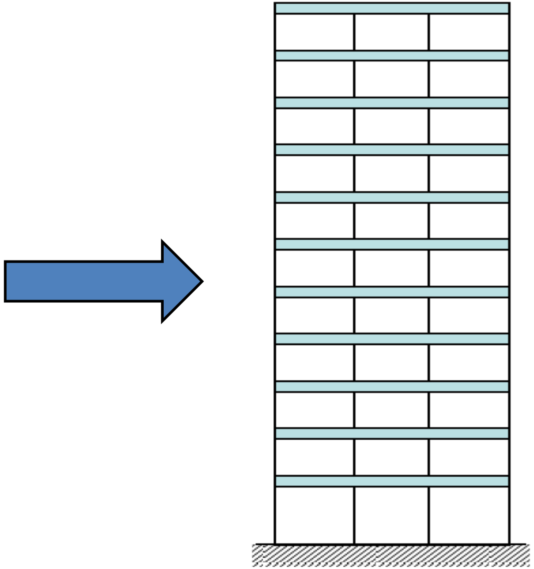
Analysis of Statically Determinate Structures

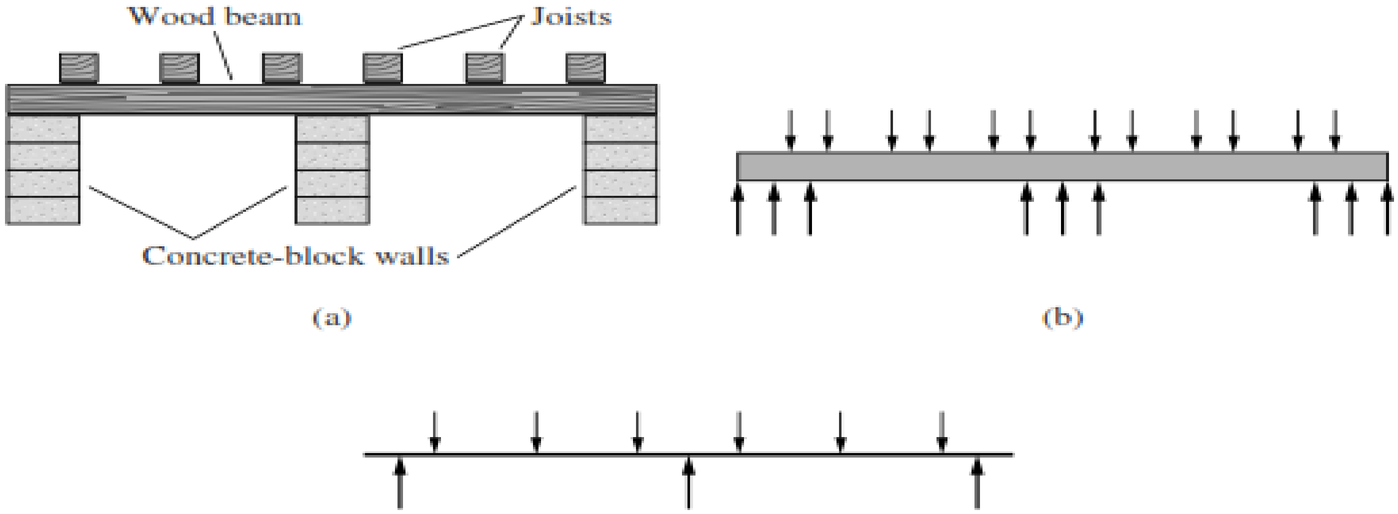
Idealized Structure

- To develop the ability to model or idealize a structure so that structural analysis can be performed

