CEE 3222 Theory of Structures

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Chapter 1:

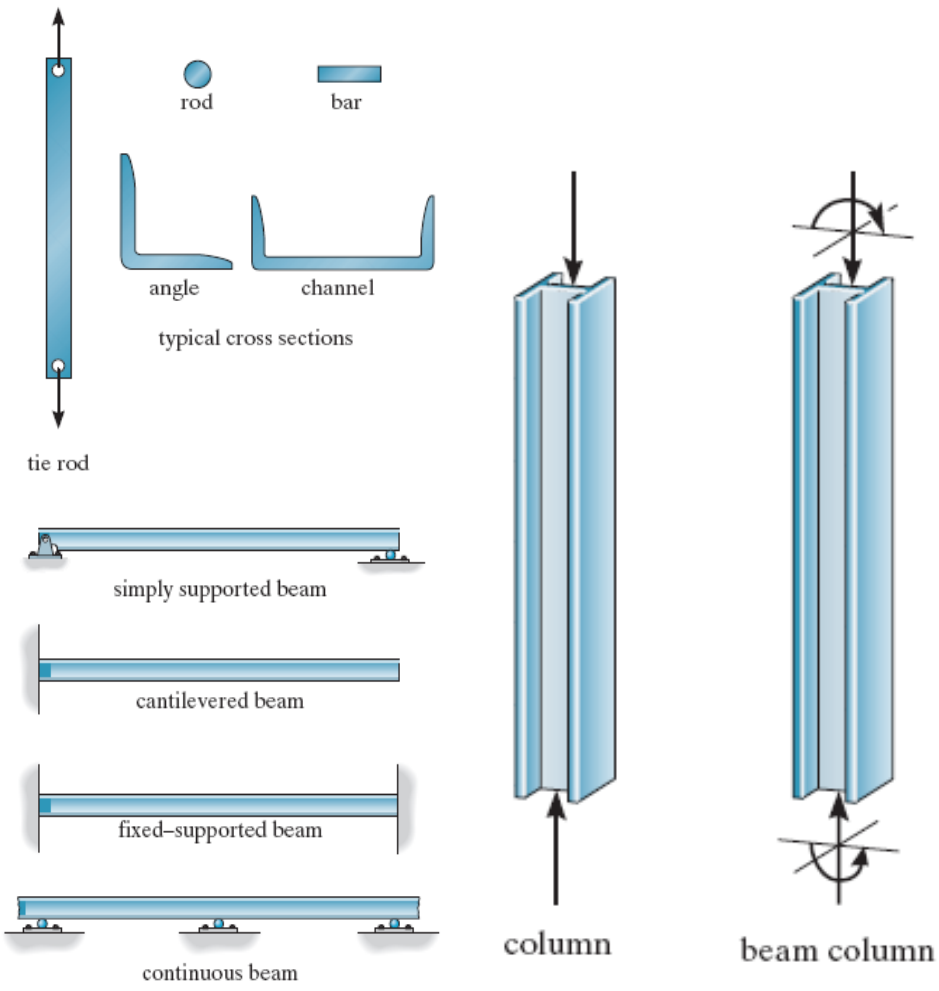
Types of Structures and Loads

Introduction

- Structures refer to a system of connected parts used to support a load
  - Tallest buildings
  - Long-span bridges

