Chapter (1): Introduction to Structural Engineering Concepts

1.1 Engineering Design Process

Conceptual Stage:

- Needs are identified then objectives are expressed to meet these needs
- Input from:
  - Clients
  - Governmental regulatory agencies
  - Architects, planners, and engineers

Preliminary Design Stage:

- Creative ideas by the engineers
- Keep in mind construction aspects
- Thorough consideration of expected loads on the structure at all construction stages and during occupancy of the finished structures.
- Sizing of structural elements for safety and serviceability
- Architectural Constraints
  - Simplicity & Duplication
  - Fabrication & Construction Procedures
- Preliminary design approximate theories of structural analysis are used to minimize time during this phase

Selection Stage:

- At this stage, all alternatives are presented and all parties involved participate in the selection stage so the final design stage can begin

Final Design Stage:

- Loads are determined in greater accuracy than the preliminary stage.
- All loading combinations are examined in this stage.
- Structural analysis is carried with greater accuracy than the preliminary stage with the elimination of all approximations
- The results are presented in sets of drawings and specifications showing
  - Sizing of Members
  - Detailing
  - Quality of workmanship
  - Design/building codes used.
  - Bill of Materials
  - Total Cost

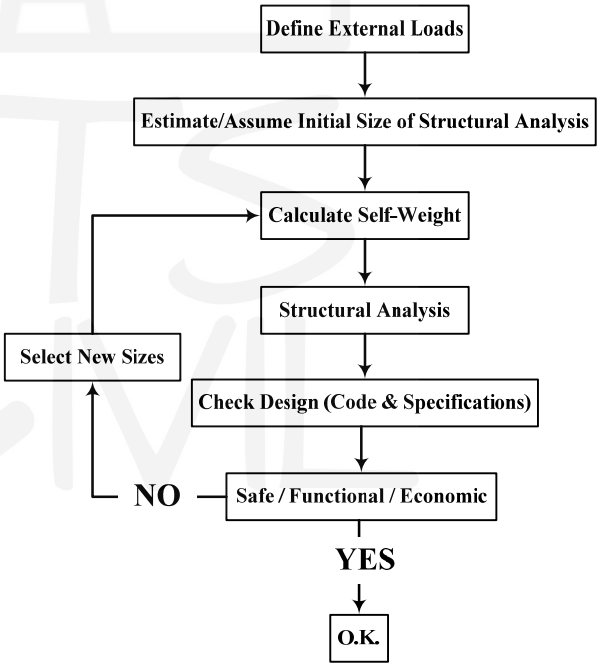

Figure 1-1: Summary of structural engineering design process

1.2 Structural Analysis

- Structural Analysis: the determination of the structural response to specific loads and actions.
- Response: measured by establishing the forces and deformations throughout the structure
- Analysis: based on engineering mechanics theory, laboratory research, experience, and engineering judgement

1.3 Structural Form

The form of the structure depends on many considerations as:

- Functional requirements
- Aesthetic (Beauty) requirement
- Surface and subsurface conditions
- Material availability
- Construction Expertise
- Economical limitations
- Environmental impact
- Safety

1.4 Structural Elements:

1.4.1 Tie Rods:

- Subjected to tensile force only.
- They are slender.
- They are referred to as "tie rods" and "bracing ties"
- They are made from bars, angles, and channels.
- Strength is limited only by material strength

Figure 1-2: Tie Rods

1.4.2 Beams:

- Usually straight, horizontal members used to resist bending moments and shear forces.
- Classified to the way they are supported.
- Resist shear force and bending moment.

Figure 1-3: Steel and concrete beams

1.4.3 Columns:

- Vertical elements resisting axial compressive loads.
- When subjected to both bending moments and axial load, they are referred to as "beam column"
- Susceptible to buckling which limits the strength of the member

Figure 1-4: Steel and concrete columns

1.5 Types of Structures:

Combination of structural elements is referred to as a "structural system". Some Examples are:

1.5.1 Trusses:

- Used for large spanned structures.
- Consist of slender elements arranged in a triangular fashion.
- Two major types: Planner and Space.
- Convert outside loads to compression and tension forces in members.

Figure 1-5: Steel and timber trusses

1.5.2 Cables and arches:

- Used to span long distances.
- Cables are flexible and carry the loads in tension.
- Arch achieves its strength in compression.
- Arch must be rigid.