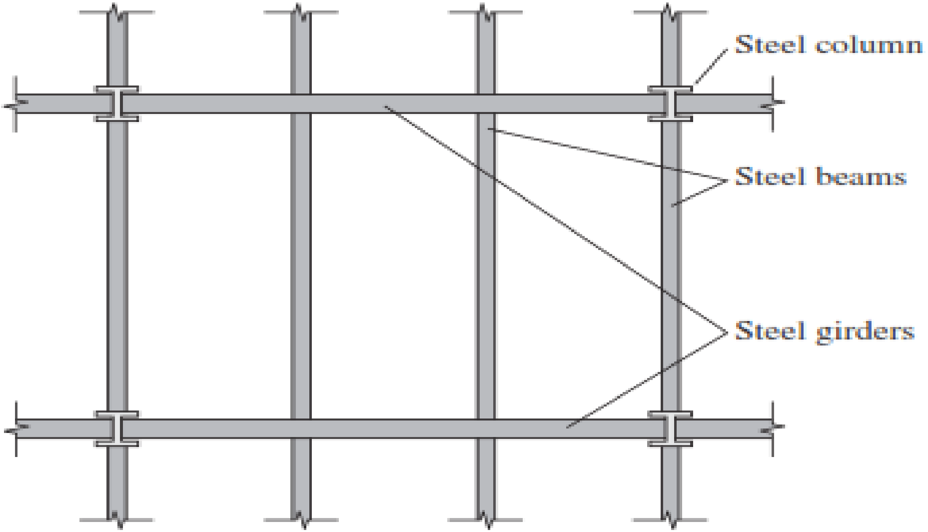


Idealization Cont’d

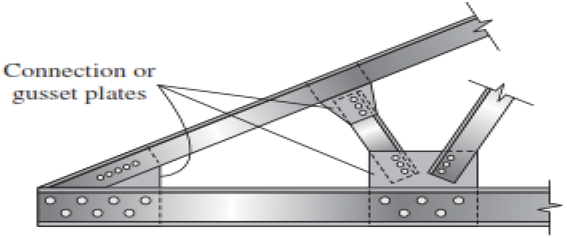
- In the figure below (a), the wooden beam supports several floor joists and in turn it is supported by three concrete block walls. The actual distribution of the forces acting on the beam is shown in figure (b). For purposes of analysis, though, we can conservatively represent the beam and its loads and reactions with the line diagram in figure (c).



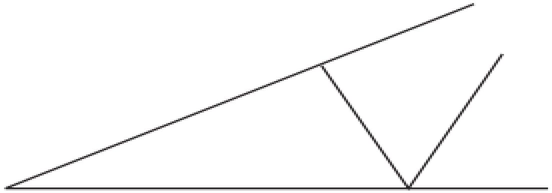
(a) (b) (c)



Part of the floor system of a steel frame building (Plan)



(a)

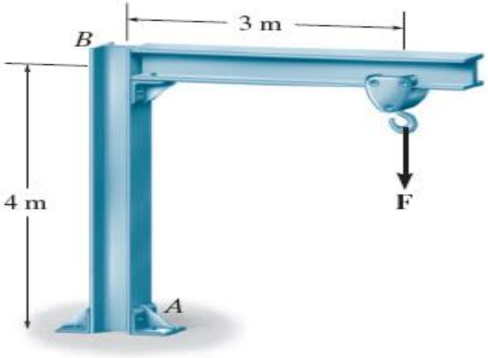


(b)

Part of a steel roof truss

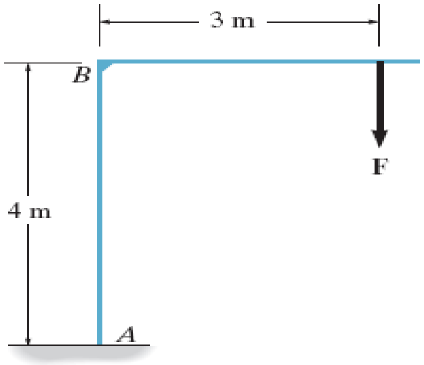
Idealized Structure

- Idealized Structure
  - No thickness for the components
  - The support at A can be modeled as a fixed support



actual structure

(a)

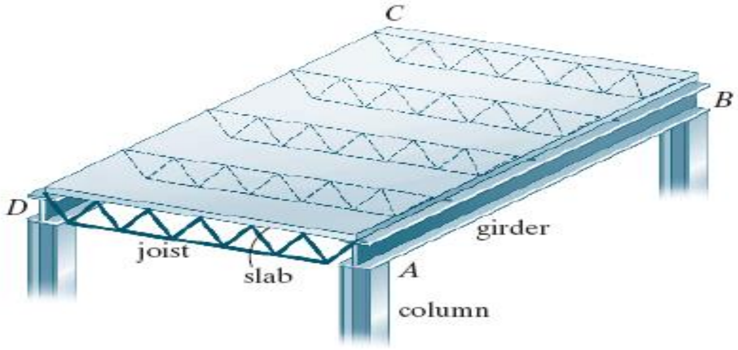


idealized structure

(b)

Idealized Structure

- Idealized Structure
  - Consider the framing used to support a typical floor slab in a building
  - The slab is supported by floor joists located at even intervals
  - These are in turn supported by 2 side girders AB & CD



Idealized Structure

- Idealized Structure
  - For analysis, it is reasonable to assume that the joints are pin and /or roller connected to girders & the girders are pin and/or roller connected to columns

idealized framing plan

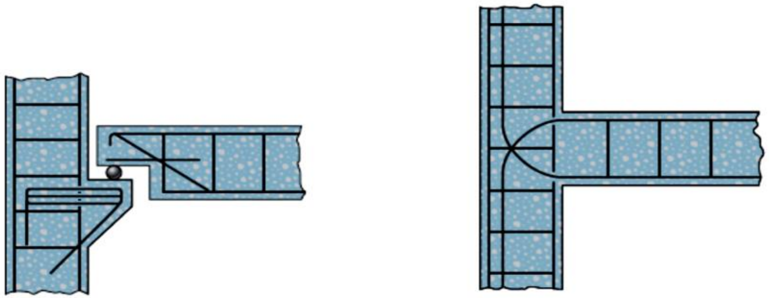
Idealized Structure

Support Connections

Pin connection (allows slight rotation)

Roller support (allows slight translation)

Fixed joint (allows no rotation/translation



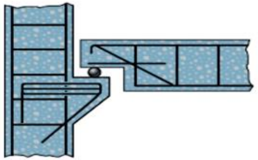
typical "roller-supported" connection (concrete)
(a)

typical "fixed-supported" connection (concrete)
(b)