Structures

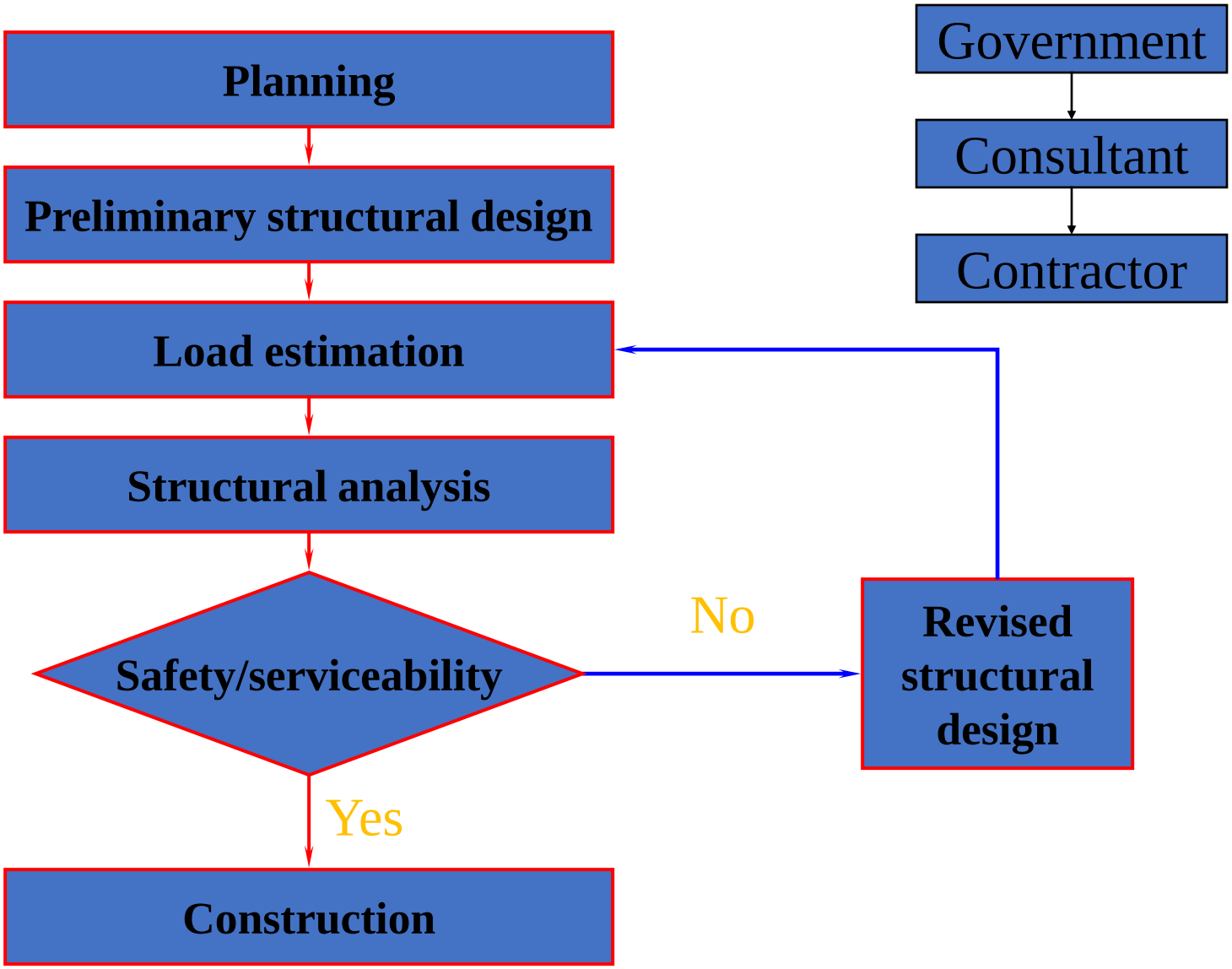
- Classification of structures
  - Beam structures
  - Arch structures
  - Truss structures
  - Domes and shells
  - Columns and frames
- Structural elements
  - Tie rods
  - Beams
  - Columns



