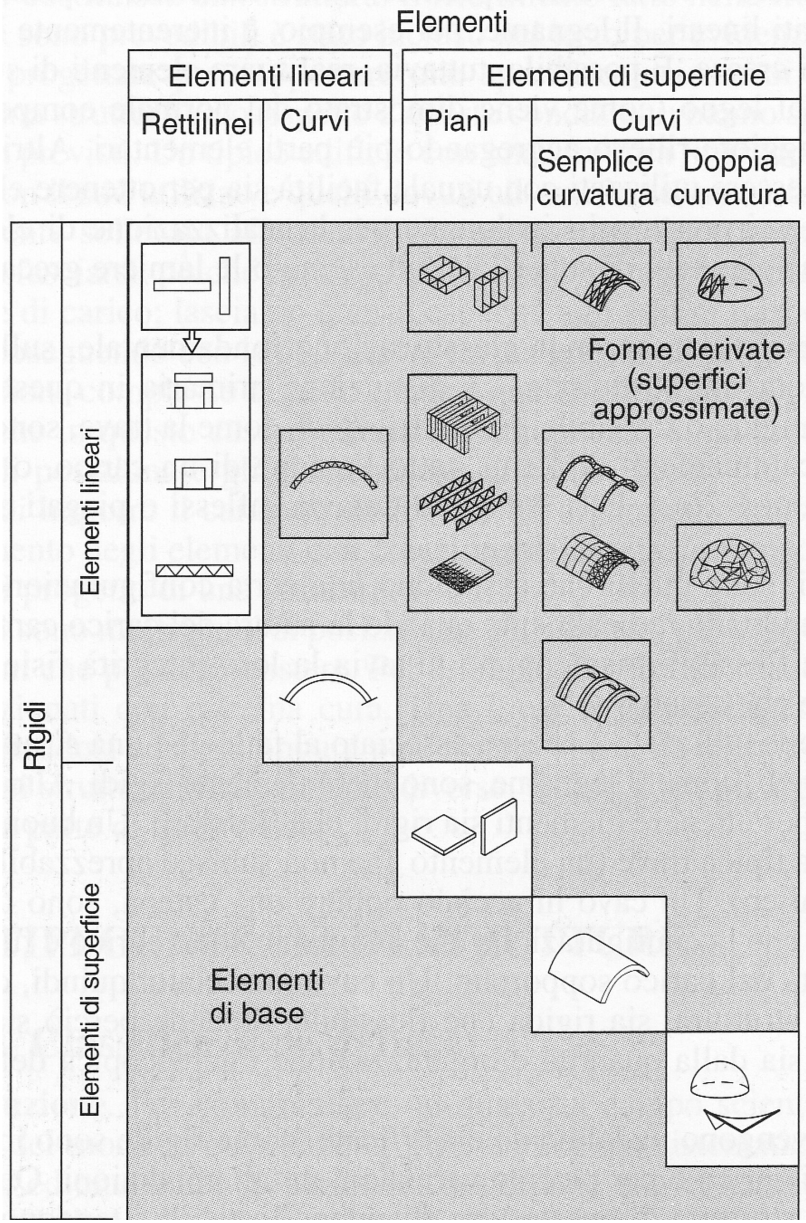
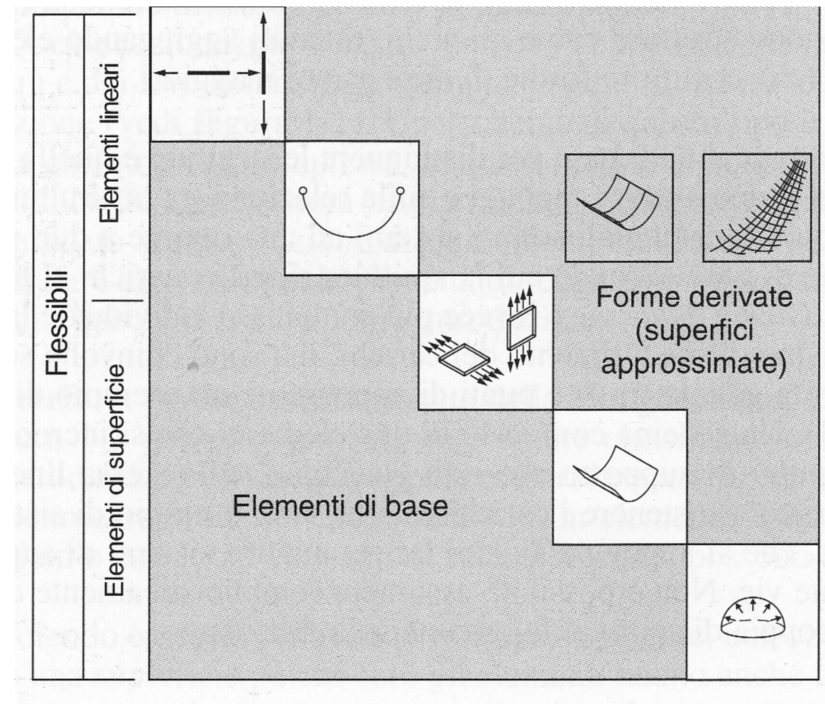
3 – Una panoramica sugli elementi strutturali

(Rev 02/2020)