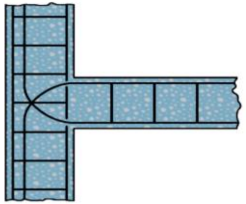
typical "pin-supported" connection (metal)
(a)

typical "fixed-supported" connection (metal)
(b)

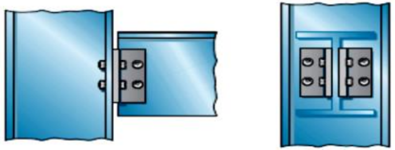
Idealized Structure



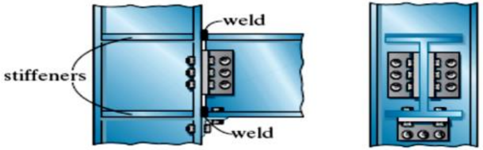
typical "roller-supported" connection (concrete)
(a)



typical "fixed-supported" connection (concrete)
(b)



typical "pin-supported" connection (metal)
(a)



typical "fixed-supported" connection (metal)
(b)

pin support

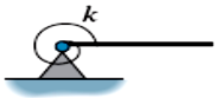
pin-connected joint

(a)

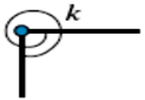
fixed support

fixed-connected joint

(b)



torsional spring support

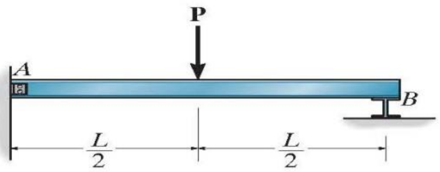


torsional spring joint

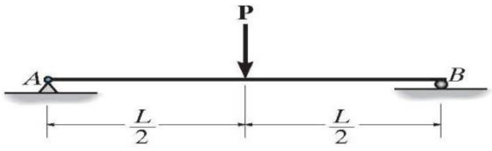
(c)

Idealized Structure

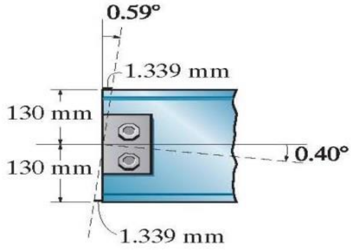
- In reality, all connections and supports are modeled with assumptions. Need to be aware how the assumptions will affect the actual performance



actual beam
(a)



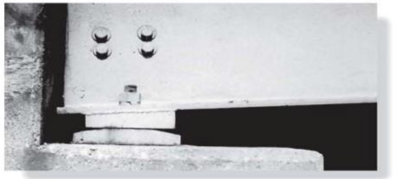
idealized beam
(b)



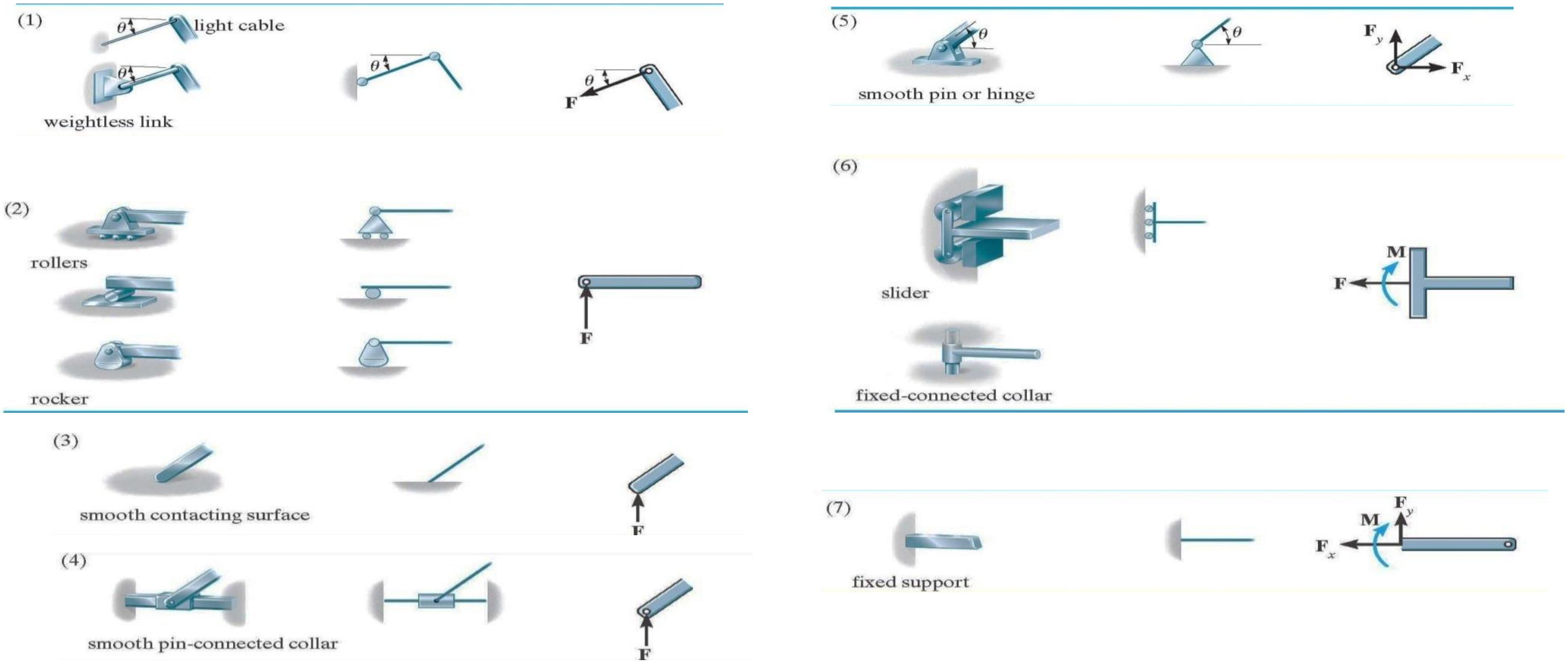
(c)