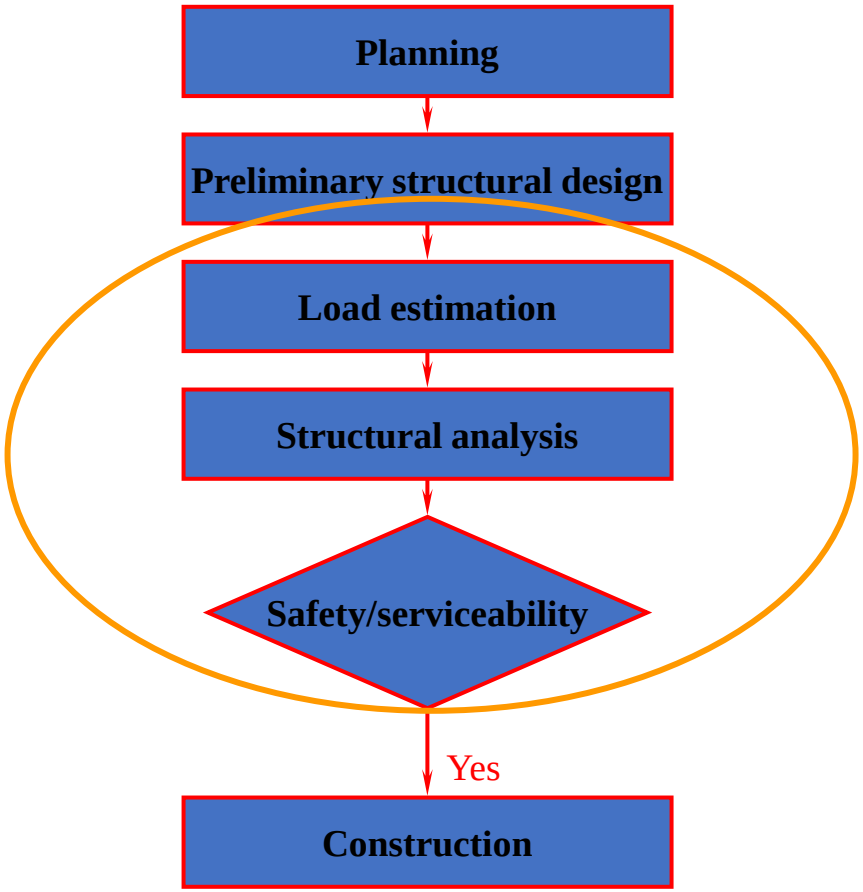
Issues

- How are they designed?
- How are they built?
- How safe are they under earthquake, typhoon, or terrorist attack?

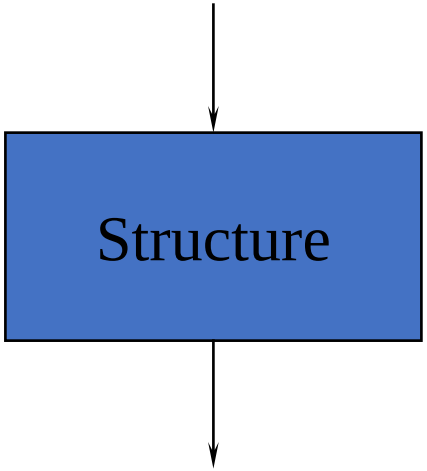
A typical structural engineering project



Structural Analysis



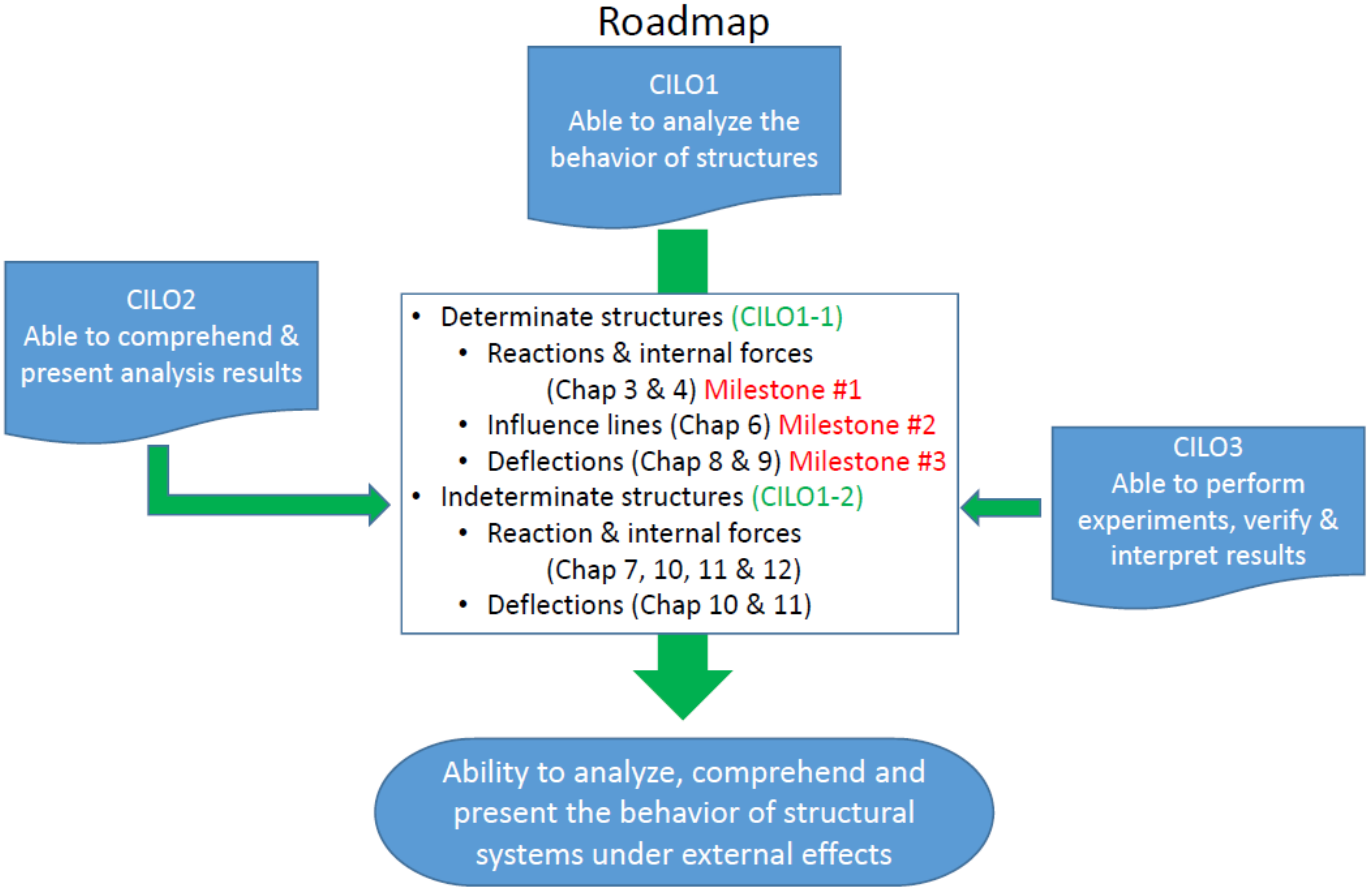
Factors:
Load, Temperature, etc.



