

Design of 2D Steel Trusses



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INTRODUCTION

Simple beams, lattice girders and trusses

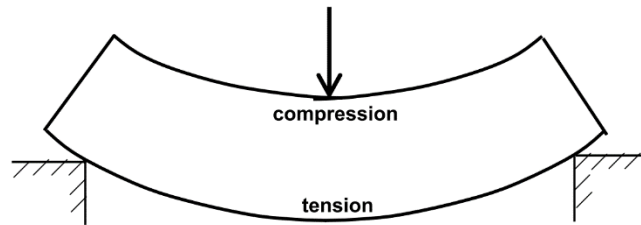
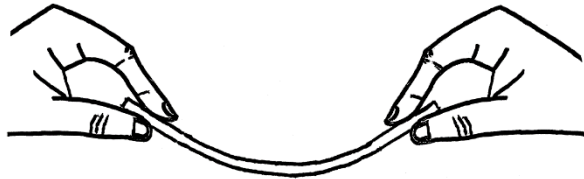
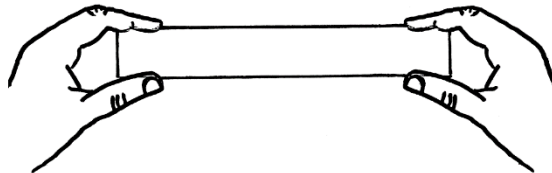


Fig. 12.1 Bending of beams.



(a) Ruler flat: easy to bend



(b) Ruler on edge: hard to bend

Fig. 12.2 Deeper beams are stronger.

- Instead of having a **solid deep beam**, it is possible to achieve the same result by having a framework members as shown in Fig. 12.3.

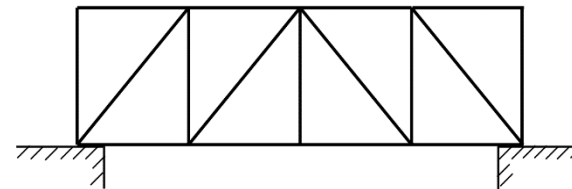


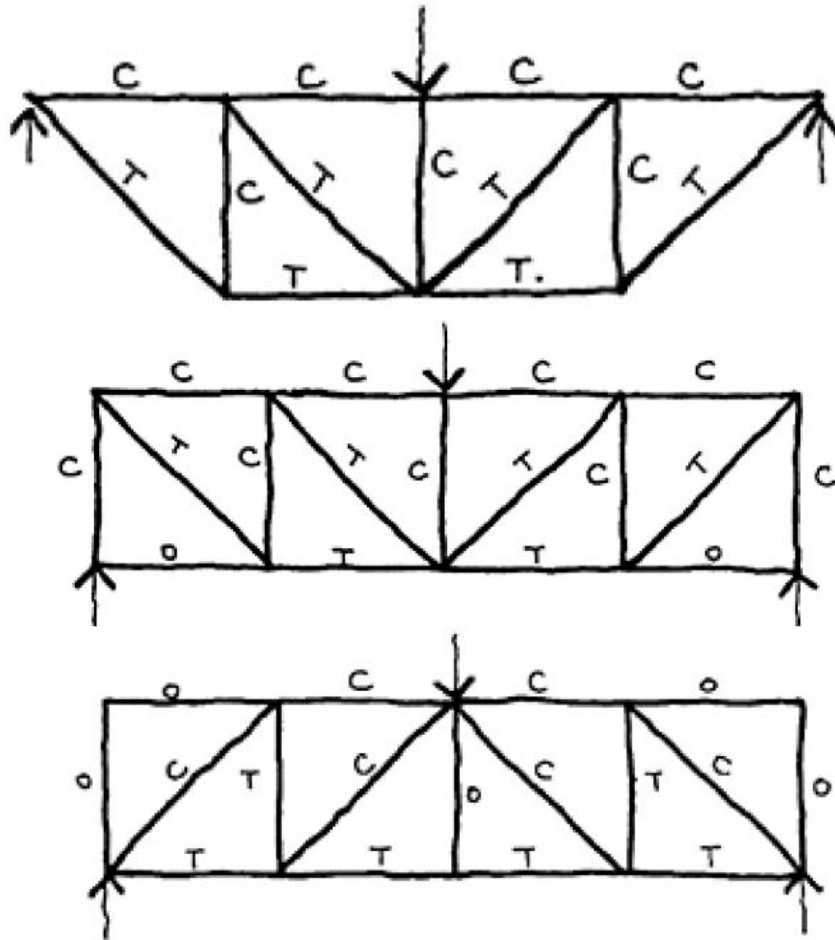
Fig. 12.3 A steel railway bridge.

HISTORY (Railroad Bridges)



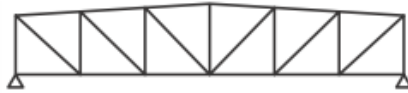
Erected in 1880, the Milwaukee Road's metal, deck-truss bridge across the Mississippi River between Minneapolis and St. Paul continues to mark the waterway just downstream of the Cappelen Memorial Bridge. *Photograph by Sweet, ca. 1904; courtesy of the Minnesota Historical Society.*

STRUCTURAL BEHAVIOR

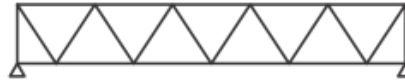


- Top and vertical members in compression (C), bottom and sloping members in tension (T).
- Structural designer can alter the force pattern by choice of structural arrangement.

FORMS OF TRUSSES



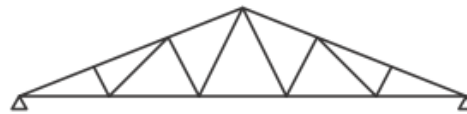
(a) Pitched Pratt truss (spans > 20 m)



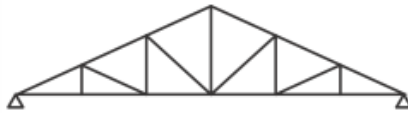
(b) Warren girder (spans > 20 m)



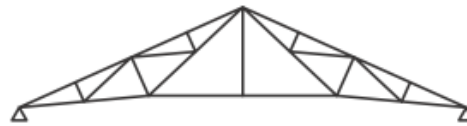
(c) Fink truss (spans up to 10 m)



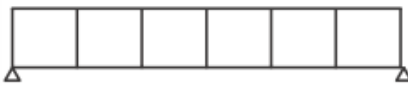
(d) Double Fink truss (spans between 10 and 15 m)



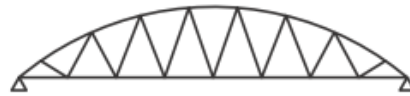
(e) Howe truss (spans up to 15 m)



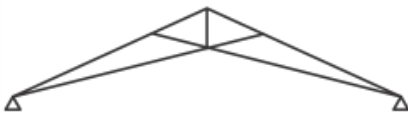
(f) French truss (spans between 12 and 20 m)



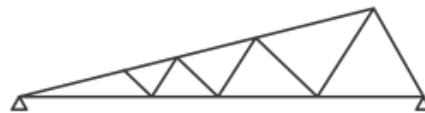
(g) Vierendeel girder (spans up to 20 m)



(h) Bowstring truss (very long spans > 30 m)



(i) Scissors truss (used to give additional headroom) (spans < 15 m)



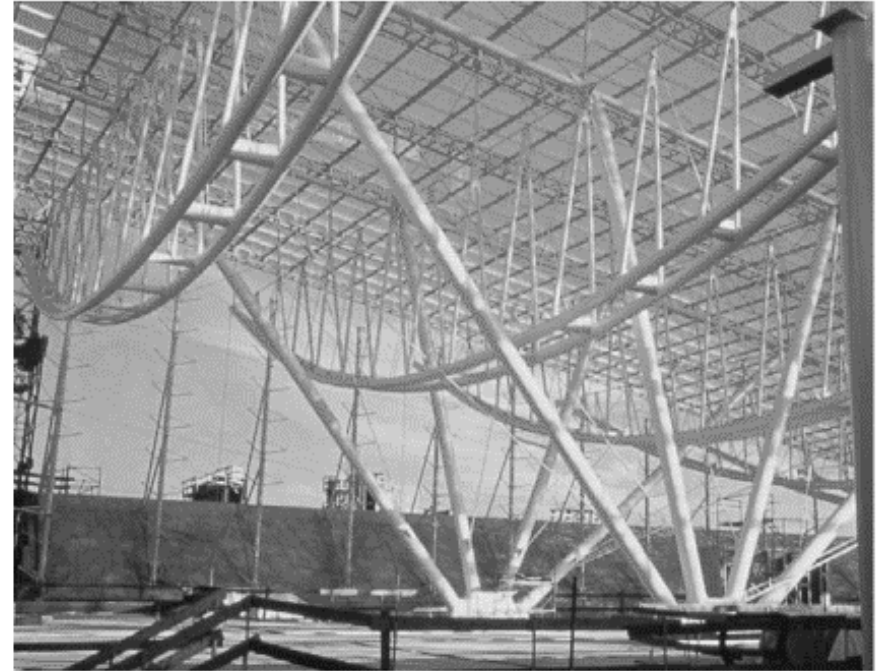
(j) North light truss (spans < 15 m)

4.30 Different forms of conventional roof trusses and lattice girders

FORMS OF TRUSSES



4.40 Stratford Market depot, London (architect: Wilkinson Eyre)



4.41 Deep curved roof trusses at the TGV terminal at Charles de Gaulle Airport, Paris (architect: Aeroports de Paris)

FORMS OF TRUSSES



4.42 Triangular roof trusses at Hamburg Airport (architect: Von Gerkan Marg and Partners)

FORMS OF TRUSSES



Fig. 12.6 Roof structure, Manchester Victoria station.