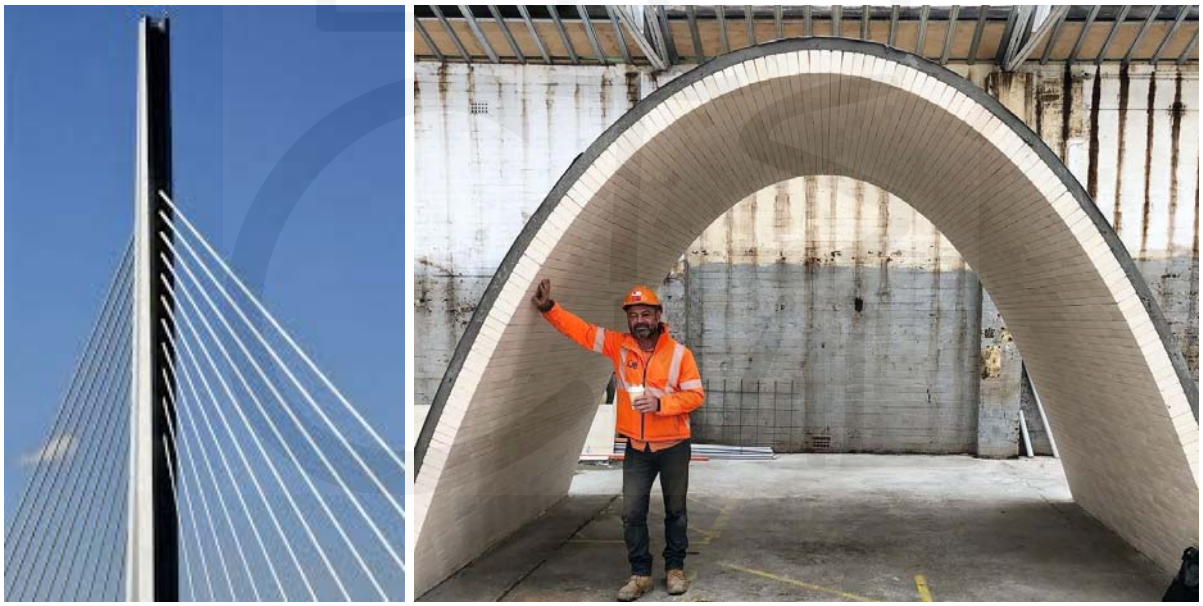

Figure 1-6: Cables and arches

1.5.3 Frames:

- Composed of beams and columns that are pinned or fixed.
- Extents in two or three dimensions.
- Its strength is derived from the moment interaction between beams and columns.

- Economical when using small beams and larger columns due to beam column action.

Figure 1-7: Steel and concrete frames

1.5.4 Surface Structures:

- Made from materials (flexible or rigid) having very small thickness compared to its other dimensions.
- They take several shapes like “thin plates” or “shells”.
- They support loads mainly in tension or compression with very little bending.
- Three-Dimensional

Figure 1-8: Examples of surface structures

1.6 Codes and Loads types and categories:

1.6.1 Codes:

- The design loading for structures is often specified in codes such as:
  - Minimum Design Loads for Buildings and Other Structures ASCE 7-16
  - International Building Code – 2018 (IBC-2018)

Figure 1-9: ASCE and IBC codes

- Design codes provide detailed technical standards used to establish actual structural design. Some Examples:
  - Building Code Requirements for Reinforced Concrete by American Concrete Institute (ACI)
  - Steel Construction Manual, by American Institute of Steel Construction (AISC)
  - British Standards (BS)
  - EURO Code (European Code)

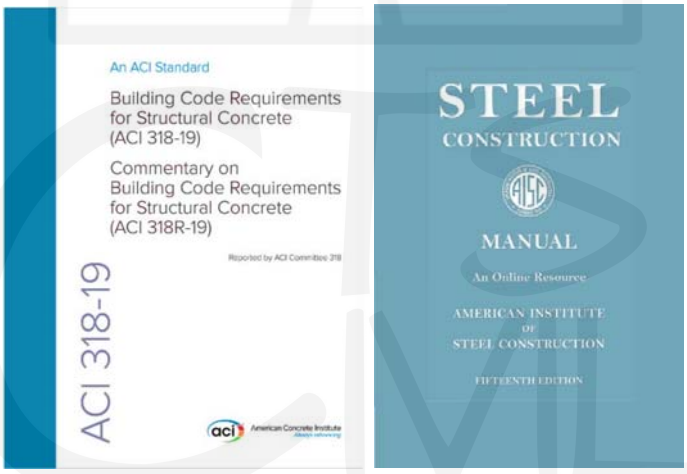

Figure 1-10: ACI and AISC codes

1.6.2 Load Types:

- **Concentrated loads:**
  - Applied over relatively small area
  - Examples: Column loads, Vehicular wheel load