Rollers and associated bearing pads are used to support the prestressed concrete girders of a highway bridge.


Typical pin used to support the steel girder of a railroad bridge.


A typical rocker support used for a bridge girder.

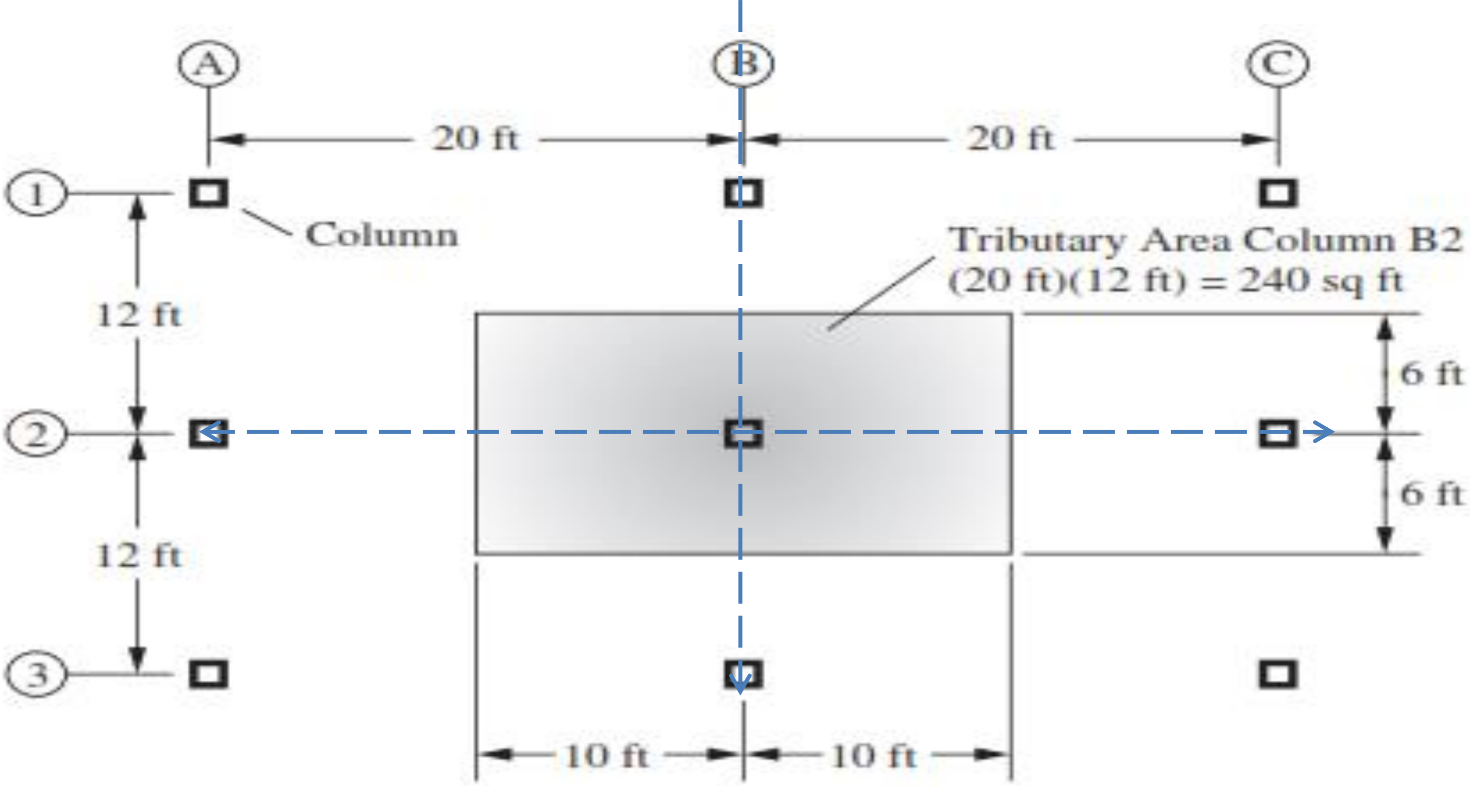
Idealized Structure



Idealized Structure

Tributary area is defined as the loaded area of a structure that directly contributes to the load applied to a particular member.