FORMS OF TRUSSES



Fig. 12.4 Trussed bridge across River Spree, Berlin.

FORMS OF TRUSSES



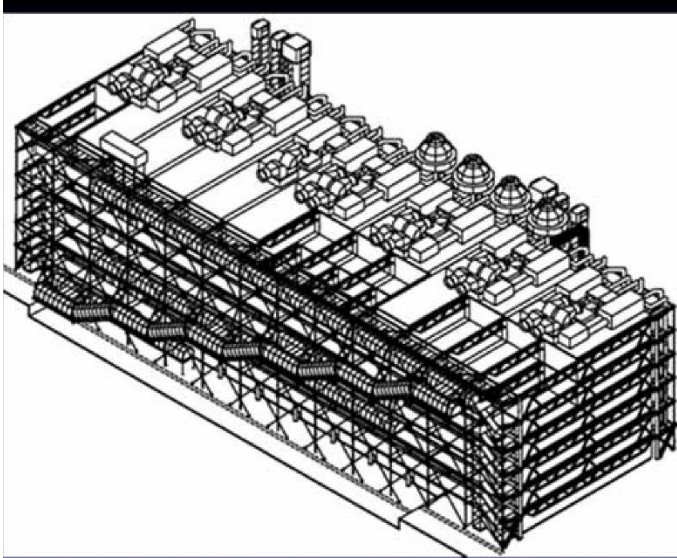
Fig. 12.5 Truss in façade, Sony Centre, Berlin.

FORMS OF TRUSSES



3.14 Example of continuity achieved through a series of pinned connections, Centre Pompidou, Paris (architect: Renzo Piano and Richard Rogers)

FORMS OF TRUSSES



Centre Pompidou, Paris

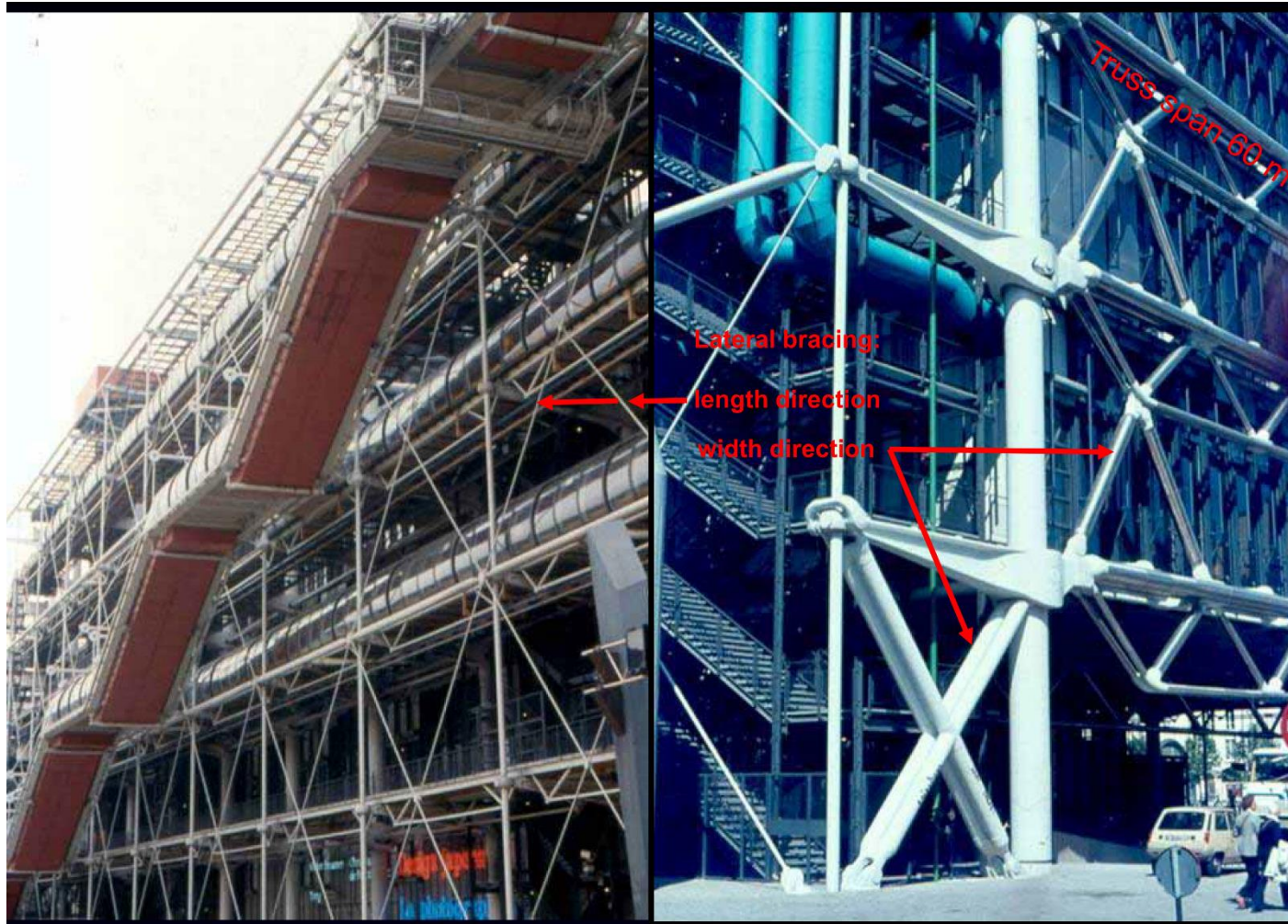
Architect: Piano and Rogers

Engineer: Ove Arup

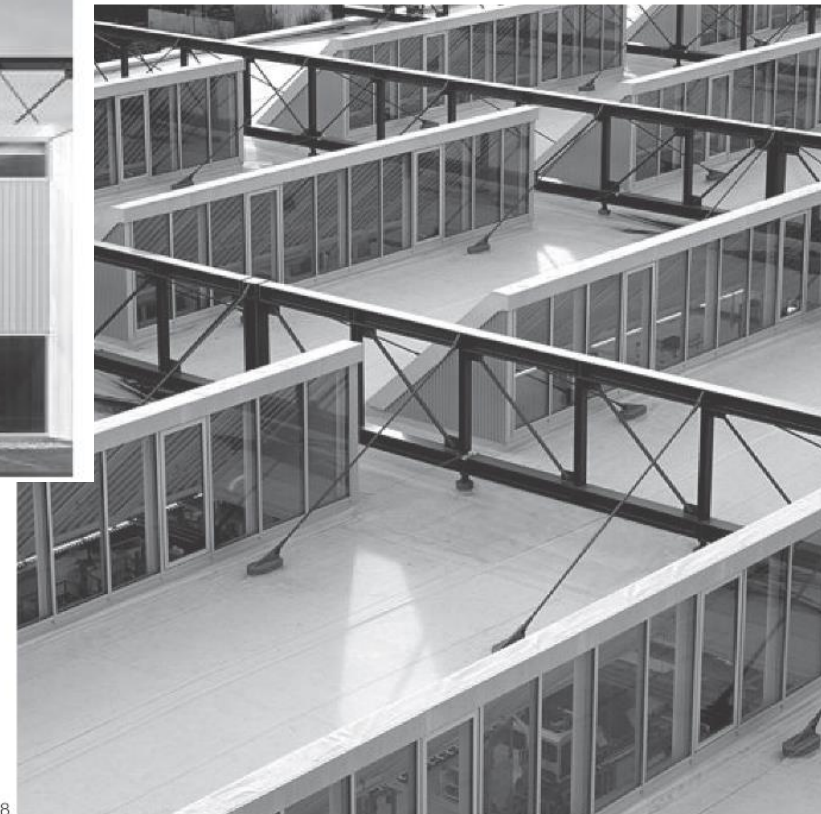
Bracing provides lateral stability in both width and length directions



FORMS OF TRUSSES



LATTICE BEAMS



- 7 Valeo motors plant, Beitingheim-Bissingen, 2003
Architects: Ackermann & Partner
Structural engineer: Christoph Ackermann
- 8 View of roof as "fifth facade" with external lattice beams and self-supporting northlights for admitting daylight. This non-glare lighting arrangement is a reliable way of creating an optimum workplace quality and also improves the building's energy balance.
- 9 Longitudinal section, scale 1:250
- 10 Section through lattice beam showing suspended secondary beams, scale 1:250
- 11 Detail of lattice beam with solid round section diagonals welded to gusset plates, scale 1:20
- 12 Section through lattice beam showing connection of secondary beam hangers, scale 1:20