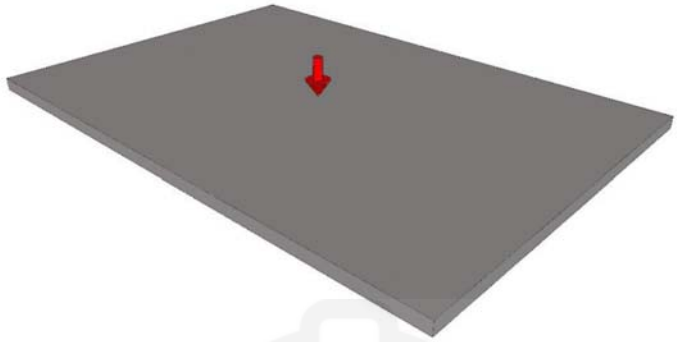

Figure 1-11: Concentrated load

- **Line loads:**
  - Distributed along a narrow strip of the structure
  - Examples: Beam self-weight, weight of wall or partition

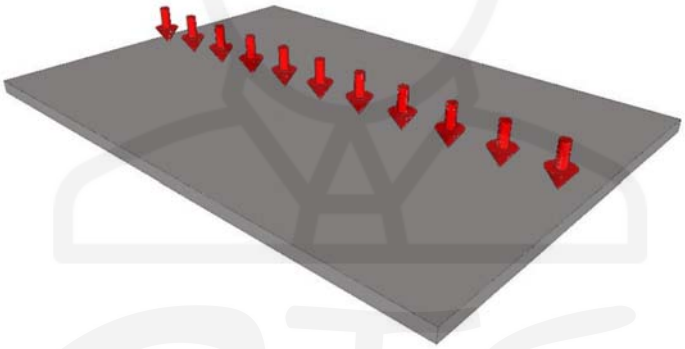

Figure 1-12: Line load

- **Surface loads:**
  - Distributed over an area of the structure
  - Examples: floor and roof loads

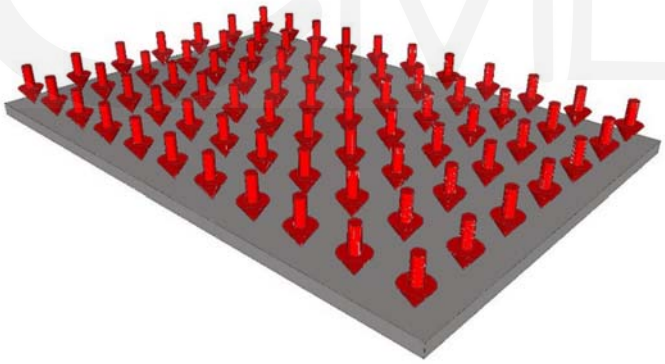

Figure 1-13: Surface load

1.6.3 Load Categories:

- **Dead Load:**
  - Weight of the various structural members and the weights of any objects that are **permanently attached** to the structures.
  - For a building, dead loads include weight of:

✓ Roof Slab	✓ Walls
✓ Floor Slab	✓ Windows
✓ Beams	✓ Plumbing
✓ Girders	✓ Electrical Fixtures
✓ Columns	✓ Ducts

  - The dead loads can be calculated knowing the densities and dimensions of the structural components.
  - The unit weights of typical building materials can be found in codes and standards.
  - For loads associated with service equipment, they can be obtained from the manufactures.
  - They are usually small for small structures and errors can be neglected. Yet, for multistory structures the error is high and cannot be ignored.

Table 1: Minimum Design Dead Loads

Component	Load (kN/m^2)	Component	Load (kN/m^2)
CEILINGS		Decking, 51 mm wood (Douglas fir)	0.24
Acoustical Fiber Board	0.05	Decking, 76 mm wood (Douglas fir)	0.35
Gypsum board (per min thickness)	0.008	Fiberboard, 13 mm	0.04
Mechanical duct allowance	0.19	Gypsum sheathing, 13 mm	0.1
Plaster on tile or concrete	0.24	**Insulation, roof boards (per mm thickness)**	
Plaster on wood lath	0.38	Cellular glass	0.0013
Suspended steel channel system	0.1	Fibrous glass	0.0021
Suspended metal lath and cement plaster	0.72	Fiberboard	0.0028
Suspended metal lath and gypsum plaster	0.48	Perlite	0.0015
Wood furring suspension system	0.12	Polystyrene foam	0.0004
COVERINGS, ROOF, AND WALL		Urethane foam with skin	0.0009
Asbestos-cement shingles	0.19	Plywood (per mm thickness)	0.006
Asphalt shingles	0.1	Rigid insulation, 13 mm	0.04
Cement tile	0.77	Skylight, metal frame, 10 mm wire glass	0.38
Clay tile (for mortar add 0.48 kN/m^2)		Slate, 5 mm	0.34
Book tile, 51 mm	0.57	Slate, 6 mm	0.48
Book tile, 76 mm	0.96	**Waterproofing membranes:**	
Ludowici	0.48	Bituminous, gravel-covered	0.26
Roman	0.57	Bituminous, smooth surface	0.07
Spanish	0.91	Liquid applied	0.05
Composition:		Single-ply, sheet	0.03
Three-ply ready roofing	0.05	Wood sheathing (per mm thickness)	0.0057
Four-ply felt and gravel	0.26	Wood shingles	0.14
Five-ply felt and gravel	0.29	**FLOOR FILL**	
Copper or tin	0.05	Cinder concrete, per mm	0.017
Corrugated asbestos-cement roofing	0.19	Lightweight concrete, per mm	0.015
Deck, metal, 20 gage	0.12	Sand, per mm	0.015
Deck, metal, 18 gage	0.14	Stone concrete, per mm	0.023