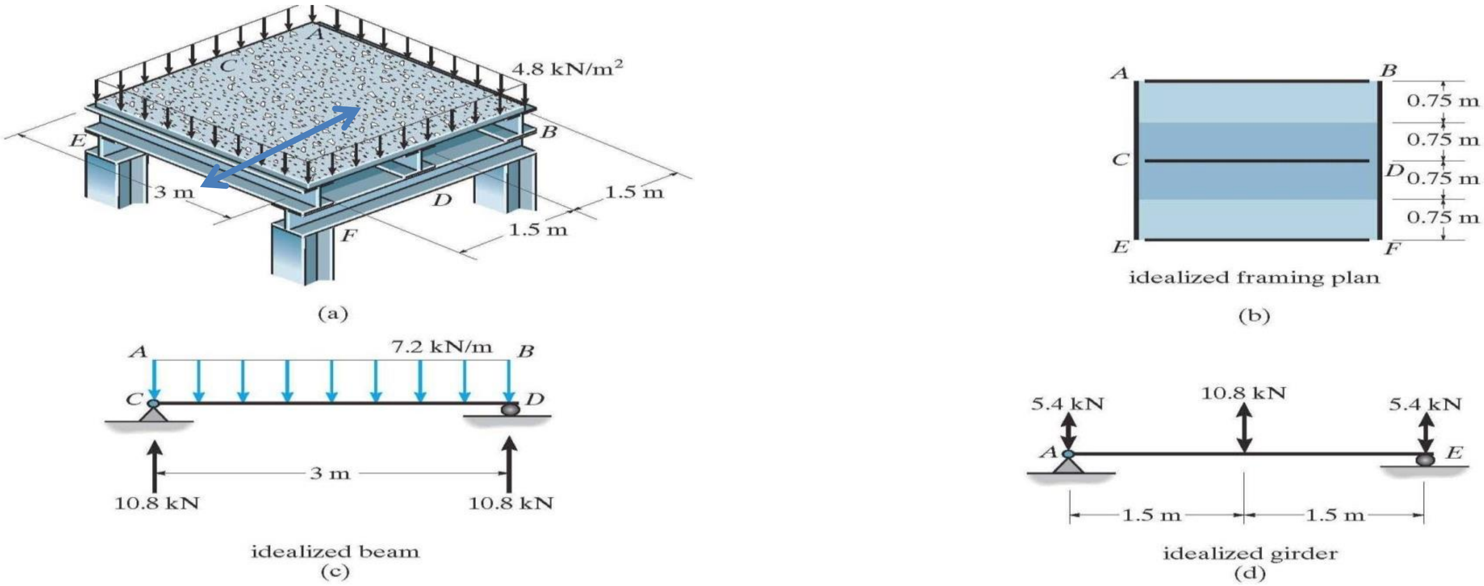
- Tributary Loadings
  - There are 2 ways in which the load on surfaces can transmit to various structural elements
  - 1-way system
  - 2-way system