Performance
Deformation, Stress, etc.

Objective of this Course

- To analyze, comprehend and present the behavior of structural systems under external effects

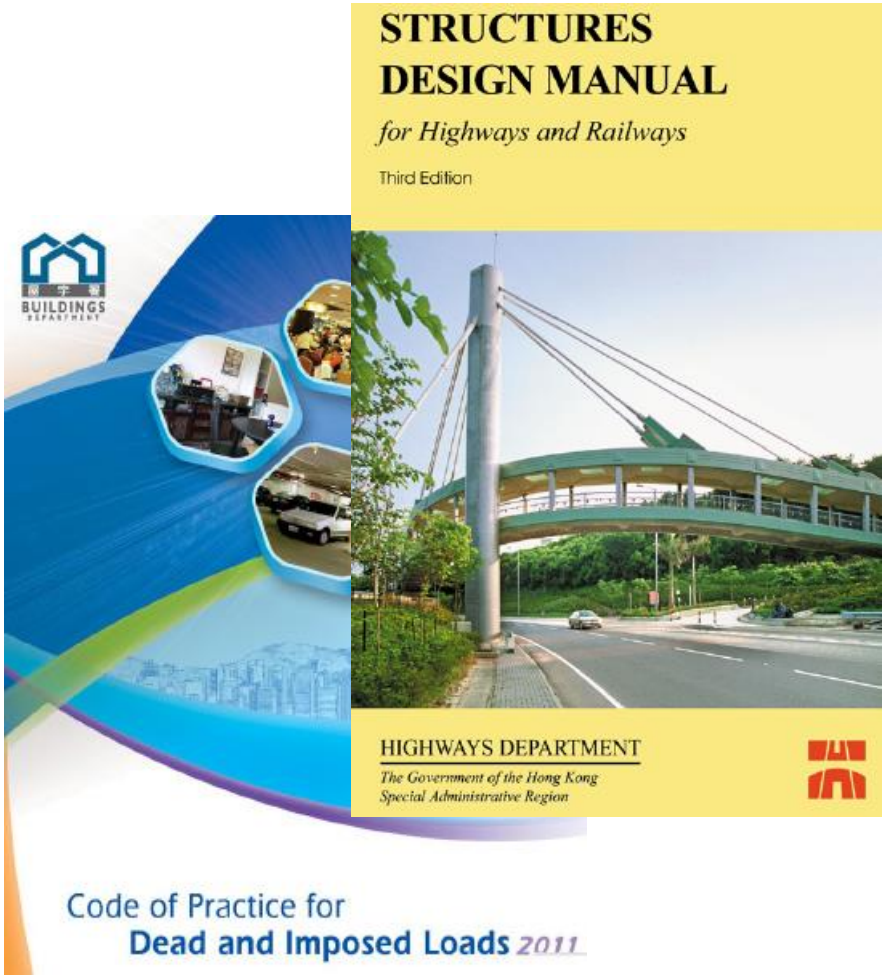


Loads

- Design loading for a structure is often specified in codes
  - General building codes
  - Design codes