8

FORMS OF TRUSSES

Sainsbury Center, UK, 1977

Architect: Norman Foster

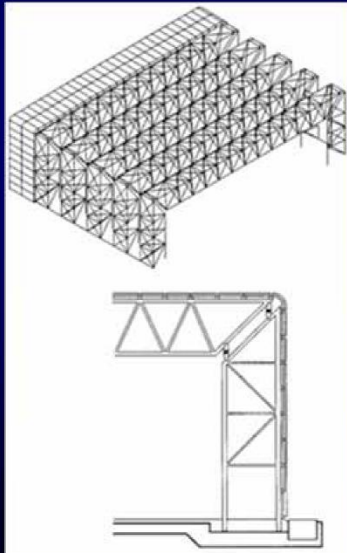
Engineer: Anthony Hunt

<http://www.fosterandpartners.com/Projects/0188/Default.aspx>

Prismatic truss frame, 34 m span

Frame action resist gravity **and** lateral load

Prismatic cross section provides stability
to prevent lateral buckling and rotation



OTHER APPLICATIONS OF TRUSSES

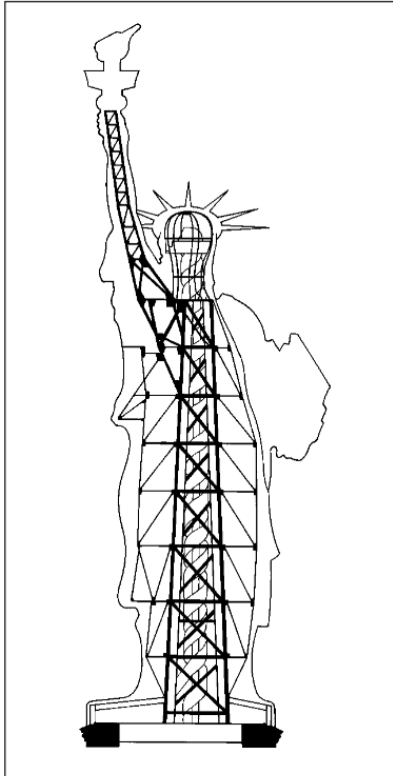
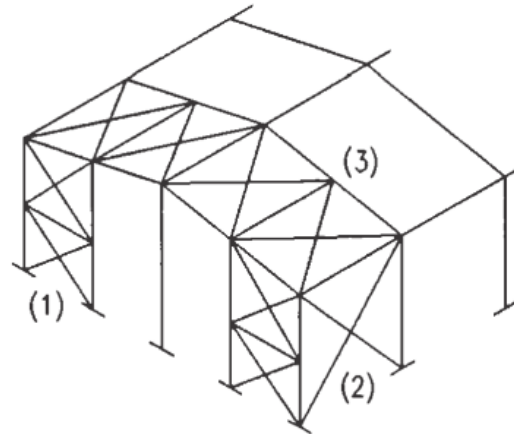
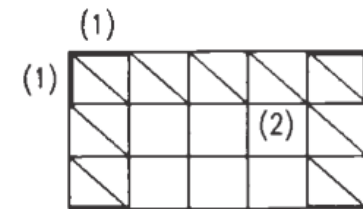
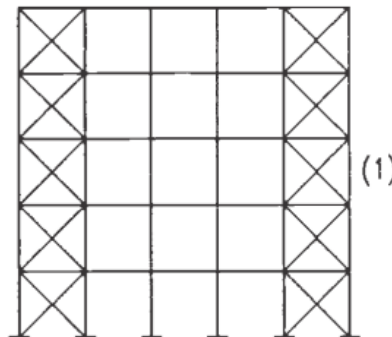


Fig. ii The thin external surface of the Statue of Liberty in New York Harbour, USA, is supported by a triangulated structural framework. The influence of structural considerations on the final version of the form was minimal.



- (1) transverse vertical bracing
- (2) longitudinal vertical bracing
- (3) plan bracing

(a)

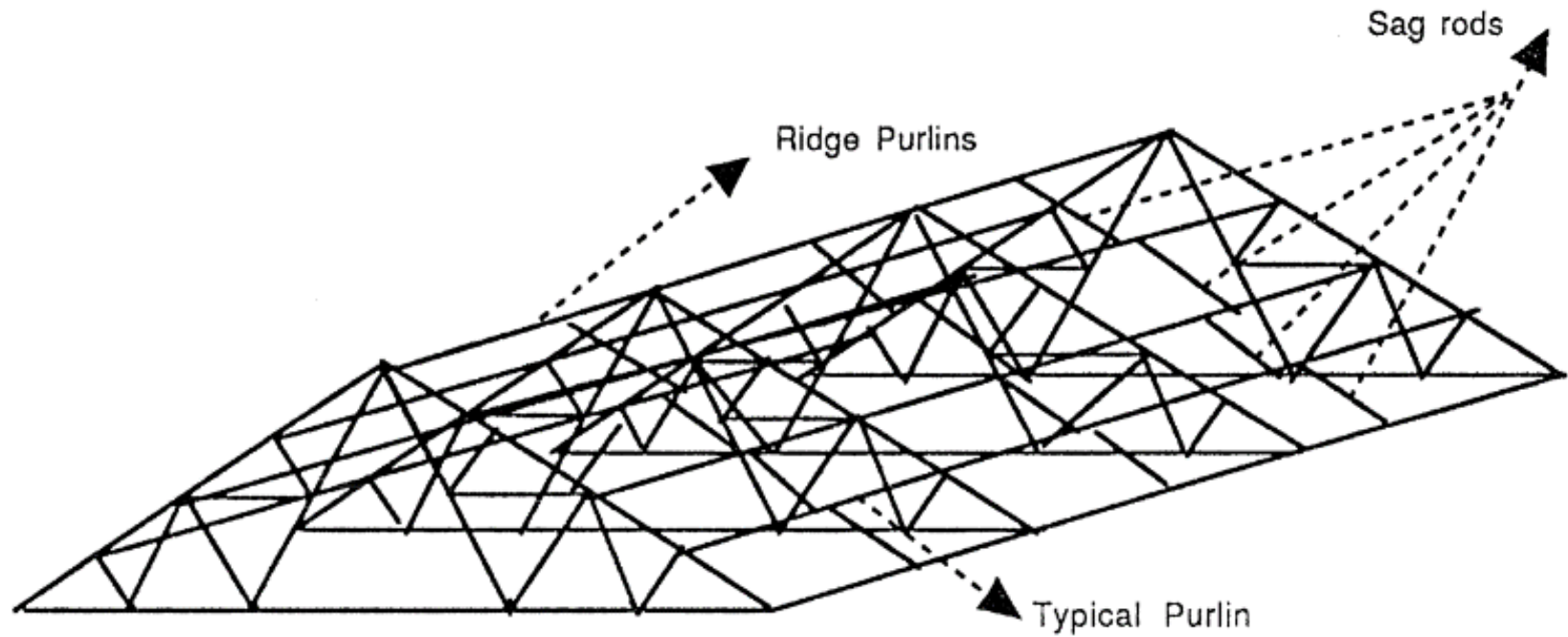


- (1) vertical bracing
- (2) plan bracing

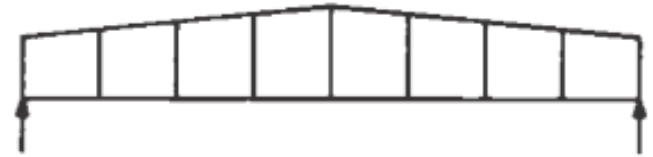
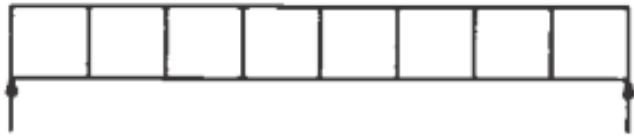
(b)

Fig. 19.7 Other applications of trusses. (a) Bracing to single-storey building; (b) bracing to multi-storey building;