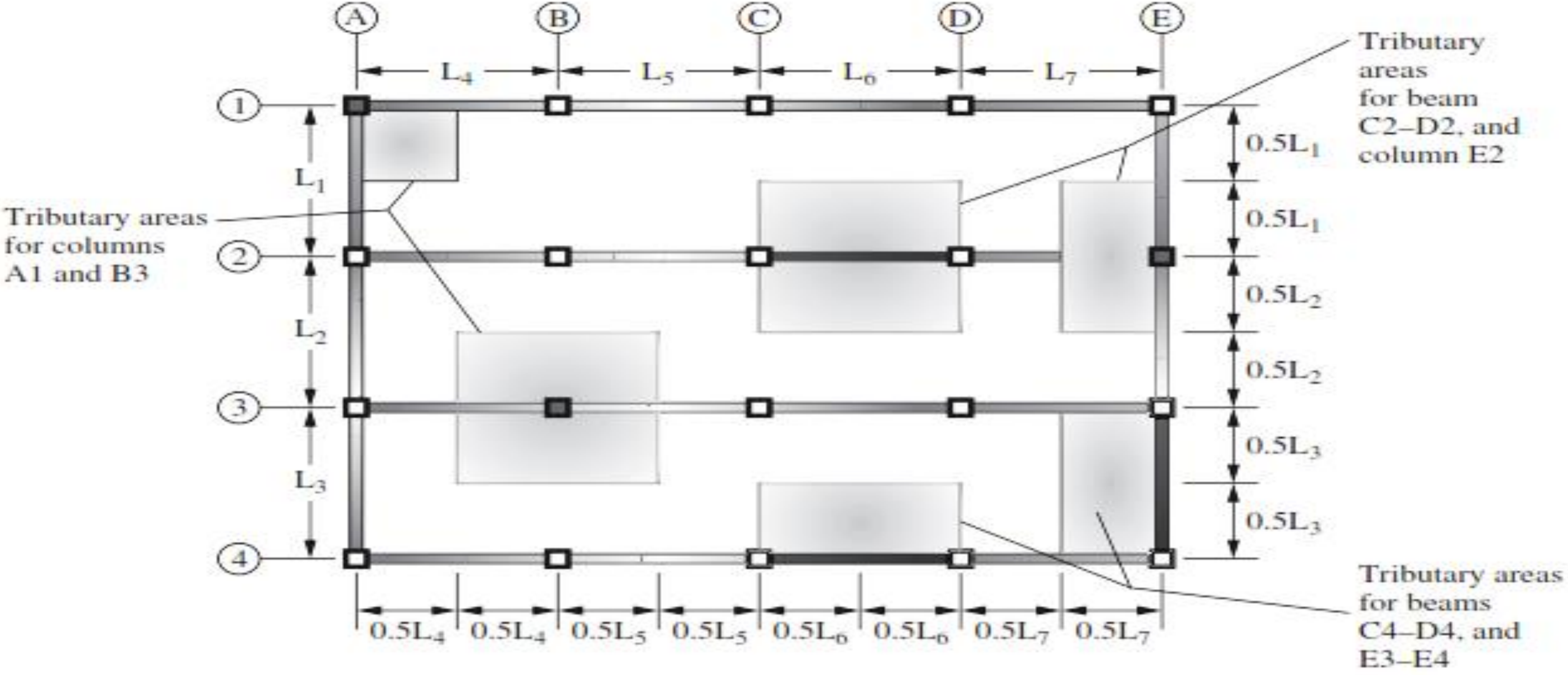


Tributary area for a column (Column B2)

Idealized Structure

- Tributary Loadings
  - 1-way system

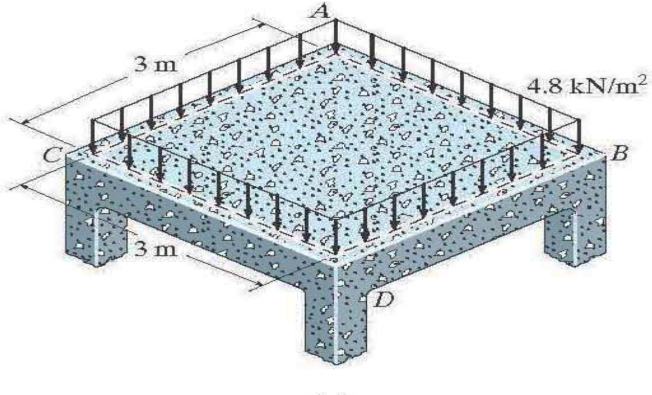




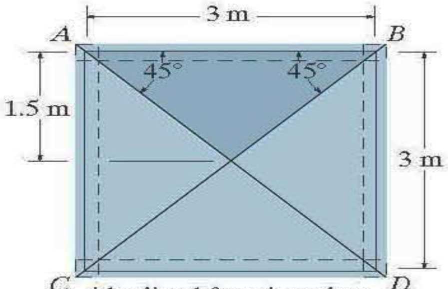
Tributary area for selected columns and beams

Idealized Structure

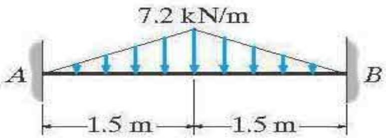
- Tributary Loadings
  - 2-way system



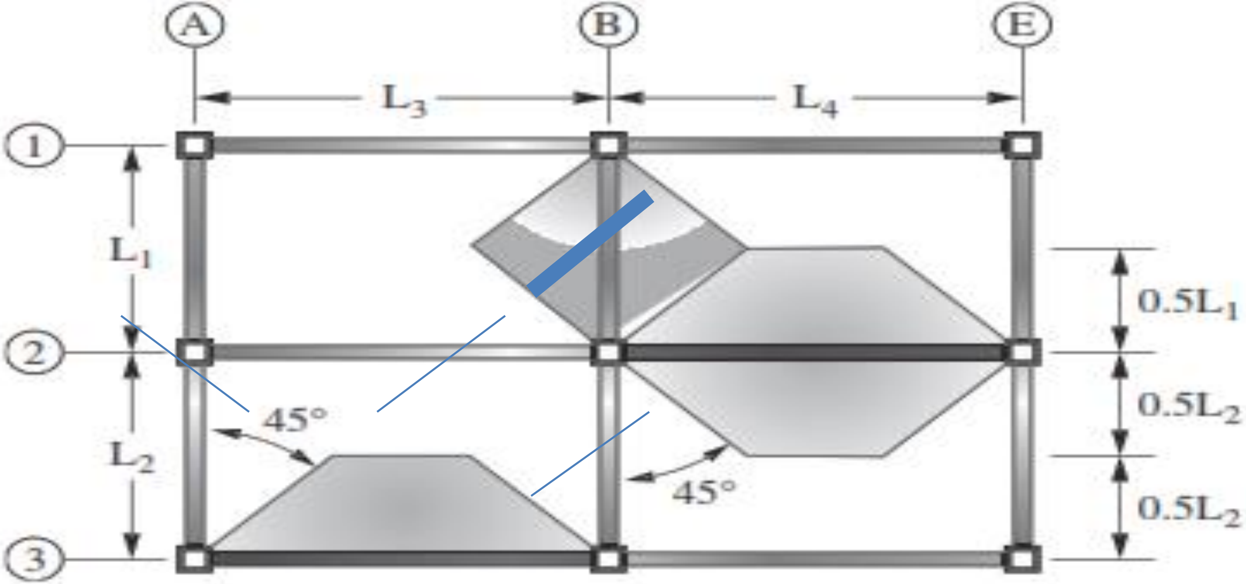
(a)