Note: Weights of masonry include mortar but not plaster. For plaster, add 0.24 kN/m^2 for each face of plastered. Values given represent averages. In some cases there is a considerable range of weights for the same construction.

Table 2. Minimum Design Dead Loads – Continued

Component				Load (kN/m^2)
FLOORS AND FLOOR FINISHES				
Asphalt block (51 mm), 13 mm mortar				1.44
Cement finish (25 mm) on stone-concrete fill				1.53
Ceramic or quarry tile (19 mm) on 13 mm. mortar bed				0.77
Ceramic or quarry tile (19 mm) on 25 mm mortar bed				1.10
Concrete fill finish (per mm thickness)				0.023
Hardwood flooring, 22 mm				0.19
Linoleum or asphalt tile, 6 mm				0.05
Marble and mortar on stone-concrete fill				1.58
Slate (per mm thickness)				0.028
Solid flat tile on 25 mm mortar base				1.10
Subflooring, 19 mm				0.14
Terrazzo (38 mm) directly on slab				0.91
Terrazzo (25 mm) on stone-concrete fill				1.53
Terrazzo (25 mm), 51 mm stone concrete				1.53
Wood block (76 mm) on mastic, no fill				0.48
Wood block (76 mm) on 13 mm mortar base				0.77
FLOORS. WOOD-JOIST (NO PLASTER)				
DOUBLE WOOD FLOOR				
Joist sizes (mm)	305 mm spacing (kN/m^2)	406 mm spacing (kN/m^2)	610 mm spacing (kN/m^2)	
51 x 152	0.29	0.24	0.24	
52 x 203	0.29	0.29	0.24	
53 x 254	0.34	0.29	0.29	
54 x 305	0.38	0.34	0.29	
FRAME PARTITIONS				
Movable steel partitions				0.19
Wood or steel studs, 1/2-in. gypsum board each side				0.38
Wood studs, 51 x 102, unplastered				0.19
Wood studs, 51 x 102, plastered one side				0.57
Wood studs, 51 x 102, plastered two sides				0.96
FRAME WALLS				
Exterior stud walls:				
51 x 102 @ 406 mm, 16 mm gypsum, insulated, 10 mm, siding				0.53
52 x 152 @ 406 mm, 16 mm gypsum, insulated, 10 mm, siding				0.57
Exterior stud walls with brick veneer				2.30

Component						Load (kN/m^2)
Windows, glass, frame, and sash						0.38
Clay brick wythes:						
102 mm						1.87
203 mm						3.78
305 mm						5.51
406 mm						7.42
Hollow concrete masonry unit wythes:						
Wythe thickness (in mm)		102	152	203	254	305
Density of unit (16.49 kN/m^2)						
No grout		1.1	1.29	1.65	2.01	2.35
1219 mm			1.48	1.92	2.35	2.78
1016 mm	grout		1.58	2.06	2.54	3.02
813 mm	spacing		1.63	2.15	2.68	3.16
610 mm			1.77	2.35	2.92	3.45
406 mm			2.01	2.68	3.35	4.02
Full grout			2.73	3.69	4.69	5.70
Density of unit (19.64 kN/m^2)						
No grout		1.3	1.34	1.72	2.11	2.39
1219 mm			1.58	2.11	2.59	2.97
1016 mm	grout		1.63	2.15	2.68	3.11
813 mm	spacing		1.72	2.25	2.78	3.26
610 mm			1.87	2.44	3.02	3.59
406 mm			2.11	2.78	3.50	4.17
Full grout			2.82	3.88	4.88	5.89
Density of unit (21.21 kN/m^2)						
No grout		1.4	1.68	2.15	2.59	3.02
1219 mm			I .55	2.39	2.92	3.45
1016 mm	grout		1.72	2.54	3.11	3.69
813 mm	spacing		1.82	2.63	3.26	3.83
610 mm			1.96	2.82	3.50	4.12
406 mm			2.25	3.16	3.93	4.69
Full grout			3.06	4.17	5.27	6.37
Solid concrete masonry unit wythes thickness (in mm):						
Wythe thickness (in mm)		102	152	203	254	305
Density of unit (16.49 kN/m^3)		1.5	2.35	3.21	4.02	4.88
Density of unit (19.64 kN/m^3)		1.8	2.82	3.78	4.79	5.79
Density of unit (21.21 kN/m^3)		2	3.02	4.12	5.17	6.27