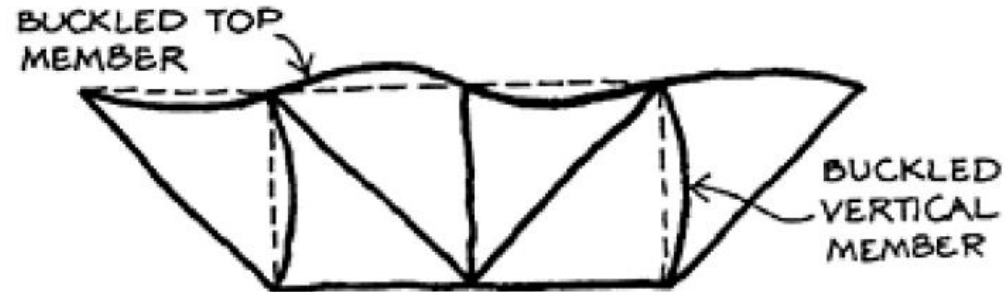
ROOF TRUSS FRAMING SYSTEM



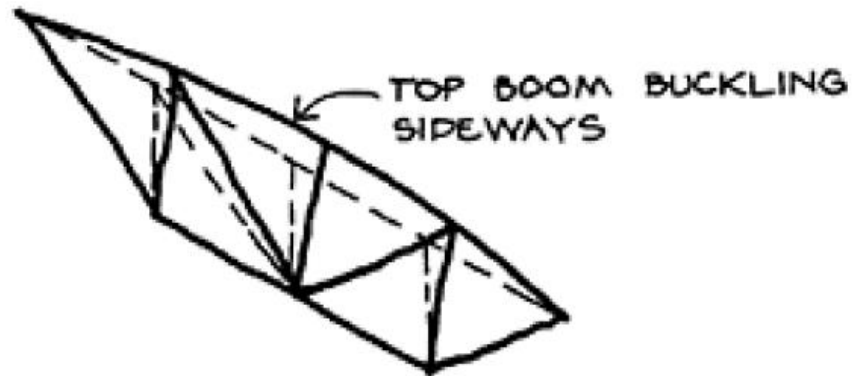
VIERENDEEL GIRDERS



BEHAVIOR OF COMPRESSION MEMBERS

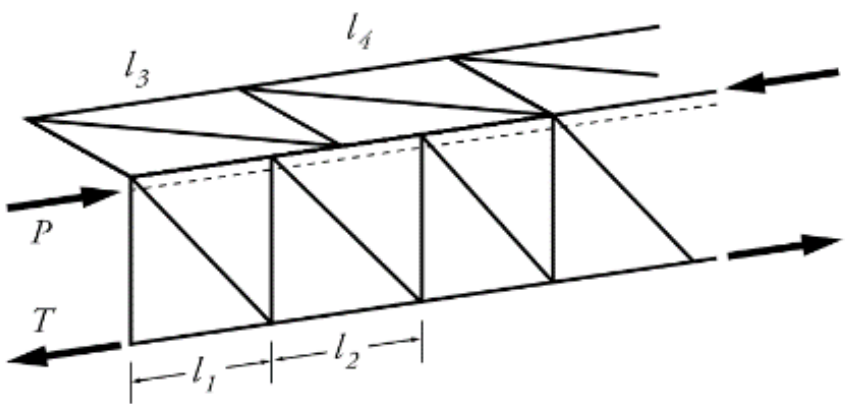
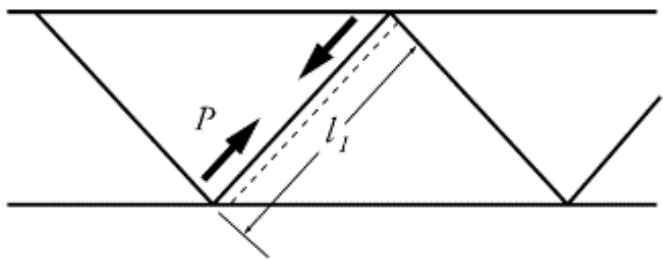


In plane behavior



Out of plane behavior

BEHAVIOR OF COMPRESSION MEMBERS

Member	Buckling plane	Effective length l_e
 <p>A 3D perspective diagram of a truss member. The member is a diagonal chord. It is subjected to a compressive force P and a tension force T. The member is divided into two segments of length l_1 and l_2. The overall length of the member is l_3. The effective length for buckling in the plane of the truss is l_4.</p>	In plane of truss	$1.0 l_1$ or l_2
	Out of truss plane	$1.0 l_3$ or l_4
 <p>A 2D diagram of a truss member. The member is a diagonal chord. It is subjected to a compressive force P. The length of the member is l_1.</p>	In plane of truss	$1.0 l_1$
	Out of plane	$1.0 l_1$

TYPICAL SECTIONS FOR TRUSS MEMBERS

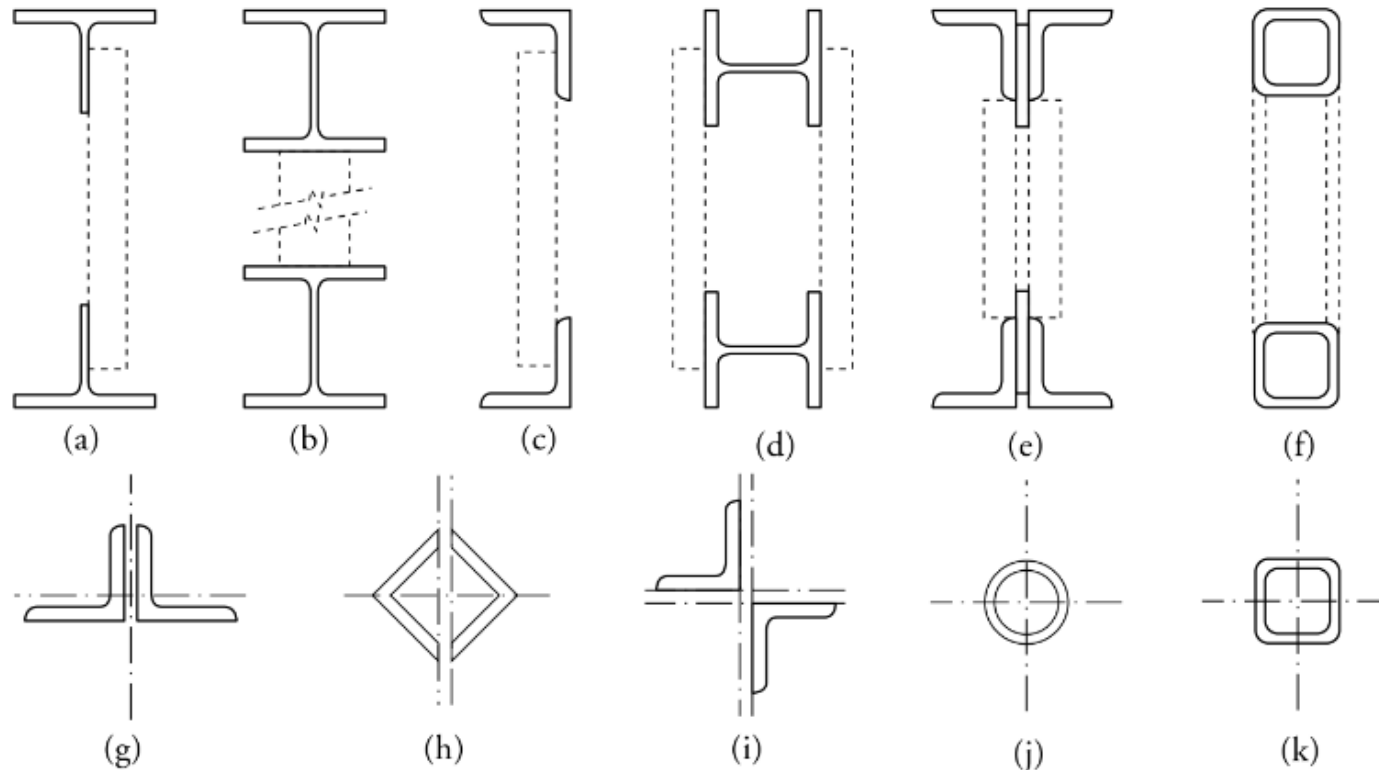


Figure 10.10 Typical sections for truss members: (a) to (f) commonly used in welded construction (though (a), (c), (d) and (e) may be bolted), and; (g) to (k) common sections used for chord and web/diagonal members