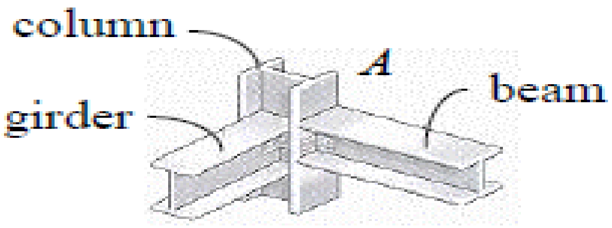
idealized framing plan
(b)

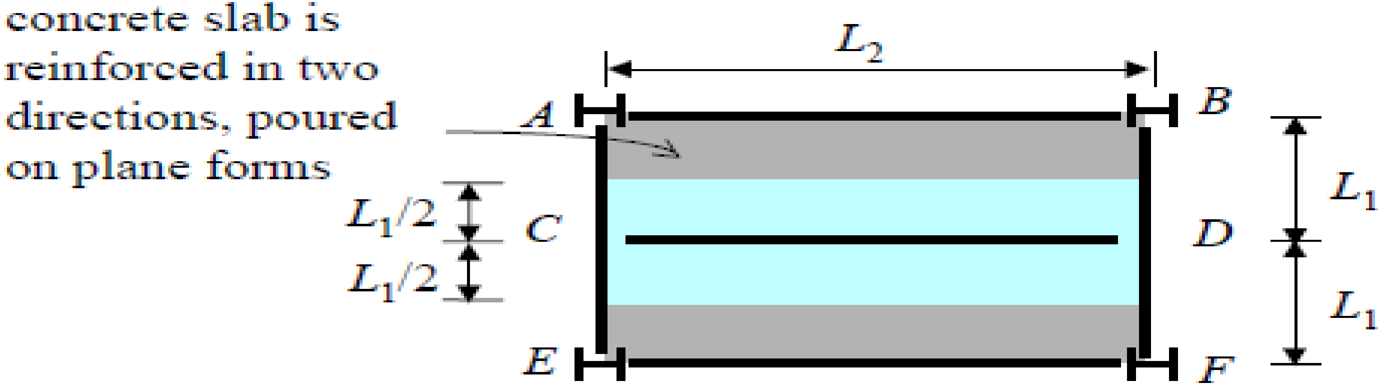


idealized beam
(c)



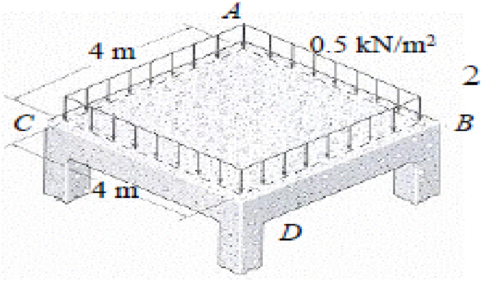
Tributary area for a beam with two-way bending



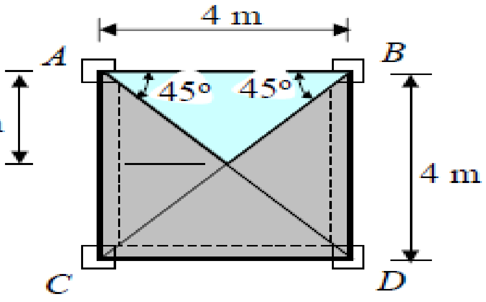


Idealized framing plan for one-way slab action requires $L_2 / L_1 \geq 2$

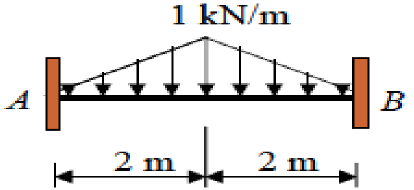
Two-Way System.



$L_2/L_1 = 1$

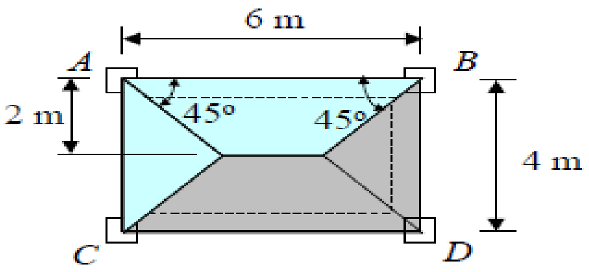


idealized framing plan

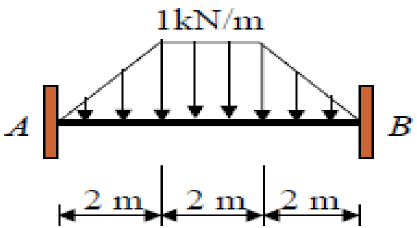


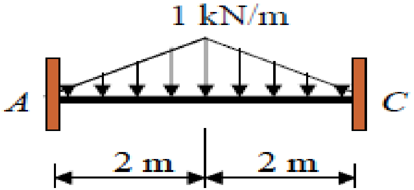
idealized beam, all

$L_2/L_1 = 1.0 < 2$



idealized framing plan





idealized beam

Types of Loads

- **Dead loads**
- **Live Loads**
- **Wind Load**
- **Snow Load**

Dead Loads

- The dead loads that must be supported by a particular structure include all of the loads that are permanently attached to that structure. They include the weight of the structural frame and also the weight of the walls, roofs, ceilings, stairways, and so on.
- Permanently attached equipment, described as "fixed service equipment" in ASCE 7-02, also is included in the dead load applied to the building. This equipment will include ventilating and air-conditioning systems, plumbing fixtures, electrical cables, support racks, and so forth. Depending upon the use of the structure, kitchen equipment such as ovens and dishwashers, laundry equipment such as washers and dryers, or suspended walkways could be included in the dead load.