TABLE 1–1 • Codes

General Building Codes
Minimum Design Loads for Buildings and Other Structures, SEI/ASCE 7-05, American Society of Civil Engineers
International Building Code
Design Codes
Building Code Requirements for Reinforced Concrete, Am. Conc. Inst. (ACI)
Manual of Steel Construction, American Institute of Steel Construction (AISC)
Standard Specifications for Highway Bridges, American Association of State Highway and Transportation Officials (AASHTO)
National Design Specification for Wood Construction, American Forest and Paper Association (AFPA)
Manual for Railway Engineering, American Railway Engineering Association (AREA)



Loads

- Types of load
  - Dead loads
    - Weights of various structural members
    - Weights of any objects that are attached to the structure

TABLE 1–2 • Minimum Densities for Design Loads from Materials*

	lb/ft^3	kN/m^3
Aluminum	170	26.7
Concrete, plain cinder	108	17.0
Concrete, plain stone	144	22.6
Concrete, reinforced cinder	111	17.4
Concrete, reinforced stone	150	23.6
Clay, dry	63	9.9
Clay, damp	110	17.3
Sand and gravel, dry, loose	100	15.7
Sand and gravel, wet	120	18.9
Masonry, lightweight solid concrete	105	16.5
Masonry, normal weight	135	21.2
Plywood	36	5.7
Steel, cold-drawn	492	77.3
Wood, Douglas Fir	34	5.3
Wood, Southern Pine	37	5.8
Wood, spruce	29	4.5

*Reproduced with permission from American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*, SEI/ASCE 7-05. Copies of this standard may be purchased from ASCE at 345 East 47th Street, New York, N.Y. 10017-2398.

TABLE 1–3 • Minimum Design Dead Loads*

Walls	psf	kN/m^2
4-in. (102 mm) clay brick	39	1.87
8-in. (203 mm) clay brick	79	3.78
12-in. (305 mm) clay brick	115	5.51
Frame Partitions and Walls		
Exterior stud walls with brick veneer	48	2.30
Windows, glass, frame and sash	8	0.38
Wood studs 2 × 4 in., (51 × 102 mm) unplastered	4	0.19
Wood studs 2 × 4 in., (51 × 102 mm) plastered one side	12	0.57
Wood studs 2 × 4 in., (51 × 102 mm) plastered two sides	20	0.96
Floor Fill		
Cinder concrete, per inch (mm)	9	0.017
Lightweight concrete, plain, per inch (mm)	8	0.015
Stone concrete, per inch (mm)	12	0.023
Ceilings		
Acoustical fiberboard	1	0.05
Plaster on tile or concrete	5	0.24
Suspended metal lath and gypsum plaster	10	0.48
Asphalt shingles	2	0.10
Fiberboard, $\frac{1}{2}$-in. (13 mm)	0.75	0.04

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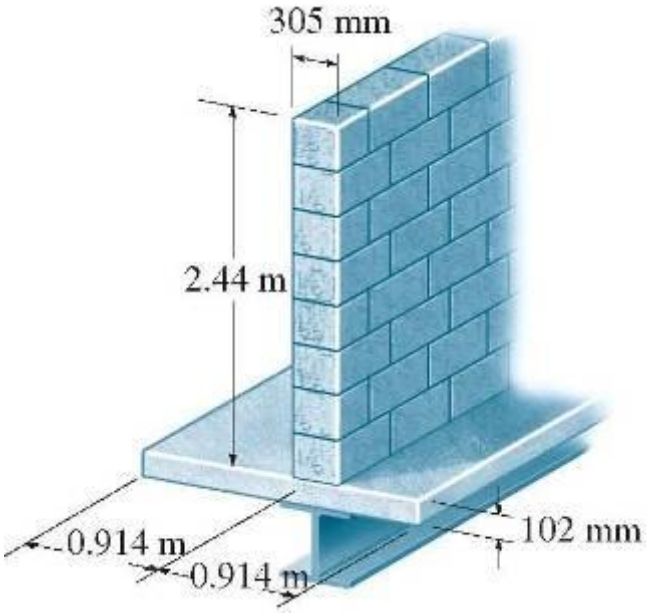
Appendix A