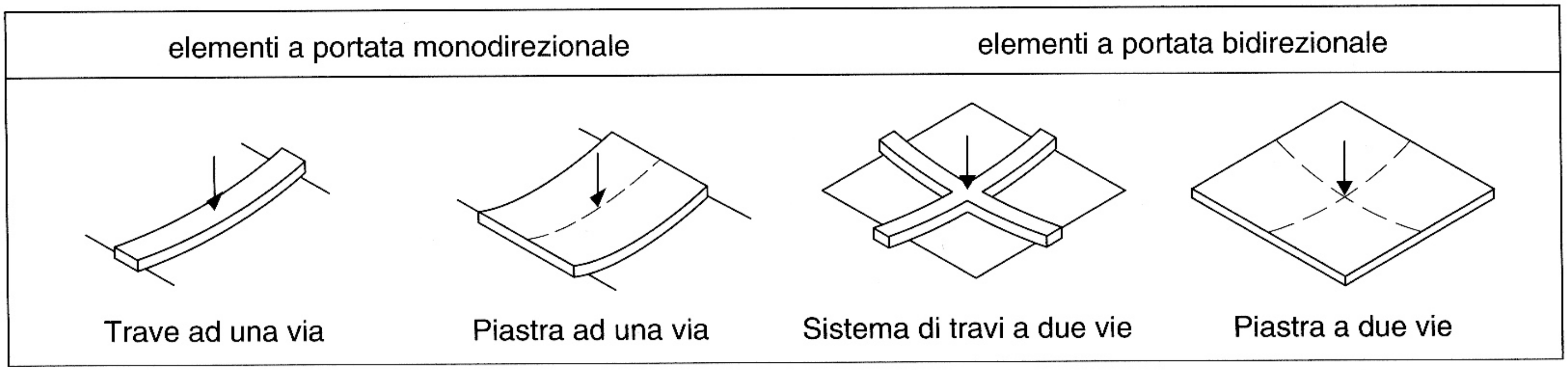
Le seguenti 'slides' costituiscono solo una base per lo sviluppo delle lezioni e, pertanto, non sostituiscono i testi consigliati