TYPICAL CONNECTION DETAILS OF TRUSSES

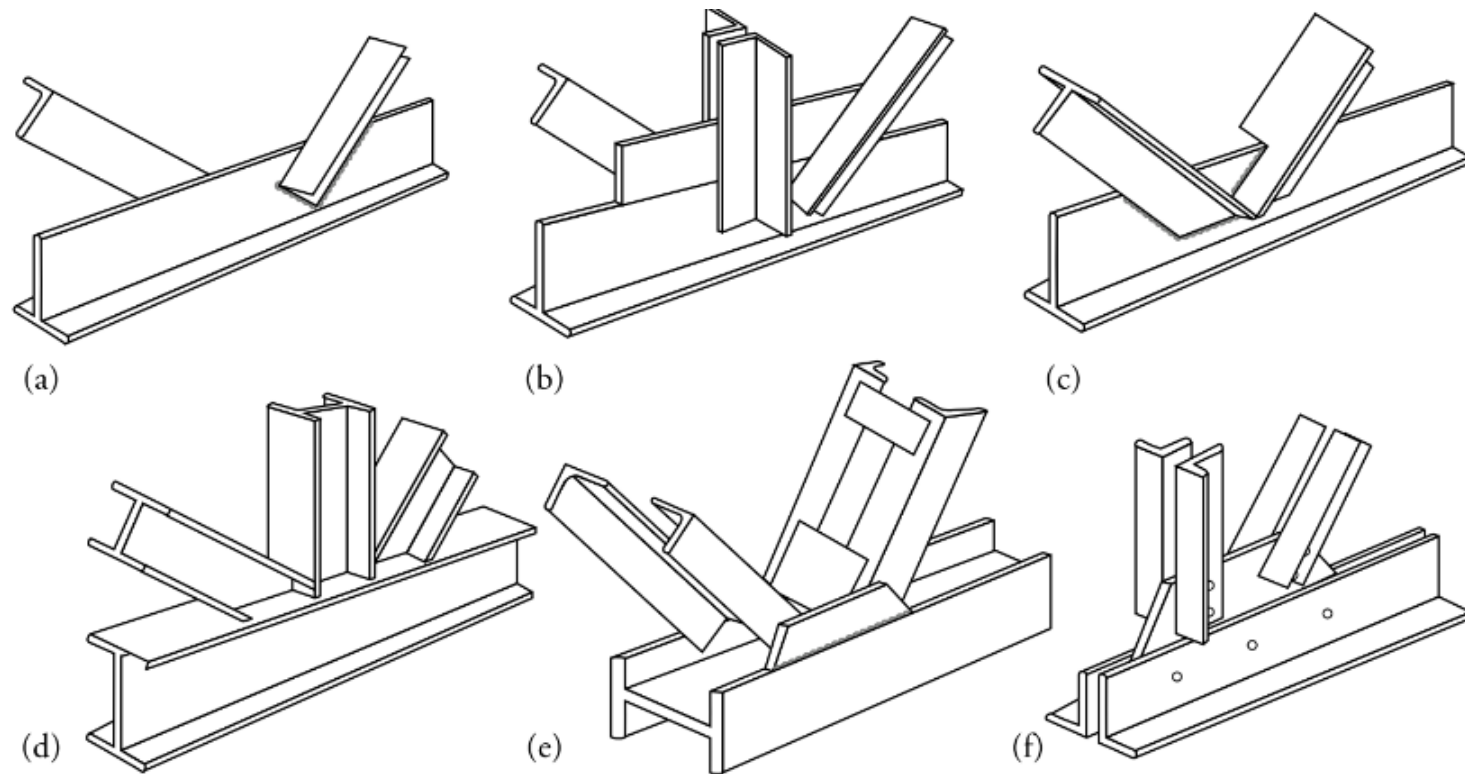
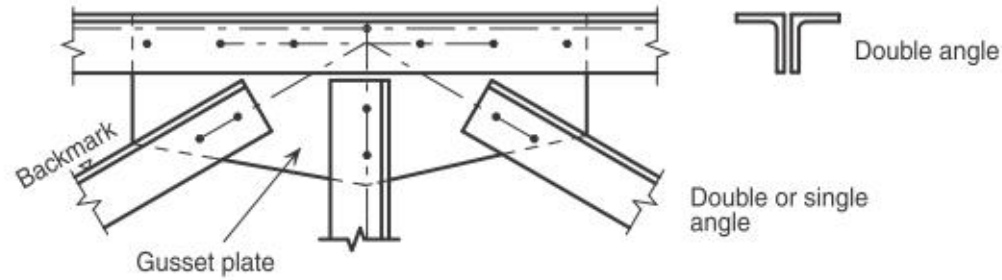
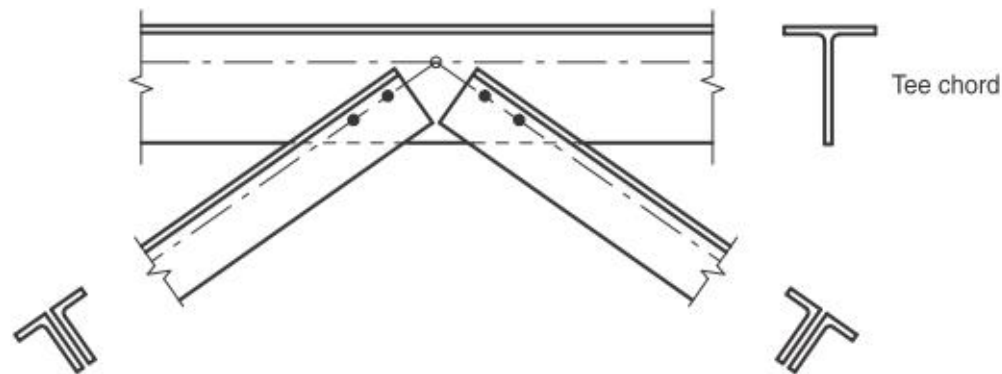


Figure 10.11 Typical node connections for trusses composed of rolled sections: (a) gussetless construction using Tee-chords; (b) gussets are required where diagonals carry large forces; (c) Tee-diagonals and chords, gussetless; (d) and (e) node detail for heavy trusswork, and (f) riveted/bolted nodes

TYPICAL CONNECTION DETAILS OF TRUSSES

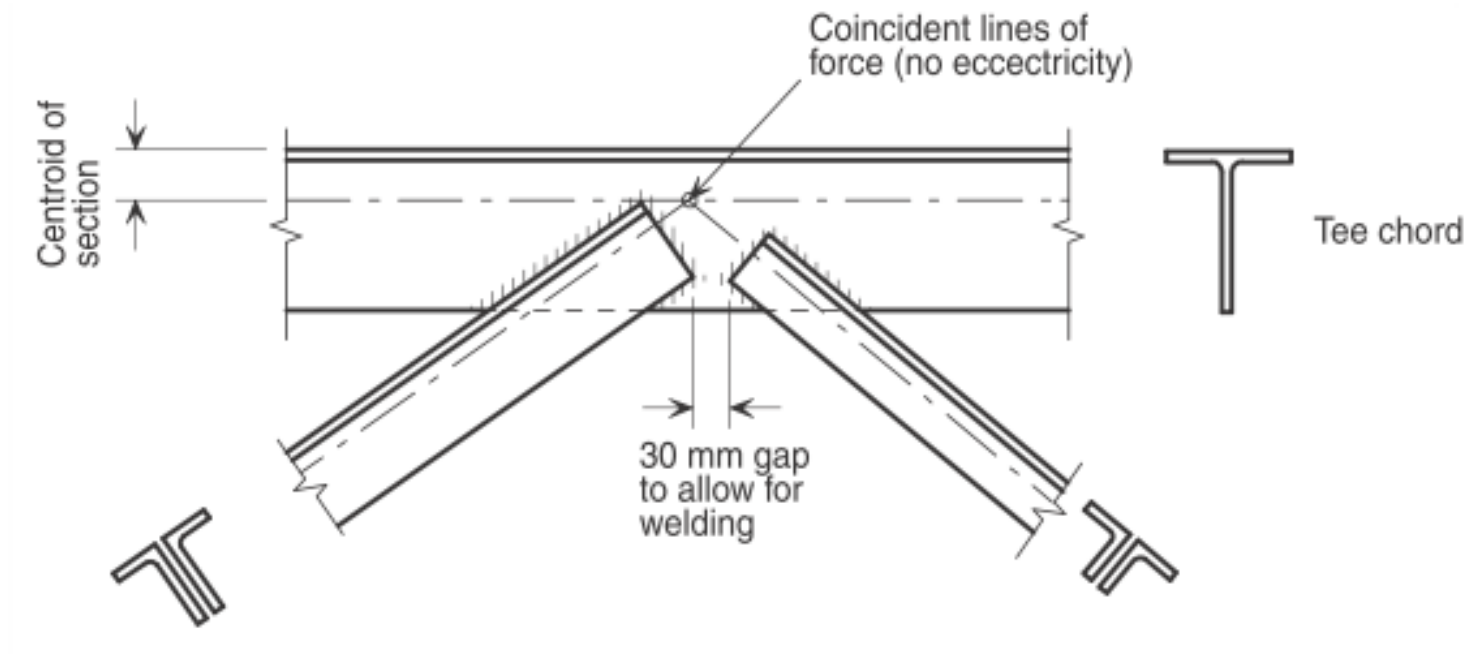


(a) Typical bracing-chord bolted connection using angle chords



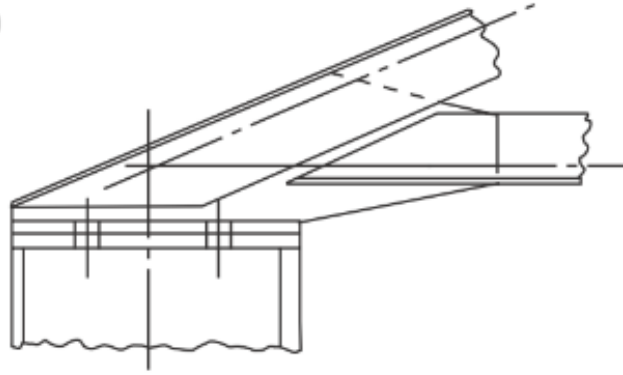
(b) Typical bracing - chord connection using T section chord