Density of Materials

Materials		Density (kN/m³)
Concrete (normal weight aggregate, with or without PFA)	Plain	23.6
	Reinforced	24.5
	Prestressed	24.5
Brick and block work	Brick work	21.7
	Concrete blocks	20.6
Metals	Aluminium	27.2
	Brass	83.3
	Bronze	87.7
	Copper	87.7
	Iron (cast)	70.7
	Iron (wrought)	75.4
	Lead	111.0
	Steel	77.0
	Zinc	70.0
Mortar	Cement mortar	23
	Gypsum mortar	18
	Lime-cement mortar	20
	Lime mortar	18
Natural stone	Granite	29
	Marble	27
	Basalt	30
	Sandstone	25
	Slate	28
Wood	Timber	Refer to suppliers specifications
	Hardboard	11
	Chipboard	8
	Plywood	6
	Blockboard	5
	Wood-wool	6
Other materials	Glass	26
	Soil	20
	Acrylic sheet	12
	Asphaltic concrete	25
	Mastic asphalt	18
	Hot rolled asphalt	23

Example 1.1

The floor beam is used to support the 1.83m width of lightweight plain concrete slab having a thickness of 102mm. The slab serves as a portion of the ceiling for the floor below & its bottom coated with plaster. A 2.44m high, 305mm thick lightweight solid concrete block wall is directly over the top flange of the beam. Determine the loading on the beam measured per m length of the beam.



Loads

- Live loads (Imposed loads)
  - Varies in magnitude & location
  - Building loads
    - Depends on the purpose for which the building is designed
    - These loadings are generally tabulated in local, state or national code

TABLE 1–4 • Minimum Live Loads*

Occupancy or Use	Live Load psf	Live Load kN/m^2	Occupancy or Use	Live Load psf	Live Load kN/m^2
Assembly areas and theaters			Residential		
Fixed seats	60	2.87	Dwellings (one- and two-family)	40	1.92
Movable seats	100	4.79	Hotels and multifamily houses		
Dance halls and ballrooms	100	4.79	Private rooms and corridors	40	1.92
Garages (passenger cars only)	50	2.40	Public rooms and corridors	100	4.79
Office buildings			Schools		
Lobbies	100	4.79	Classrooms	40	1.92
Offices	50	2.40	Corridors above first floor	80	3.83
Storage warehouse					
Light	125	6.00			
Heavy	250	11.97			

*Reproduced with permission from *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-05.

Loads

Code of Practice for Dead and Imposed Loads 2011

Table 3.1
Classification of Floor Uses

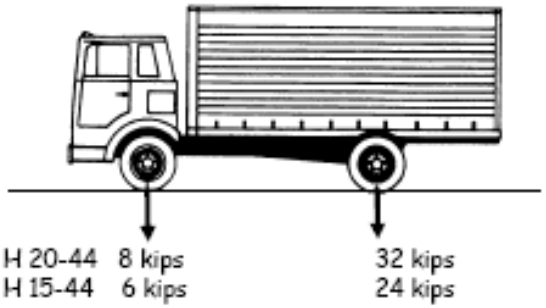
Class	Use
1	Floors for domestic use and residential activities
2	Floors for offices and other non-industrial work places
3	Floors where people may congregate
4	Floors for shopping purposes
5	Floors for storage, equipment, plant and industrial use
6	Areas for vehicular traffic
7	Roofs
8	Affiliated building elements