Classificazione

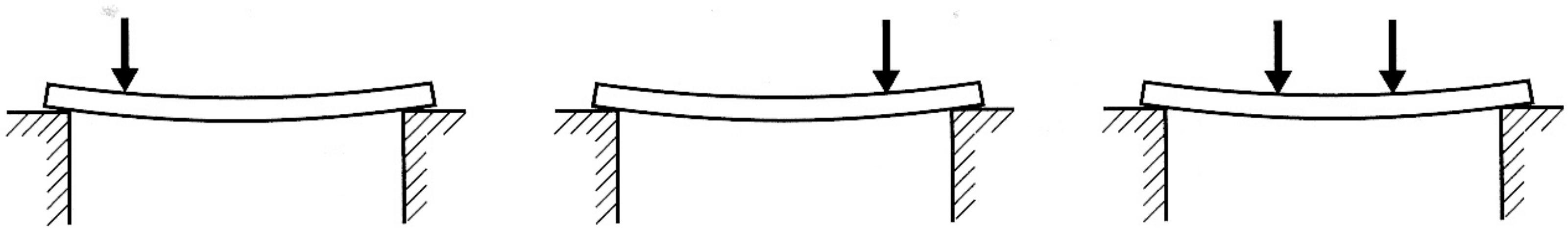




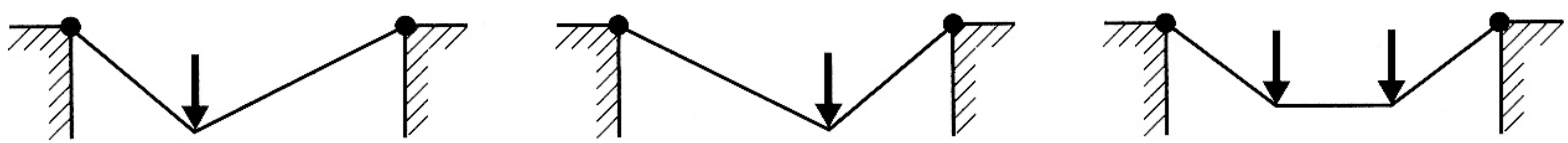
Strutture a una e due vie



Strutture rigide e deformabili

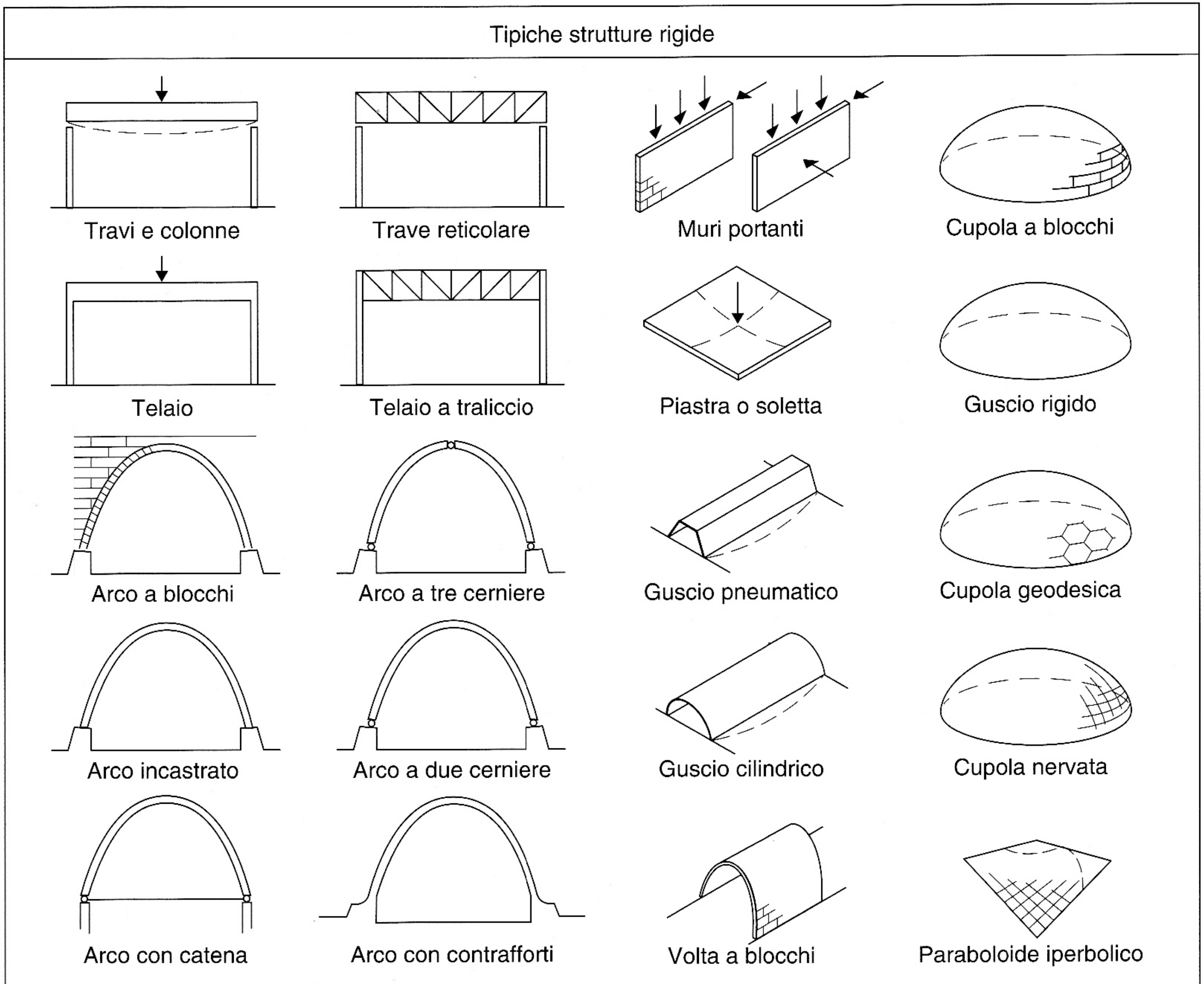


(a) Struttura rigida (ad es. una trave). La struttura è rigida e non