TYPICAL CONNECTION DETAILS OF TRUSSES

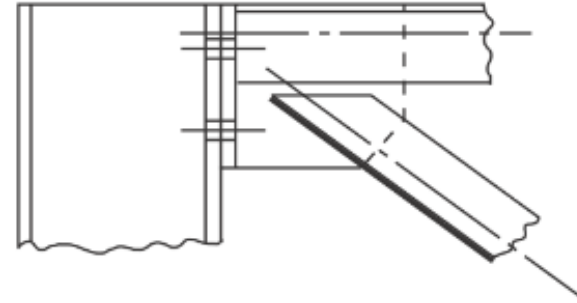


TYPICAL CONNECTION DETAILS OF TRUSSES

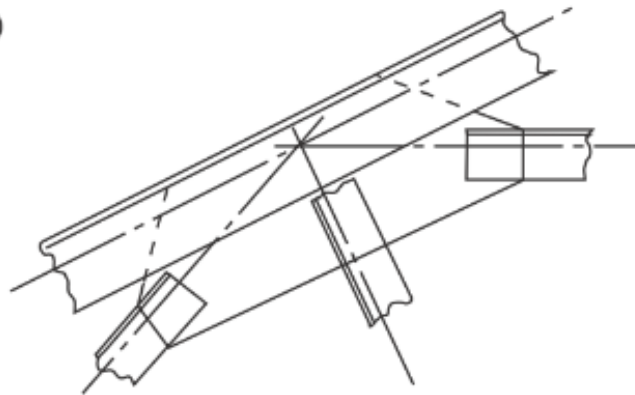
(a)



End connections – A

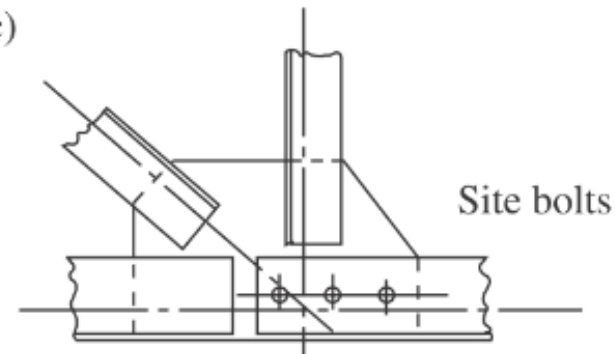


(b)



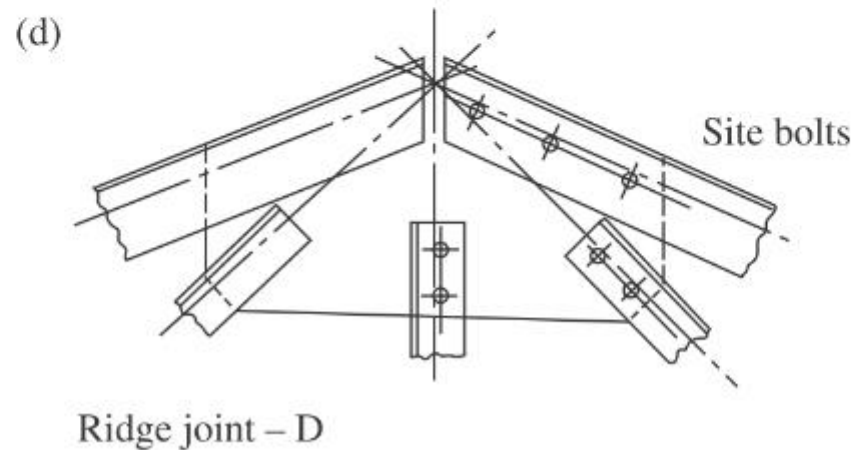
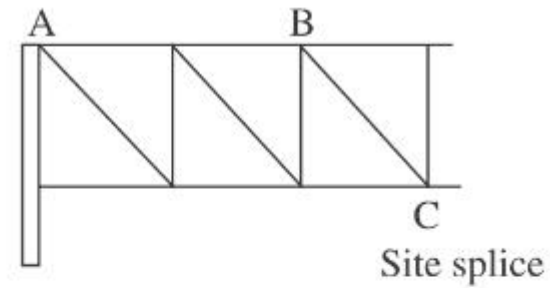
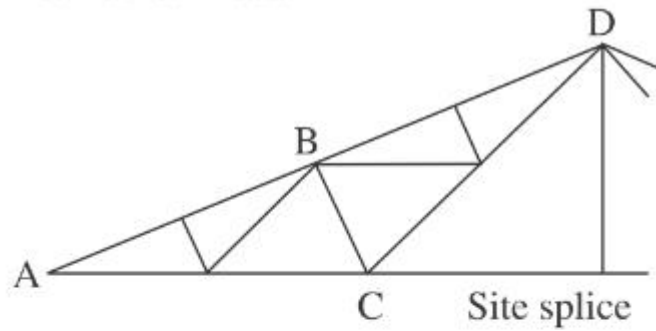
Internal connection – B

(c)



Site splice – C

TYPICAL CONNECTION DETAILS OF TRUSSES



TYPICAL CONNECTION DETAILS OF VIERENDEEL GIRDERS

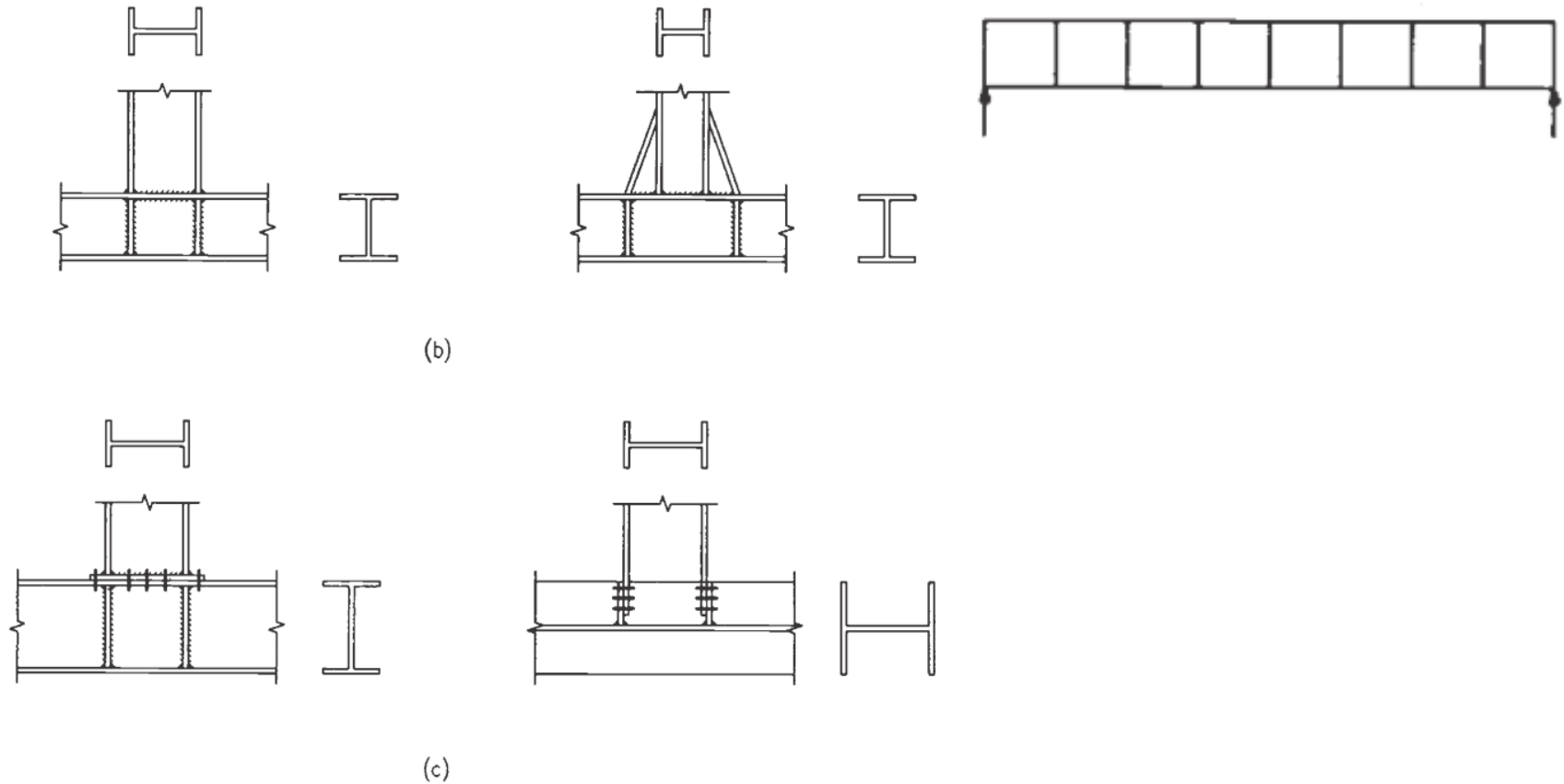


Fig. 19.8 Typical details of Vierendeel girders: (a) typical forms, (b) welded connections, (c) bolted connections

TUBULAR TRUSSES



4.36 Trusses at Toyota HQ, Swindon
(architect: Sheppard Robson)

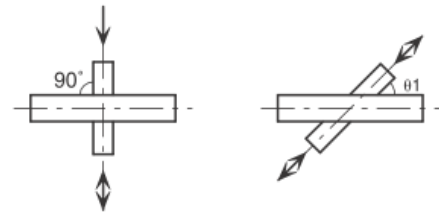


Airport Terminal Hamburg
Architect: Von Gerkan / Marg
Engineer: Kockjoy Schwarz Weber
Prismatic Truss