The dead loads

- acting on the structure are determined by reviewing the architectural, mechanical, and electrical drawings for the building. From these drawings, the structural engineer can estimate the size of the frame necessary for the building layout and the equipment and finish details indicated. Standard handbooks and manufacturers' specifications can be used to determine the weight of floor and ceiling finishes, equipment, and fixtures. The approximate weights of some common materials used for walls, floors, and ceilings are shown in Table (follow slide).

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*, ASCE/SEI 7-10. Copies of this standard may be purchased from ASCE at www.pubs.asce.org.

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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EXAMPLE 1.1

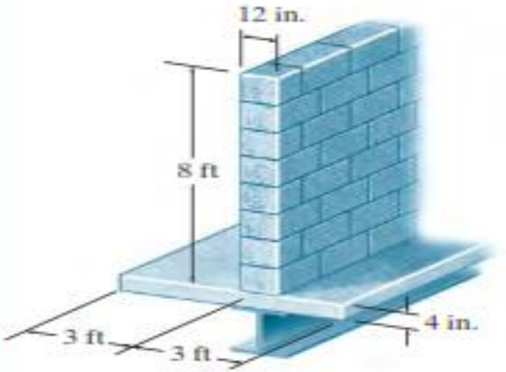

Fig. 1–8

The floor beam in Fig. 1–8 is used to support the 6-ft width of a lightweight plain concrete slab having a thickness of 4 in. The slab serves as a portion of the ceiling for the floor below, and therefore its bottom is coated with plaster. Furthermore, an 8-ft-high, 12-in.-thick lightweight solid concrete block wall is directly over the top flange of the beam. Determine the loading on the beam measured per foot of length of the beam.

SOLUTION

Using the data in Tables 1–2 and 1–3, we have

Concrete slab:	$[8\ \text{lb}/(\text{ft}^2 \cdot \text{in.})](4\ \text{in.})(6\ \text{ft}) =$	192 lb/ft
Plaster ceiling:	$(5\ \text{lb}/\text{ft}^2)(6\ \text{ft}) =$	30 lb/ft
Block wall:	$(105\ \text{lb}/\text{ft}^3)(8\ \text{ft})(1\ \text{ft}) =$	840 lb/ft
Total load		1062 lb/ft = 1.06 k/ft

Ans.

Here the unit k stands for "kip," which symbolizes kilopounds. Hence, 1 k = 1000 lb.

Live Loads

- Live loads are those loads that can vary in magnitude and position with time. They are caused by the building being occupied, used, and maintained. Most of the loads applied to a building that are not dead loads are live loads. Environmental loads, which are actually live loads by our usual definition, are listed separately in ASCE 7-02 and IBC-2003.

- Although environmental loads do vary with time, they are not all caused by gravity or operating conditions, as is typical with other live loads.

- Some typical live loads that act on building structures are presented in Table. The loads shown in the table were taken from Table 4-1 in ASCE 7-02 and Table 1607.1 in IBC-2003. They are acting downward and are distributed uniformly over the entire floor or roof.
- Many building specifications provide concentrated loads to be considered in design. This is the situation in Section 4.3 of the ASCE 7-02 and Section 1607.4 of IBC-2003.
- These specifications state that the designer must consider the effect of certain concentrated loads as an alternative to the previously discussed uniform loads. The intent, of course, is that the loading used for design be the one that causes the most severe stresses.

TABLE 1–4 Minimum Live Loads*

Occupancy or Use	Live Load psf	Live Load kN/m²	Occupancy or Use	Live Load psf	Live Load kN/m²
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		
Garages (passenger cars only)	50	2.40	Private rooms and corridors	40	1.92
Office buildings			Public rooms and corridors	100	4.79
Lobbies	100	4.79	Schools		
Offices	50	2.40	Classrooms	40	1.92
Storage warehouse			Corridors above first floor	80	3.83
Light	125	6.00			
Heavy	250	11.97			

*Reproduced with permission from *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-10.

TABLE 2.3 TYPICAL CONCENTRATED LIVE LOADS

Area or Structural Component	Concentrated Live Load
Elevator Machine Room Grating on 4-in.^{2}	300 lbs
Office Floors	2000 lbs
Center of Stair Tread on 4-in.^{2}	300 lbs
Sidewalks	8000 lbs
Accessible Ceilings	200 lbs

Wind Loads:

When structures block the flow of wind, the wind's kinetic energy is converted into potential energy of pressure, which causes a wind loading.

The effect of wind on a structure depends upon:

- the density and velocity of the air,
- the angle of incidence of the wind,
- the shape and stiffness of the structure, and
- the roughness of its surface.

For design purposes, wind loadings can be treated using either a static or a dynamic approach.