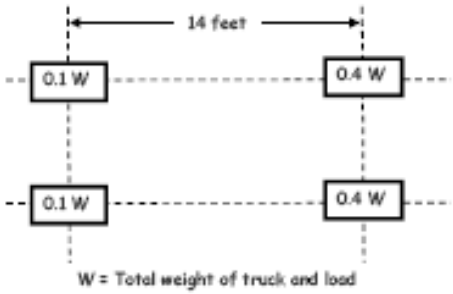
Table 3.2
Minimum Imposed Loads

Class	Use	Examples of Specific Use	q_k (kPa)	Q_k (kN)
1	Floors for domestic use and residential activities	Domestic uses	2.0	2.0
		Dormitories	2.0	2.0
		Private sitting rooms, bedrooms and toilet rooms in hotels, motels and guesthouses	2.0	2.0
		Wards, bedrooms and toilet rooms in hospitals, nursing homes and residential care homes for elderly persons	2.0	2.0
		Bathrooms (load from Jacuzzi in bathrooms shall be assessed separately and on individual basis) [1]	2.0	2.0
		Pantries [1]	2.0	2.0
		Kitchens [1]	2.0	2.0
2	Floors for offices and other non-industrial work places	Medical consulting or treatment rooms	2.5	3.0
		Hospital operating theatres and X-ray rooms	2.5	3.0
		Laboratories	3.0	4.5
		Light workrooms with neither central power-driven machines nor storage	3.0	4.5
		Offices for general use	3.0	4.5
		Rooms for lightweight electrical and electronic installations	3.0	4.5
		Rooms for meters and not for storage [1]	3.0	4.5
		Pantries [1]	3.0	4.5
		Banking halls	4.0	4.5
		Kitchens and laundries not in domestic buildings	4.0	4.5
		Projection rooms [1]	5.0	4.5

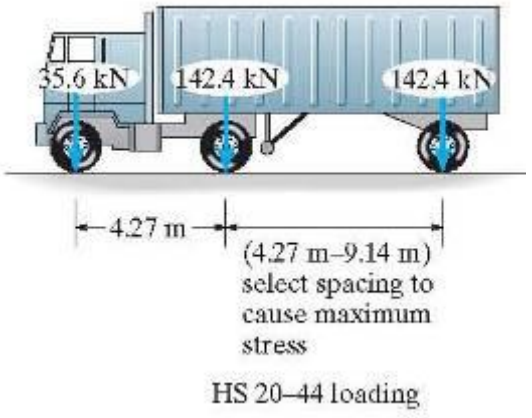
Loads

- Highway Bridge loads
  - Primary live loads are those due to traffic
  - Specifications for truck loadings are reported in AASHTO
  - For 2-axle truck, these loads are designated with H followed by the weight of truck in tons and another no. gives the year of the specifications that the load was reported