subisce cambiamenti apprezzabili di forma in corrispondenza a variazioni della condizione di carico.

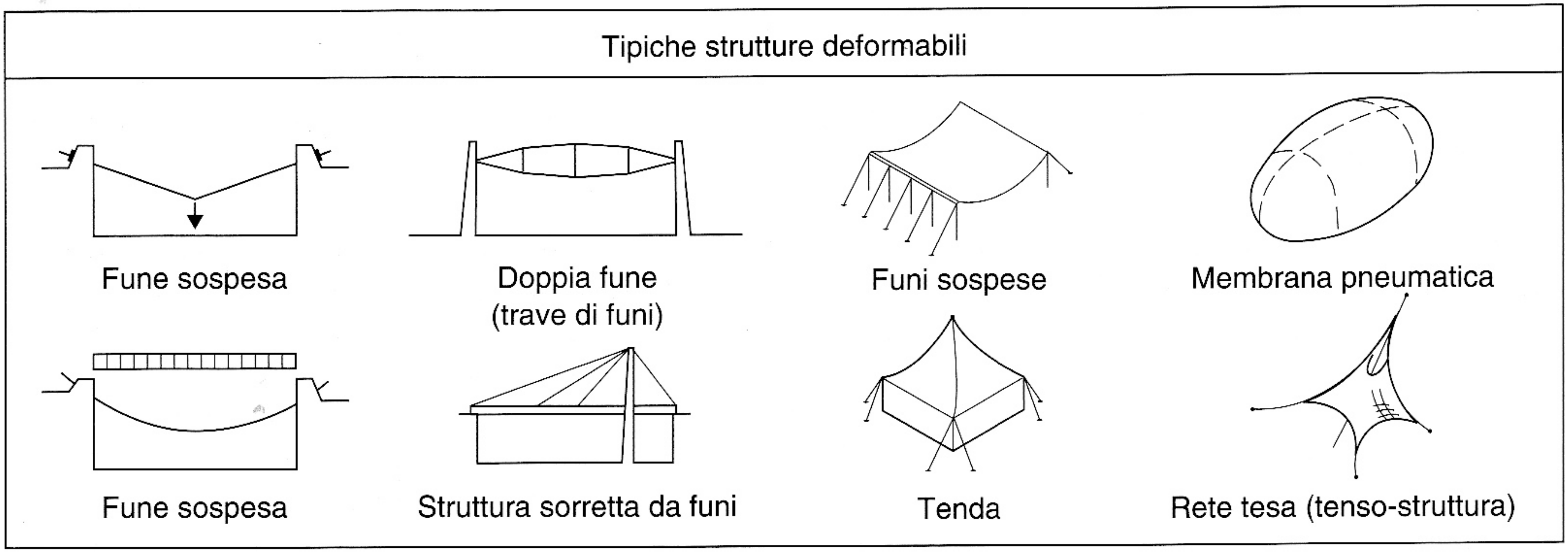


(b) Struttura non rigida o deformabile (ad es. una fune). La forma della struttura cambia al variare della condizione di carico.