Table 3: Minimum Densities for Design Loads from Materials

Material	Density (kN/m^3)	Material	Density (kN/m^3)
Aluminum	26.71	**Lime**	
Bituminous products		Hydrated, loose	5.03
Asphaltum	12.73	Hydrated, compacted	7.07
Graphite	21.21	**Masonry, ashlar stone**	
Paraffin	8.80	Granite	25.92
Petroleum, crude	8.64	Limestone, crystalline	25.92
Petroleum, refined	7.86	Limestone, oolitic	21.21
Petroleum, benzine	7.23	Marble	27.18
Petroleum, gasoline	6.60	Sandstone	22.62
Pitch	10.84	**Masonry, brick**	
Tar	11.78	Hard (low absorbtion)	20.42
Brass	82.63	Medium (medium absorbtion)	18.07
Bronze	86.72	Soft (high absorbtion)	15.71
Cast-stone masonry (cement, stone, sand)	22.62	Masonry, concrete*	
Cement, portland. loose	14.14	Lightweight units	16.50
Ceramic tile	23.57	Medium weight units	19.64
Charcoal	1.89	Normal weight units	21.21
Cinder fill	8.95	Masonry grout	21.99
Cinders, dry, in bulk	7.07	**Masonry, rubble stone**	
Coal		Granite	24.04
Anthracite, piled	8.17	Limestone, crystalline	23.09
Bituminous, piled	7.38	Limestone, oolitic	21.68
Lignite, piled	7.38	Marble	24.51
Peat, dry, piled	3.61	Sandstone	21.52
Concrete, plain		Mortar, cement or lime	20.42
Cinder	16.97	Particleboard	7.07
Expanded-slag aggregate	15.71	Plywood	5.66
Haydite (burned-clay aggregate)	14.14	**Riprap (not submerged)**	
Slag	20.74	Limestone	13.04
Stone (including gravel)	22.62	Sandstone	14.14
Vermiculite and perlite aggregate, nonload-bearing	3.93 – 7.86	Sand	
Other light aggregate, load-bearing	11.0 – 16.5	Clean and dry	14.14
Concrete, reinforced		River, dry	16.65
Cinder	17.44	**Slag**	
Slag	21.68	Bank	11.00
Stone (including gravel)	23.57	Bank screenings	16.97
Copper	87.35	Machine	15.08
Cork, compressed	2.20	Sand	8.17
Earth (not submerged)		Slate	27.02
Clay, dry	9.90	Steel, cold-drawn	77.29
Clay, damp	17.44	**Stone, quarried, piled**	
Clay and gravel, dry	15.71	Basalt, granite, gneiss	15.08
Silt, moist, loose	12.25	Limestone, marble, quartz	14.92
Silt, moist, packed	15.08	Sandstone	12.88
Silt, flowing	16.97	Shale	14.45
Sand and gravel, dry, loose	15.71	Greenstone, hornblende	16.81
Sand and gravel, dry, packed	17.28	**Terra Cotta, architectural**	
Sand and gravel, wet	18.85	Voids filled	18.85
Earth (submerged)		Voids unfilled	11.31
Clay	12.57	Tin	72.11
Soil	11.00	**Water**	
River mud	14.14	Fresh	9.74
Sand or gravel	9.43	Sea	10.05
Sand or gravel and clay	10.21	**Wood, seasoned**	
Glass	25.14	Ash, commercial white	6.44
Gravel, dry	16.34	Cypress, southern	5.34
Gypsum, loose	11.00	Fir, Douglas, coast region	5.34
Gypsum, wallboard	7.86	Hem fir	4.40
Ice	8.95	Oak, commercial reds and whites	7.38
Iron		Pine, southern yellow	5.81
Cast	70.70	Redwood	4.40
Wrought	75.41	Spruce, red, white, and Stika	4.56
Lead	111.54	Western hemlock	5.03