Airport Terminal, Chicago
Architect: Helmut Jahn
Folded truss



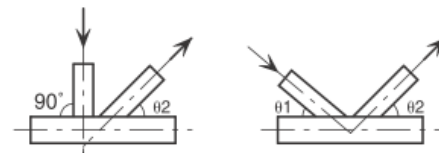
TUBULAR TRUSSES



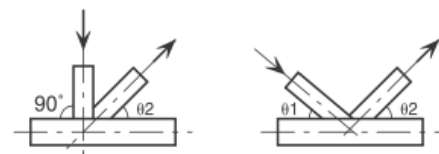
(a) X joints



(b) T and Y joints



(c) N and K joints with gap



(c) N and K joints with overlap

6.15 Connection designs in welded tubular construction



PURLINS

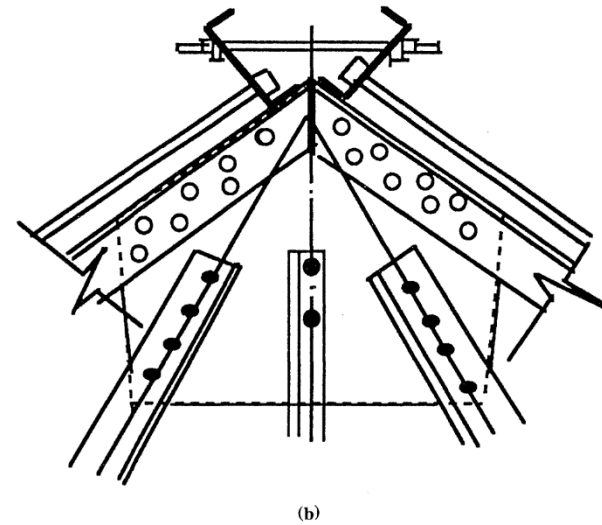
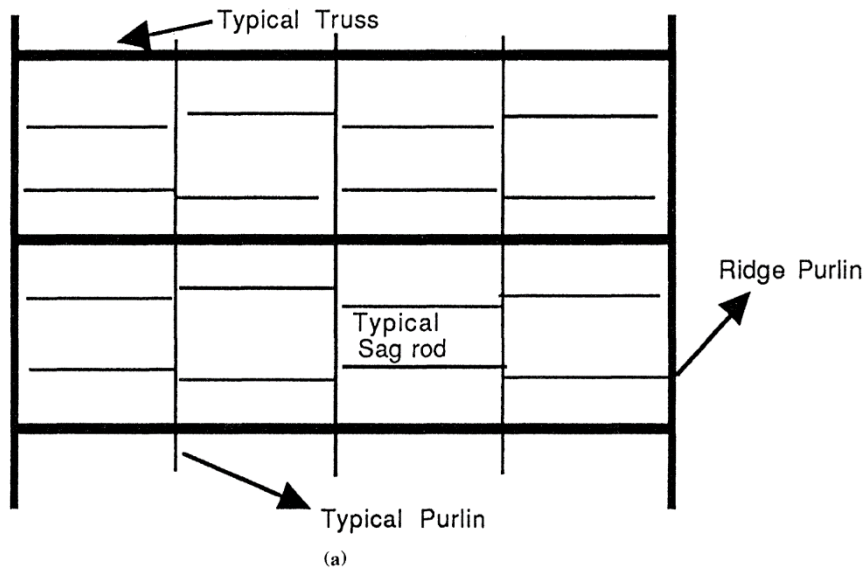
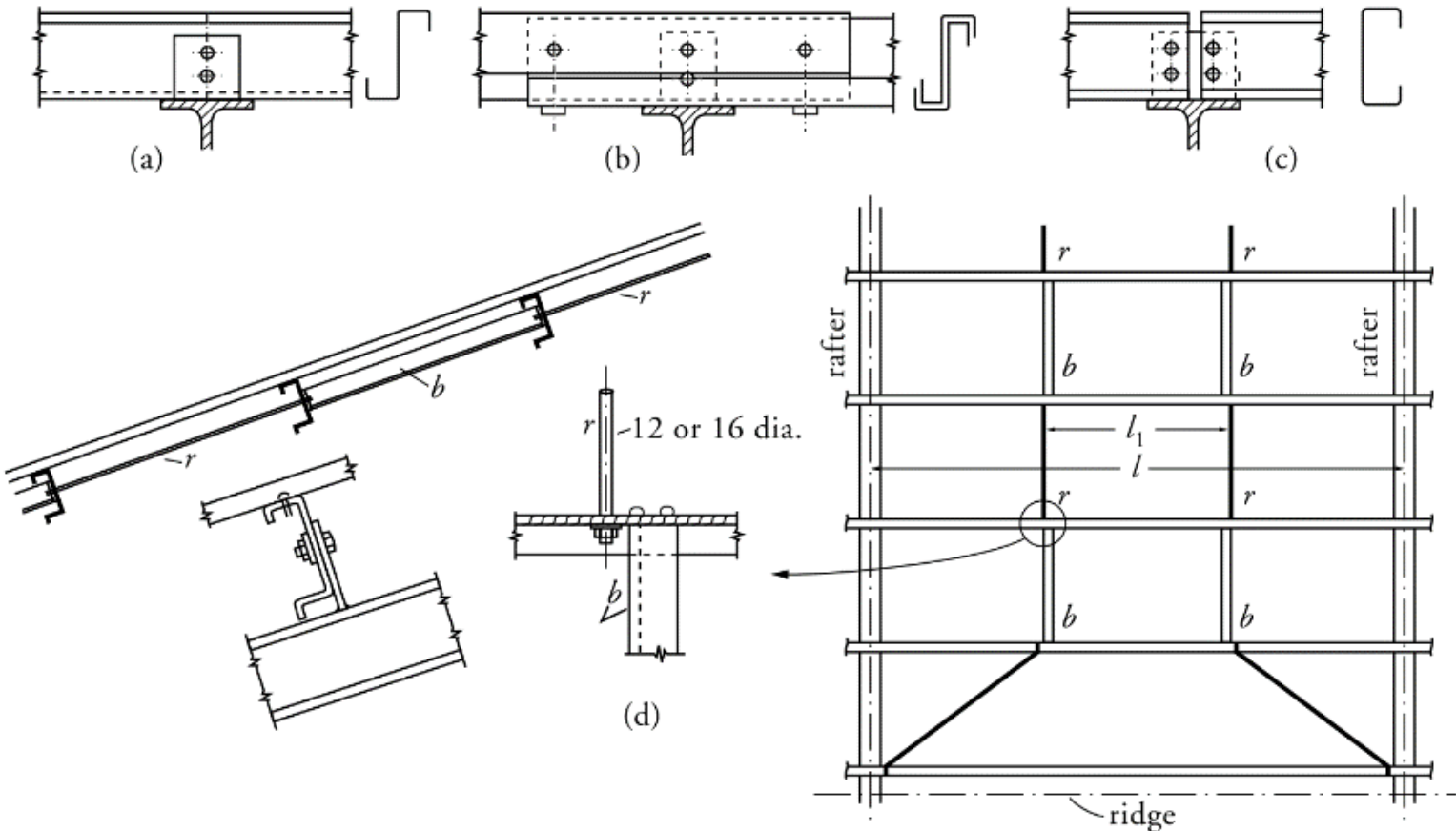
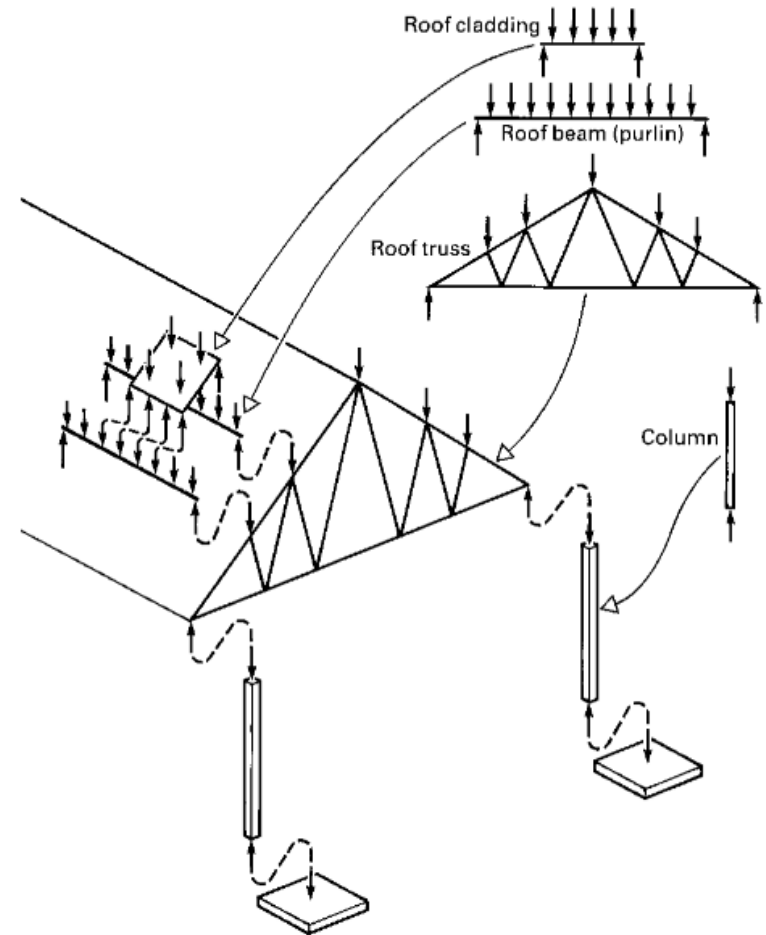
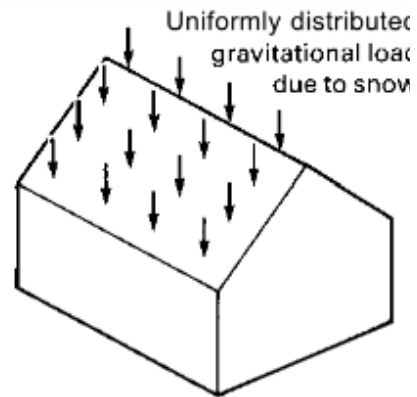
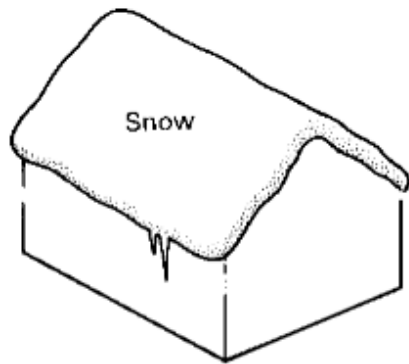