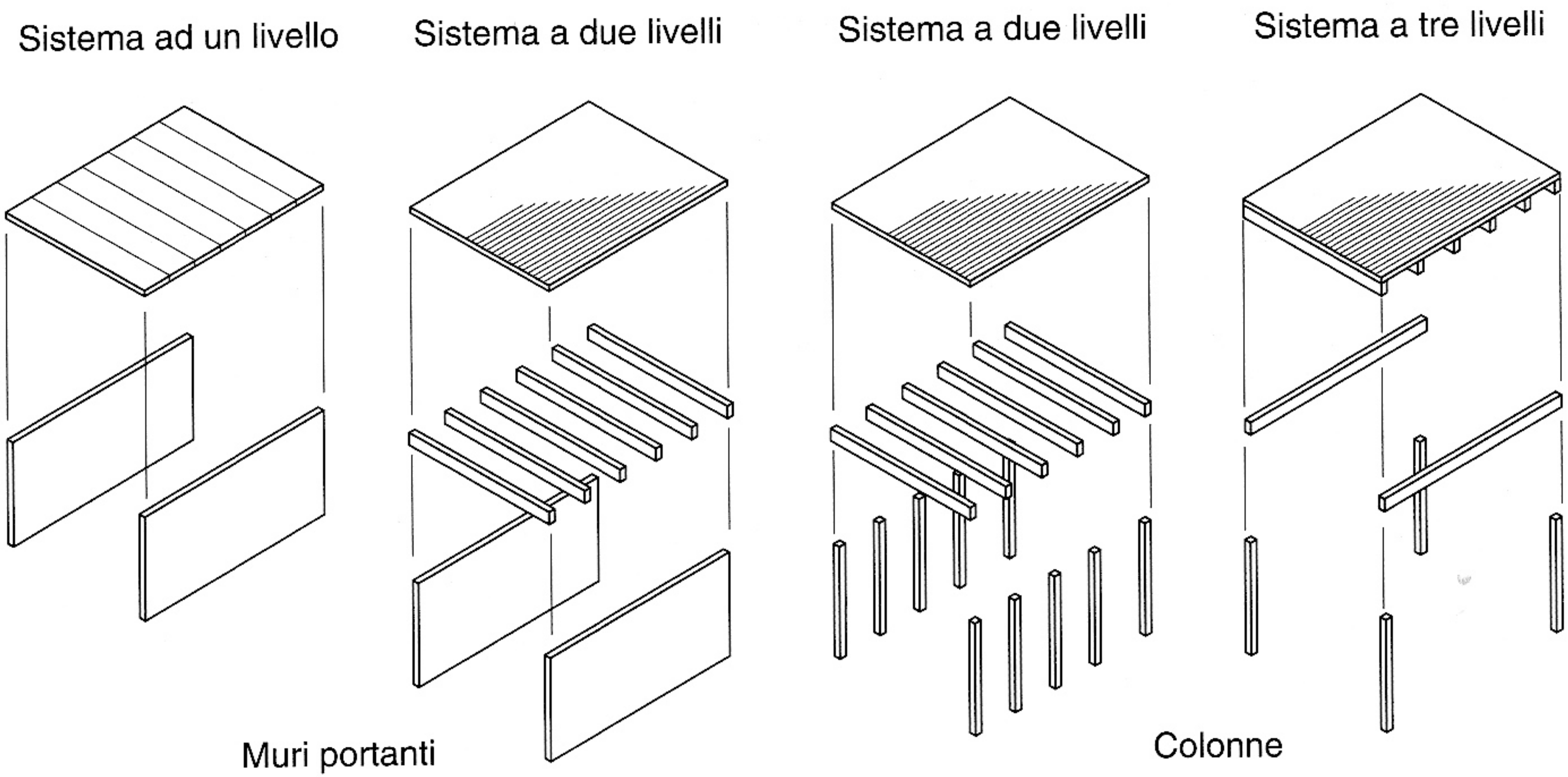
Tipi di elementi strutturali (strutture rigide)



Tipi di elementi strutturali (strutture deformabili) 2/2

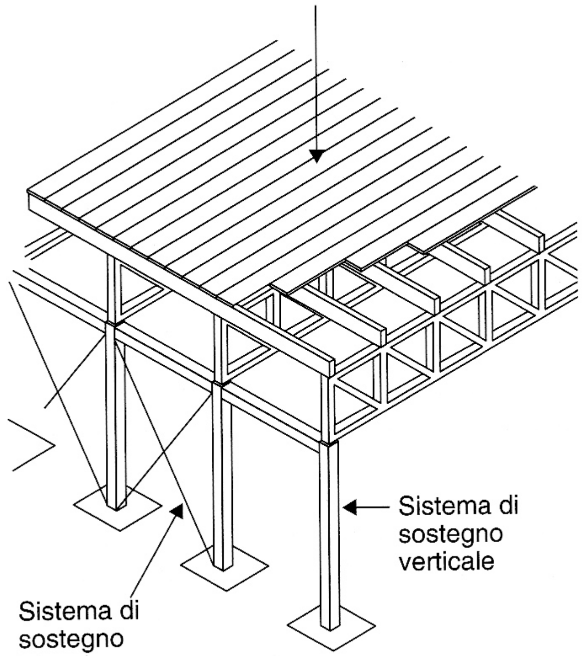


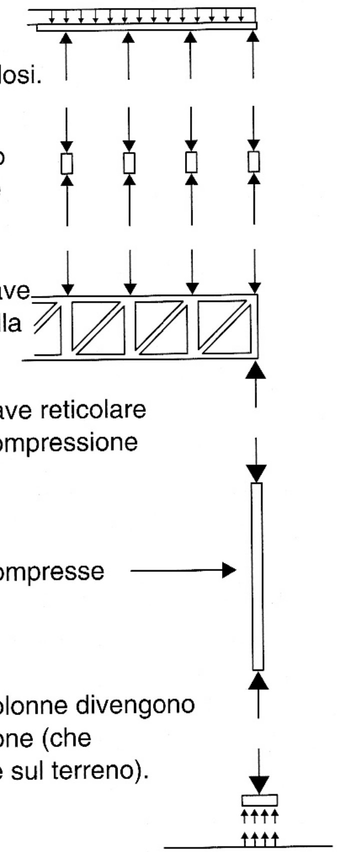
Unità strutturali primarie e loro aggregazioni