- **Live Loads:**
  - Vertical loads due to human occupancy, snow, rain ponding, furniture, partition walls and moveable equipment.
  - Horizontal (lateral) loads due to wind, earthquake, water pressure, blast/explosion, collision, etc.
  - Loads produced through construction or occupancy of the structure.
  - They can be caused by weights of objects temporarily placed on a structure, moving vehicles, or natural forces.
  - Can be categorized to:
    - Occupancy loads of buildings (ASCE-7)
    - Traffic loads for bridges (AASHTO)
    - Impact loads
      - Applied over a very short period of time
      - Have greater effect on the structure
  - Moving loads:
    - Dynamic significance.
    - Change over a period of time.
  - Codes have established its data based on studying the history of such loads.
  - Types of live loads:

✓ Building Loads	✓ Snow Load
✓ Highway Bridge Loads	✓ Earthquake Loads
✓ Railroad Bridge Loads	✓ Hydrostatic Pressure
✓ Impact Loads	✓ Soil Pressure
✓ Wind Loads	✓ Other Environmental Loads

- Floors are assumed to be under uniform live loads which depend on the purpose for which the building is designed.
- These loads are usually tabulated in adapted code.
- These values include some protection against overloading, emergency situations, construction loads, and serviceability requirements due to vibration.
- Environmental loads:
  - Snow and ice loads
  - Rain loads
    - Accumulation of rainwater on flat roof (ponding)
    - Avoid by providing (2%) slope and design adequate drainage.
  - Wind loads
    - Causes forces, vibrations, and (in some cases) instability
    - Depends on
      - Wind speed
      - Mass density of the air
      - Location of the structure
      - Geometry of the structure
      - Vibrational characteristics of the system

- Earthquake loads
  - It is the common dynamic loading associated with the ground movement
  - It affects the base of the structure
  - The rest of the structure is affected due to inertia
  - Creates horizontal shear forces and deflections
  - Depends on
    - Nature of the ground movement
    - The inertia response of the structure

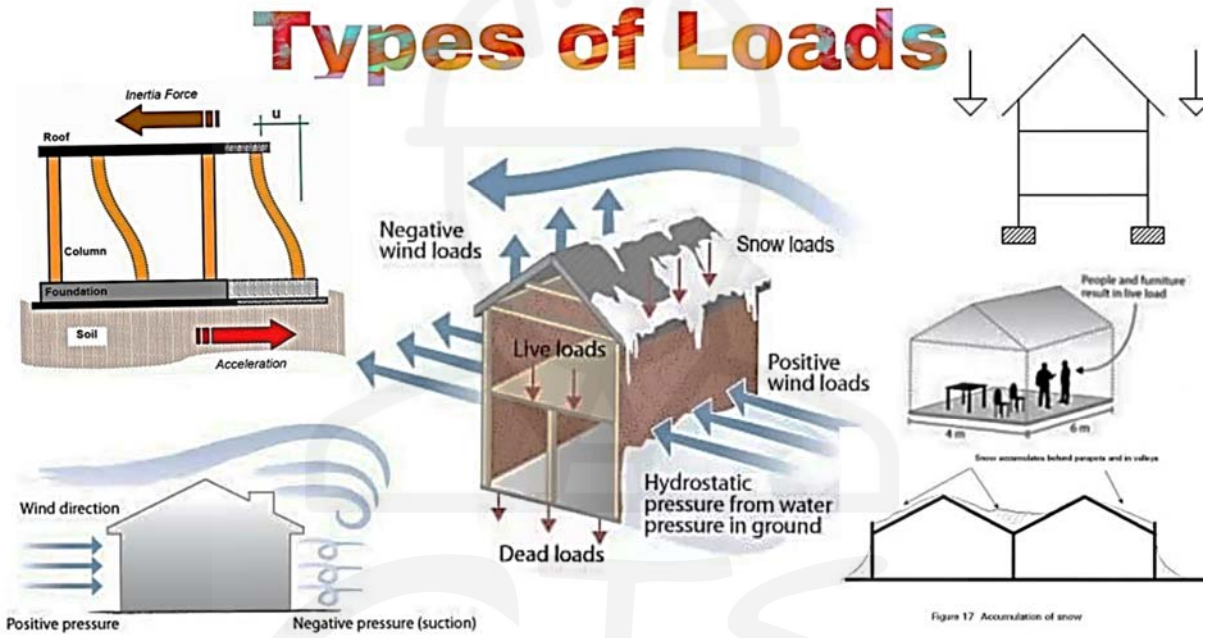

Figure 1-14: Types of loads

Minimum Uniformly Distributed Live Loads, L_o, and Minimum Concentrated Live Loads