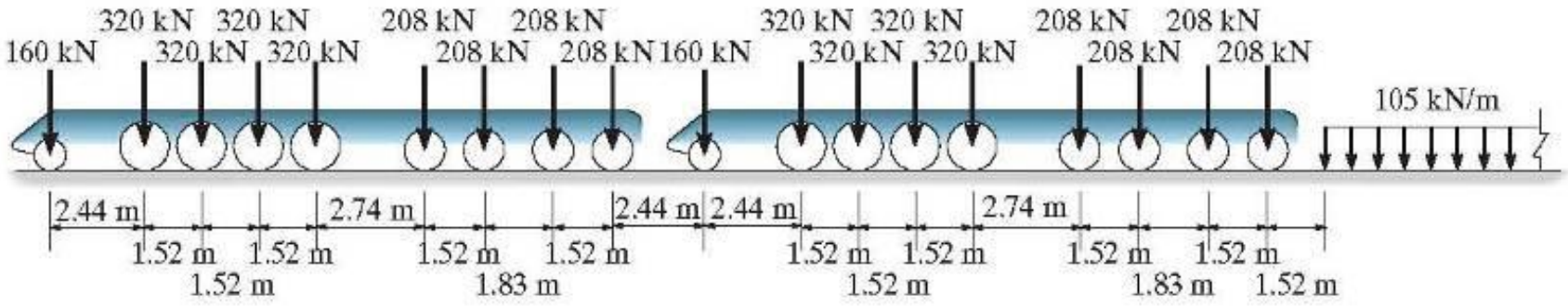
2-axle truck



with semi-trailer

Loads

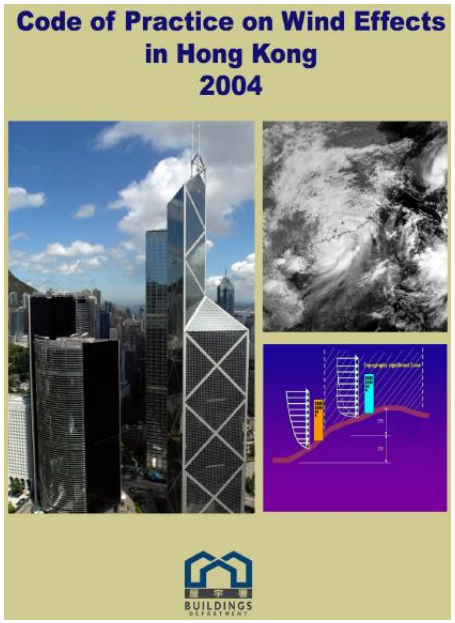
- Railway Bridge loads

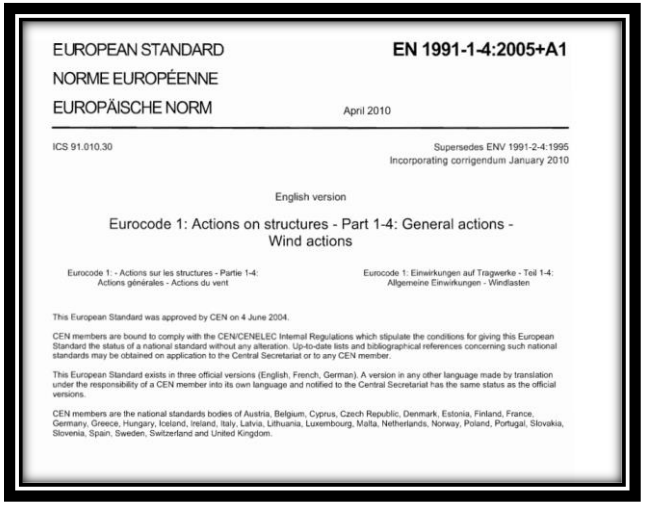


E-72 loading

Loads

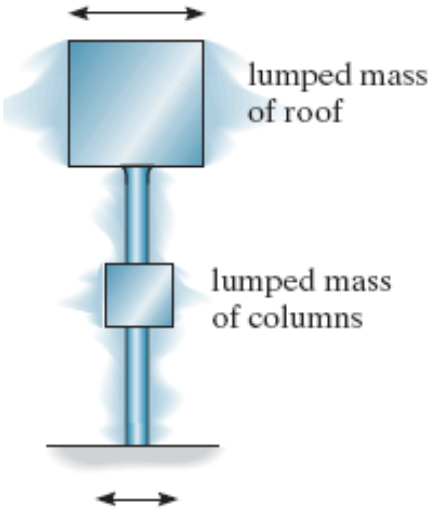
- Wind loads
  - Kinetic energy wind → potential energy of pressure
  - Depends on density & flow of air, angle of incidence, shape/stiffness of structure & roughness of surface
  - Can be treated as static or dynamic





Loads

- Earthquake loads
  - Earthquake produce loadings through its interaction with the ground & its response characteristics
  - Their magnitude depends on amount & type of ground acceleration, mass & stiffness of structure
  - During earthquake, the ground vibrates both horizontally & vertically



Loads

- Hydrostatic & Soil Pressure
  - The pressure developed by these loadings when the structures are used to retain water or soil or granular materials
  - E.g. tanks, dams, ships, bulkheads & retaining walls
- Other natural loads
  - Effect of blast
  - Temperature changes
  - Differential settlement of foundation

Structural Design

- Material uncertainties occur due to
  - variability in material properties
  - residual stress in materials
  - intended measurements being different from fabricated sizes
  - material corrosion or decay
- Many types of loads can occur simultaneously on a structure

Structural Design

- In working-stress design, the computed elastic stress in the material must not exceed the allowable stress along with the following typical load combinations as specified by the ASCE 7-02 Standard
  - Dead load
  - 0.6 (dead load) + wind load
  - 0.6 (dead load) + 0.7(earthquake load)

Structural Design

- Ultimate strength design is based on designing the ultimate strength of critical sections
- This method uses load factors to the loads or combination of loads
  - 1.4 (Dead load)
  - 1.2 (dead load) + 1.6 (live load) + 0.5 (snow load)
  - 1.2 (dead load) + 1.5(earthquake load)+ 0.5 (live load)