(a) Tipi comuni di sistemi di copertura (sistemi a uno, due e tre livelli) utilizzati in relazione a diversi tipi di sistemi portanti verticali con muri e colonne.

Unità strutturali primarie e loro aggregazioni

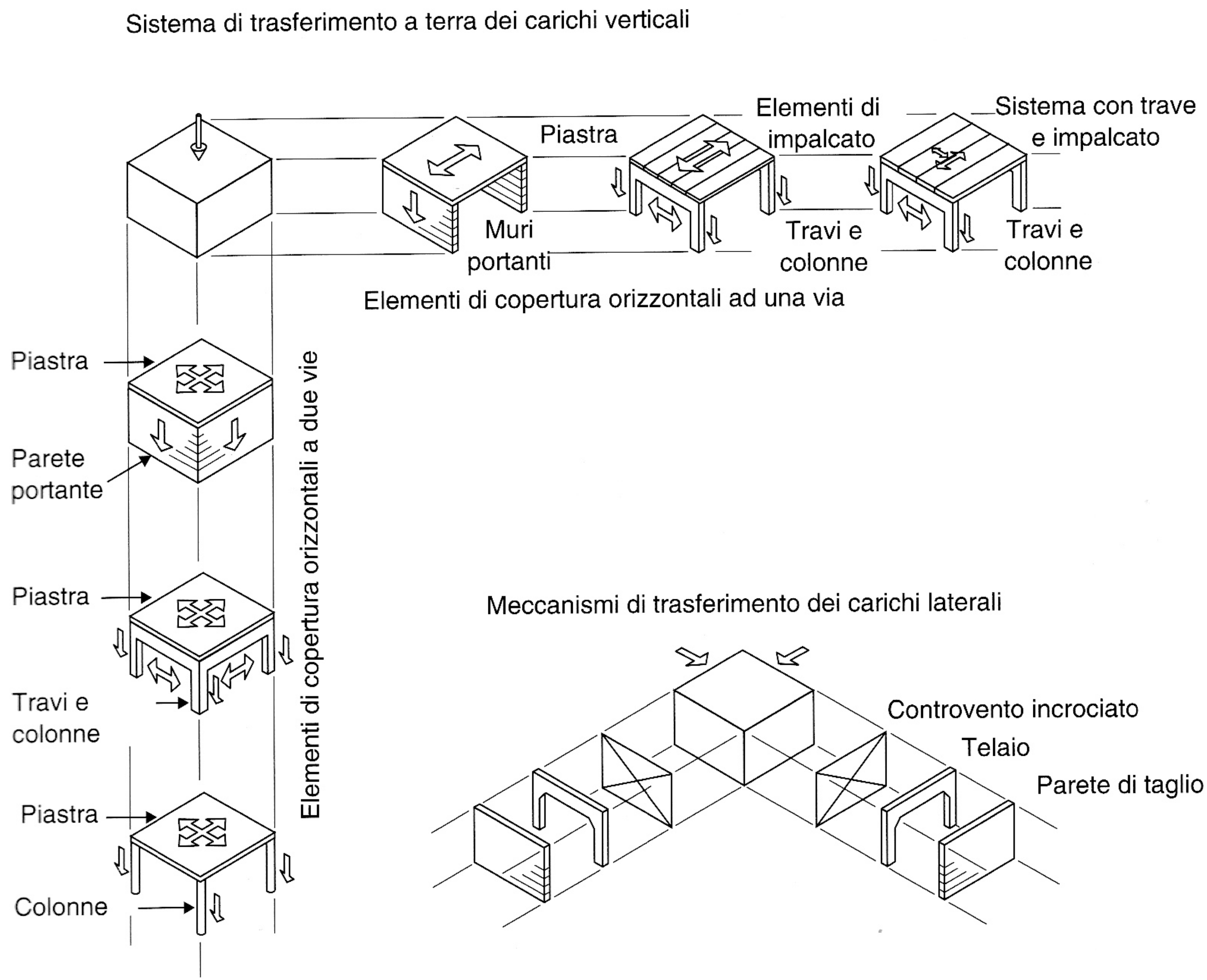




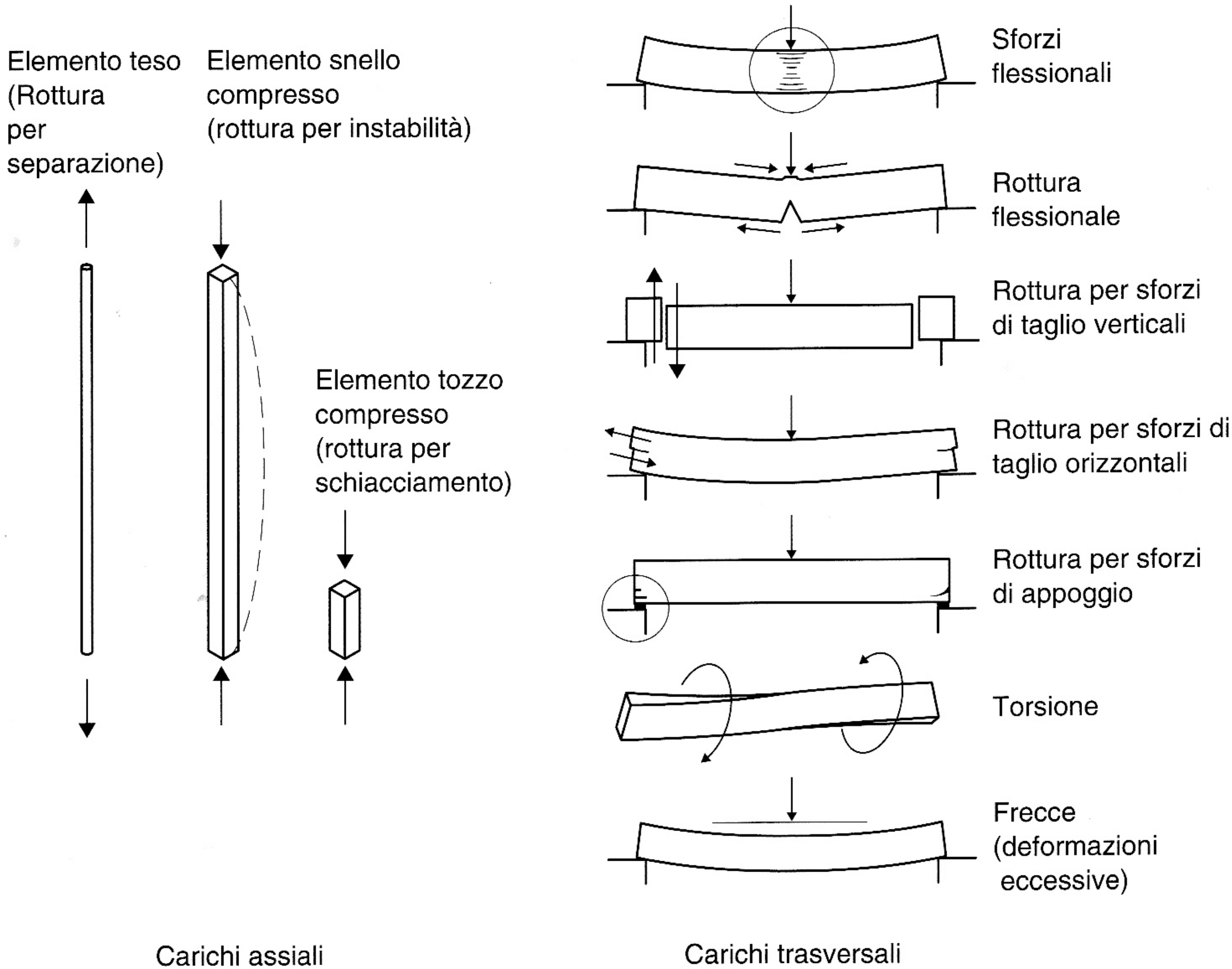
(b) Assemblaggio di elementi. Il sistema dell'impalcato, formante una superficie, viene sorretto da un sistema secondario consistente in travi ravvicinate, a sua volta sorretto da una sistema primario di travi reticolari a spaziatura maggiore. Tra le travi reticolari e le colonne che le sostengono esiste una corrispondenza uno-ad-uno.

(c) L'impalcato trasferisce i carichi del tetto al sistema di travi secondarie. Le travi secondarie trasferiscono carichi alle travi reticolari, queste a loro volta li riportano alle colonne. Le colonne trasmettono i carichi alle fondazioni. Questo trasferimento di forze avviene attraverso lo sviluppo di forze di reazione tra gli elementi che divengono sempre maggiori al diminuire del livello.

