4.1 — Minimum snow load.

4.10 — WIND FORCES

4.10.1 — General

This section provides a method to calculate wind forces on a building and on individual structural members and cladding. These requirements shall apply to buildings with regular geometric shapes, response characteristics, and site locations. Buildings that do not comply with these features shall be considered outside the scope of the *Essential Requirements*. The procedures and values given in the general building code having jurisdiction shall be used for obtaining the corresponding wind forces. See 1.4.

4.10.1.1 — Procedure. Wind pressures and wind forces shall be determined in accordance with Steps 1 through 5:

- Step 1: A velocity pressure, q_h , shall be determined in accordance with 4.10.2.1 and 4.10.2.2.
- Step 2: Appropriate C_{su} pressure coefficients shall be selected from the provisions of 4.10.3 for all wind exposed surfaces of the building, assuming that the wind acts in the positive and negative sense, in both principal directions in plan of the building.
- Step 3: The velocity pressure, q_h , affected by the force coefficients and multiplied by the exposed area of the surface, A_{su} , shall be used to determine the equivalent static wind design force, F_{su} , that act in a direction normal to the exposed surfaces of the building.
- Step 4: The components in the direction of the wind of the static wind forces that act on the surfaces, F_{su} , shall be algebraically added to obtain the wind base shear, V_w , on the building in each principal direction in plan, in both senses.
- Step 5: The static wind forces that act on the structural members and cladding shall be used to design the individual elements and their attachments to the structure.