Occupancy or Use	Uniform kN/m²	Concentrated kN
Apartments (see Residential)		
Access floor systems		
Office use	2.40	8.90
Computer use	4.79	8.90
Armories and drill rooms	7.18 a	
Assembly areas and theaters		
Fixed seats (fastened to floor)	2.87 a	
Lobbies	4.79 a	
Movable seats	4.79 a	
Platforms (assembly)	4.79 a	
Stage floors	7.18 a	
Balconies and decks		
(1.5 times the live load for the occupancy served. Not required to exceed 100 psf (4.79 kN/m²))		
On one- and two-family residences only.	4.79	
(not exceeding 100 ft² 19.3 m²)	2.87	
Catwalks for maintenance access	1.92	
Corridors		
First floor	4.79	
Other floors, same as occupancy served except as indicated		
Dining rooms and restaurants	4.79 a	
Dwellings (see Residential)		
Elevator machine room grating (on area of 2 in. by 2 in. (50 mm by 50 mm))		1.33
Finish light floor plate construction (on area of 1 in. by 1 in. (25 mm by 25 mm))		0.89
Fire escapes	4.79	
On single-family dwellings only	1.92	
Fixed ladders	See Section 4.5	
Garages		
Passenger vehicles	1.92 a,b	
Trucks and buses see notes	c	
Grandstands (see stadiums and arenas, bleachers)		
Handrails, guardrails, and grab bars	See section 4.5	
Helipads	2.87 d,e	
Hospitals		
Operating rooms, laboratories	2.87	
Patient rooms	1.92	e,f,g
Corridors above first floor	3.83	
Hotels (see Residential)		
Libraries		
Reading rooms	2.87	4.45
Stack rooms	7.18 a,h	4.45
Corridors above first floor	3.83	4.45
Manufacturing		
Light	6.00 a	4.45
Heavy	11.97 a	4.45
Marquees	3.59	

Occupancy or Use	Uniform kN/m²	Concentrated kN
Office buildings		
File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Lobbies and first-floor corridors	4.79	8.90
Offices	2.40	8.90
Corridors above first floor	3.83	13.40
Penal institutions	1.92	
Cell Blocks		
Corridors	4.79	8.90
Recreational uses		
Gymnasiums	4.79 a	
Bowling alleys, poolrooms, and similar uses	3.59 a	
Dance halls and ballrooms	4.79 a	
Reviewing stands, grandstands, and bleachers	4.79 a,k	
Stadiums and arenas with fixed seats (fastened to the floor)	2.87 a,k	
Residential		
One- and two-family dwellings		
Uninhabitable attics without storage	0.48 l	
Uninhabitable attics with storage	0.96 m	
Habitable attics and sleeping areas	1.44	
All other areas except stairs	1.92	
All other residential occupancies (ex. Hotels)		
Private rooms and corridors serving them	1.92	
Public rooms and corridors serving them	4.79 a	
Reviewing stands, grandstands, and bleachers	4.79	
Roofs		
Ordinary flat, pitched, and curved roofs	0.96 n	
Roofs used for roof gardens	4.79	
Roofs used for promenade purposes	2.87 a,k	
Roofs used for assembly purposes	Same as occupancy served	
Roofs used for other occupancies	o	o
Awnings and canopies		
Fabric construction supported by a lightweight rigid skeleton structure	0.24 non-reducible	1.33 applied to skeleton structure
Screen enclosure support frame	0.24 non-reducible and applied to the roof frame members only, not the screen	0.89 applied to supportir roof frame members onl
All other construction	0.96	
Primary roof members, exposed to a work floor		
Single panel point of lower chord of roof trusses or any point along primary structural members supporting roofs over manufacturing, storage warehouses, and repair garages		8.90
All other primary roof members		1.33
All roof surfaces subject to maintenance workers		1.33
Schools		
Classrooms	1.92	4.45
Corridors above first floor	3.83	4.45
First-floor corridors	4.79	4.45

Occupancy or Use	Uniform kN/m²	Concentrated kN
Scuttles, skylight ribs, and accessible ceilings		0.89
Sidewalks, vehicular driveways, and yards subject to trucking	11.97 a,p	35.60 q
Stairs and exit ways	4.79	r
One- and two-family dwellings only	1.92	r
Storage areas above ceilings	0.96	
Storage warehouses (shall be designed for heavier loads if required for anticipated storage)		
Light	6.00 a	300 r
Heavy	11.97 a	300 r
Stores		
Retail		
First floor	4.79	4.45
Upper floors	3.59	4.45
Wholesale, all floors	6.00 a	4.45
Vehicle barriers	See Section 4.5	
Walkways and elevated platforms (other than exit ways)	2.87	
Yards and terraces, pedestrian	4.79 a	