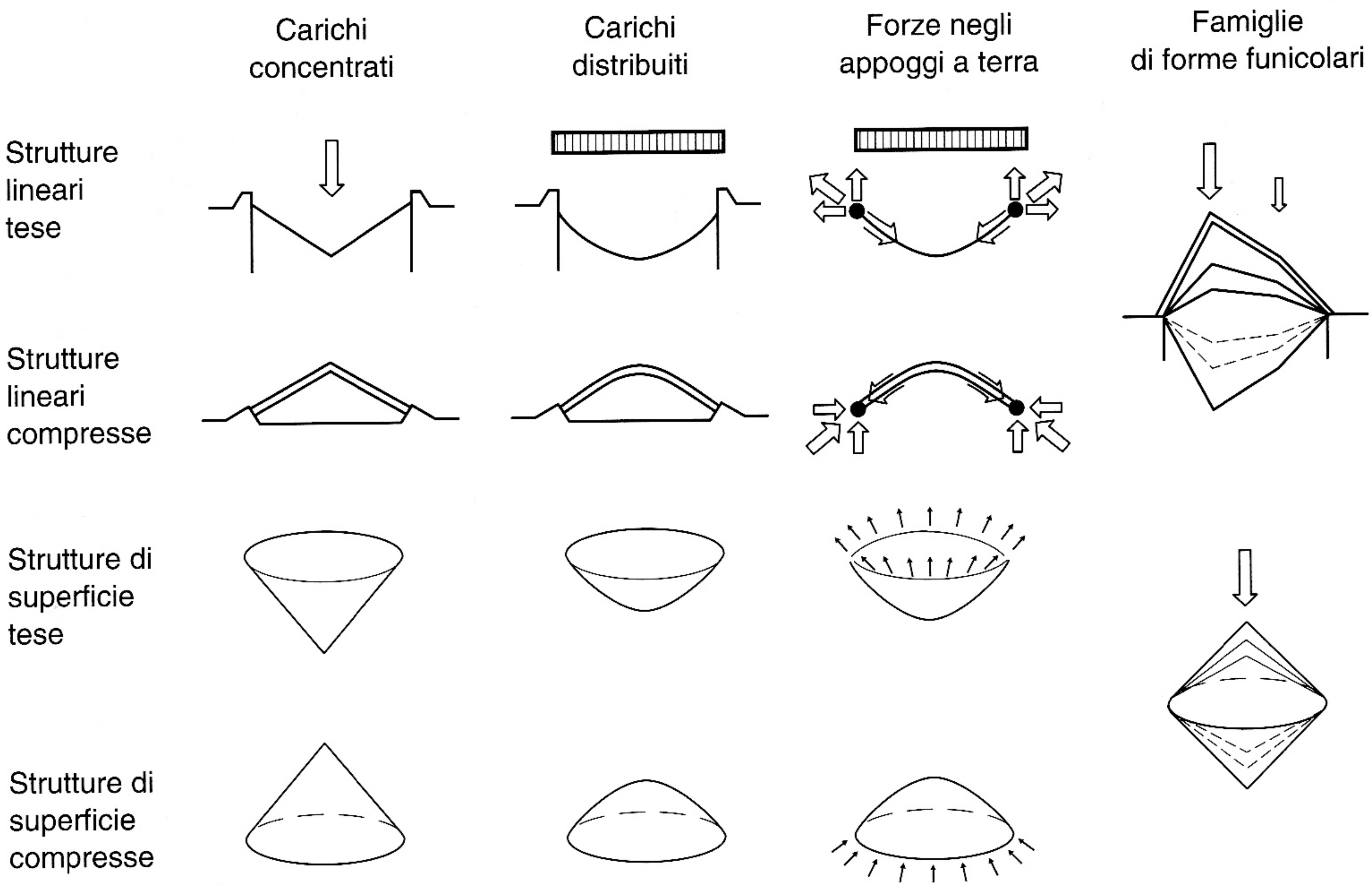
Soluzioni strutturali comuni



Tipiche rotture di elementi strutturali

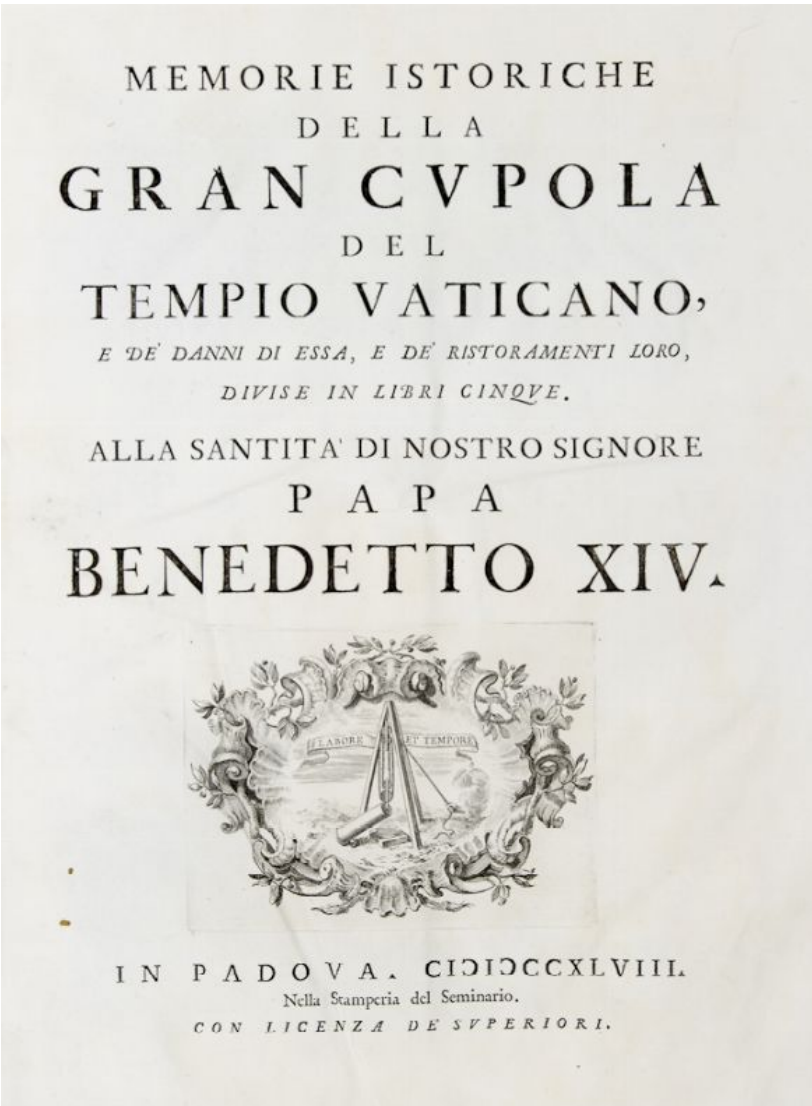


Strutture funicolari



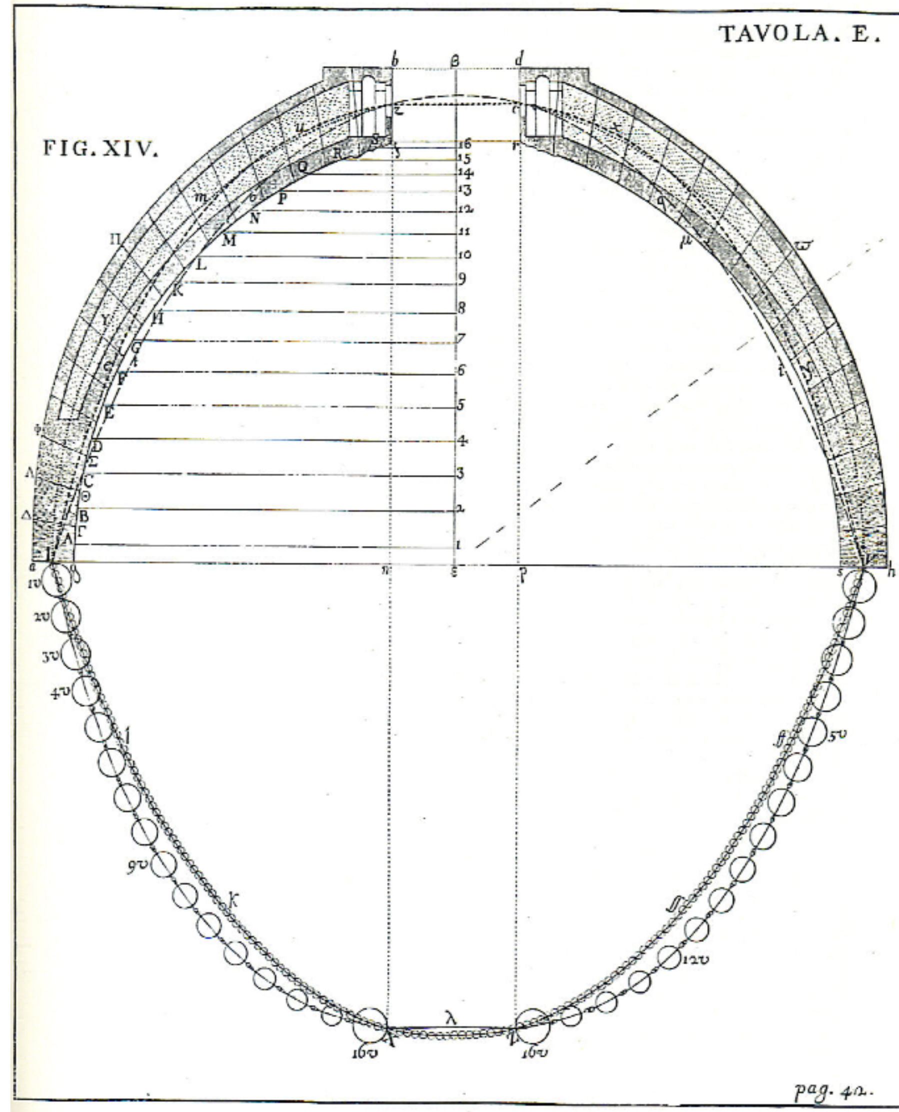
Strutture funicolari 2/2

Giovanni Poleni 1748



MEMORIE ISTORICHE
DELLA
GRAN CVPOLA
DEL
TEMPIO VATICANO,
E DE' DANNI DI ESSA, E DE' RISTORAMENTI LORO,
DIVISE IN LIBRI CINQVE.