Figure 2.9 Roof purlin and tie-rod system. (a) Plan of roof frame. (b) Sag rods for roof purlins.

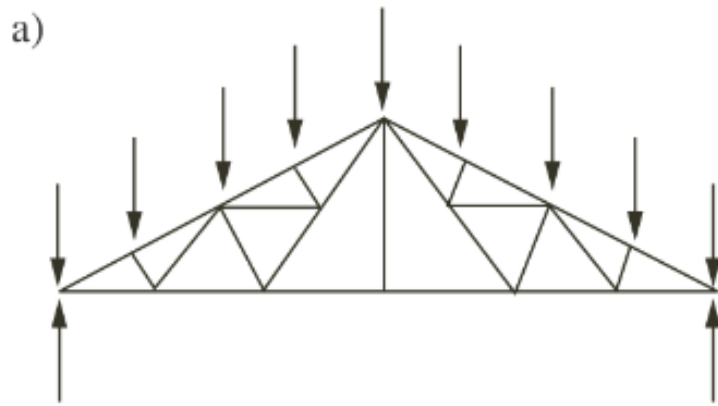
PURLINS



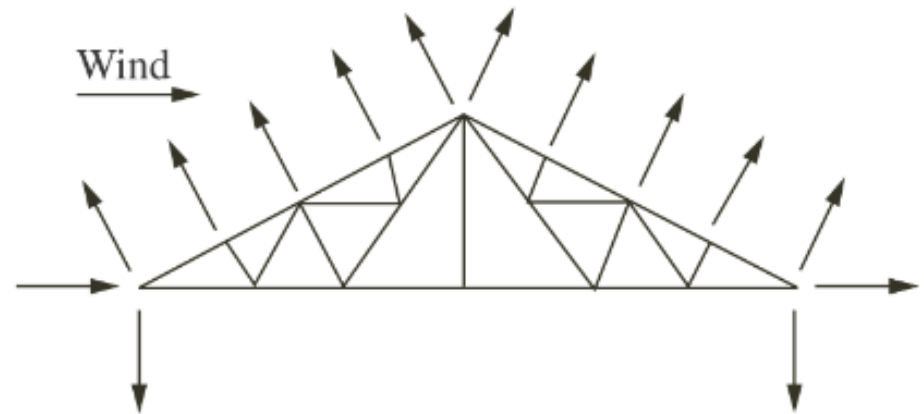
LOAD PATH



LOADS ON TRUSSES

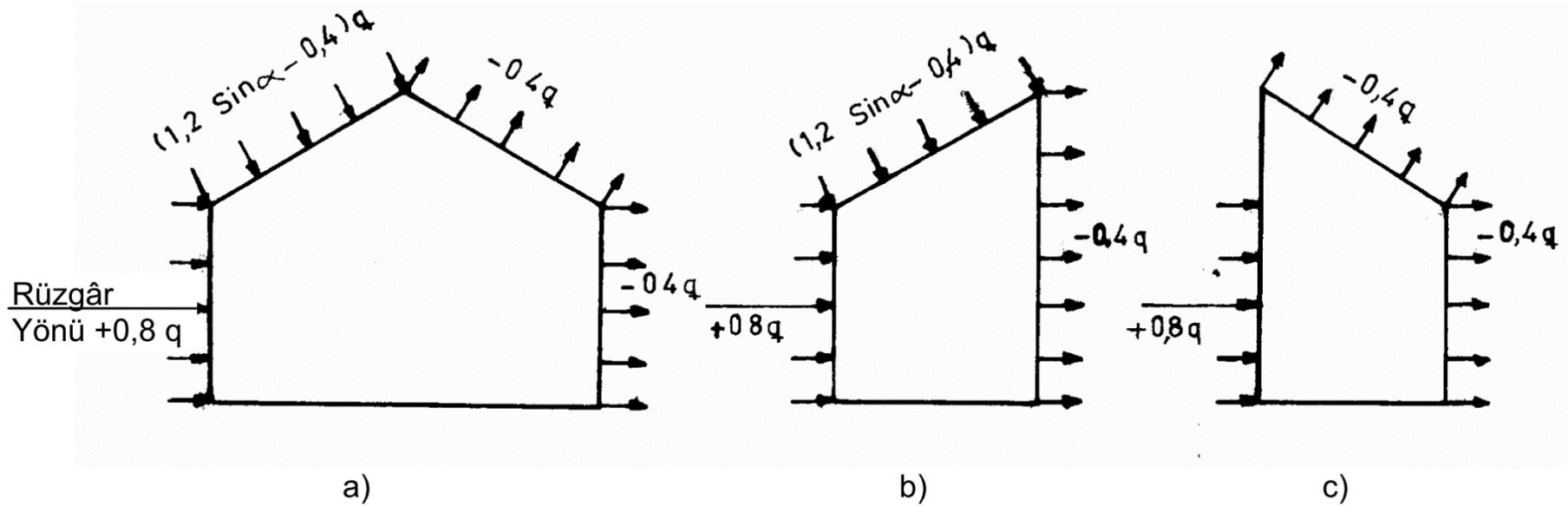


Dead and imposed loads



Wind load

WIND LOADS



LOAD COMBINATIONS

Load and Resistance Factor Design (LRFD)

$$1.2D + 1.6L + 0.5S$$

$$1.2D + 1.6S + 0.5W$$

$$1.2D + 1.0W + 0.5S$$

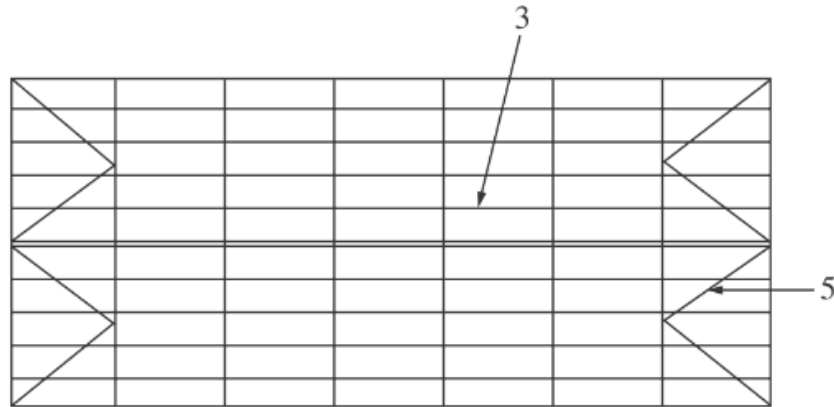
D: Dead Load

L: Live Load

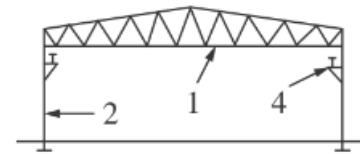
S: Snow Load

W: Wind Load

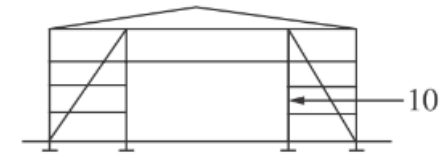
STABILITY OF THE STRUCTURE



Roof plan



Section



Gable framing

Building elements

- | | |
|------------------------------|-----------------------|
| 1 Lattice girder | 6 Lower chord bracing |
| 2 Column | 7 Wall bracing |
| 3 Purlins and sheeting rails | 8 Eaves tie |
| 4 Crane girder | 9 Ties |
| 5 Roof bracing | 10 Gable column |



Side elevation