Notes:

(a) Live load reduction for this use is not permitted by Section 4.7 unless specific exceptions apply.
(b) Floors in garages or portions of a building used for the storage of motor vehicles shall be designed for the uniformly distributed live loads of Table 4-1 or the following concentrated load: (1) for garages restricted to passenger vehicles accommodating not more than nine passengers, 3,000 lb (13.35 kN) acting on an area of 4.5 in. by 4.5 in. (114 mm by 114 mm); and (2) for mechanical parking structures without slab or deck that are used for storing passenger vehicles only, 2,250 lb (10 kN) per wheel.
(c) Design for trucks and buses shall be per AASHTO LRFD Bridge Design Specifications; however, provisions for fatigue and dynamic load allowance are not required to be applied.
(d) Uniform load shall be 40 psf (1.92 kN/m2) where the design basis helicopter has a maximum take-off weight of 3,000 lbs. (13.35 kN) or less. This load shall not be reduced.
(e) Labeling of helicopter capacity shall be as required by the authority having jurisdiction.
f Two single concentrated loads, 8 ft (2.44 m) apart shall be applied on the landing area (representing the helicopter's two main landing gear, whether skid type or wheeled type), each having a magnitude of 0.75 times the maximum take-off weight of the helicopter and located to produce the maximum load effect on the structural elements under consideration. The concentrated loads shall be applied over an area of 8 in. by 8 in. (200 mm by 200 mm) and shall not be concurrent with other uniform or concentrated live loads.
(g) A single concentrated load of 3,000 lbs. (13.35 kN) shall be applied over an area 4.5 in. by 4.5 in. (114 mm by 114 mm), located so as to produce the maximum load effects on the structural elements under consideration. The concentrated load need not be assumed to act concurrently with other uniform or concentrated live loads.
h The loading applies to stack room floors that support non-mobile, double-faced library book stacks subject to the following limitations: (1) The nominal book stack unit height shall not exceed 90 in. (2,290 mm); (2) the nominal shelf depth shall not exceed 12 in. (305 mm) for each face; and (3) parallel rows of double-faced book stacks shall be separated by aisles not less than 36 in. (914 mm) wide.
(k) In addition to the vertical live loads, the design shall include horizontal swaying forces applied to each row of the seats as follows: 24 lb per linear ft of seat applied in a direction parallel to each row of seats and 10 lb per linear ft of seat applied in a direction perpendicular to each row of seats. The parallel and perpendicular horizontal swaying forces need not be applied simultaneously.
(l) Uninhabitable attic areas without storage are those where the maximum clear height between the joist and rafter is less than 42 in. (1,067 mm), or where there are not two or more adjacent trusses with web configurations capable of accommodating an assumed rectangle 42 in. (1,067 mm) in height by 24 in. (610 mm) in width, or greater, within the plane of the trusses. This live load need not be assumed to act concurrently with any other live load requirement.
(m) Uninhabitable attic areas with storage are those where the maximum clear height between the joist and rafter is 42 in. (1,067 mm) or greater, or where there are two or more adjacent trusses with web configurations capable of accommodating an assumed rectangle 42 in. (1,067 mm) in height by 24 in. (610 mm) in width, or greater, within

the plane of the trusses. At the trusses, the live load need only be applied to those portions of the bottom chords where both of the following conditions are met:

i. The attic area is accessible from an opening not less than 20 in. (508 mm) in width by 30 in. (762 mm) in length that is located where the clear height in the attic is a minimum of 30 in. (762 mm); and

ii. The slope of the truss bottom chord is no greater than 2 units vertical to 12 units horizontal (9.5% slope).

The remaining portions of the bottom chords shall be designed for a uniformly distributed non-concurrent live load of not less than 10 lb/ft2 (0.48 kN/m2).
(n) Where uniform roof live loads are reduced to less than 20 lb/ft2 (0.96 kN/m2) in accordance with Section 4.8.1 and are applied to the design of structural members arranged so as to create continuity, the reduced roof live load shall be applied to adjacent spans or to alternate spans, whichever produces the greatest unfavorable load effect.
(o) Roofs used for other occupancies shall be designed for appropriate loads as approved by the authority having jurisdiction.
(p) Other uniform loads in accordance with an approved method, which contains provisions for truck loadings, shall also be considered where appropriate.
(q) The concentrated wheel load shall be applied on an area of 4.5 in. by 4.5 in. (114 mm by 114 mm).
(r) Minimum concentrated load on stair treads (on area of 2 in. by 2 in. [50 mm by 50 mm]) is to be applied non-concurrent with the uniform load.