ALLA SANTITA' DI NOSTRO SIGNORE
PAPA
BENEDETTO XIV.

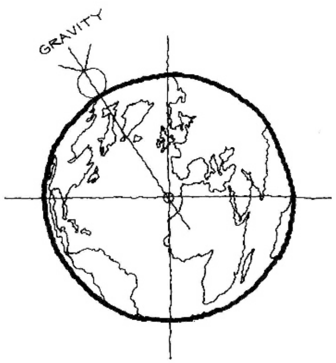
IN PADOVA. CIↃIↃCCXLVIII.
Nella Stamperia del Seminario.
CON LICENZA DE' SVPERIORI.

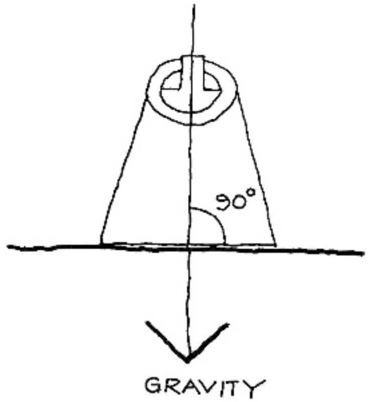


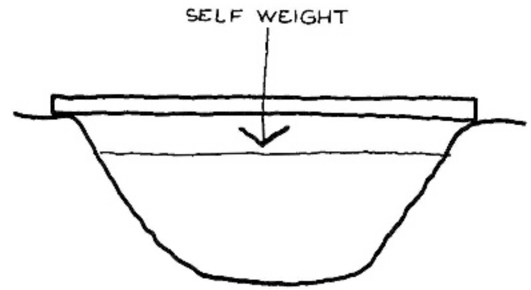
4 – Tipi di carichi

(Rev 02/2020)

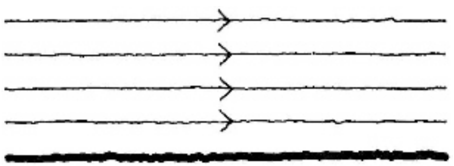
Self weight (gravity load)

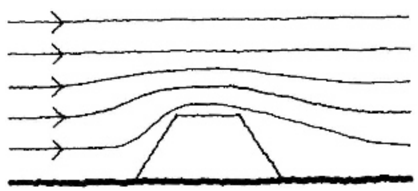


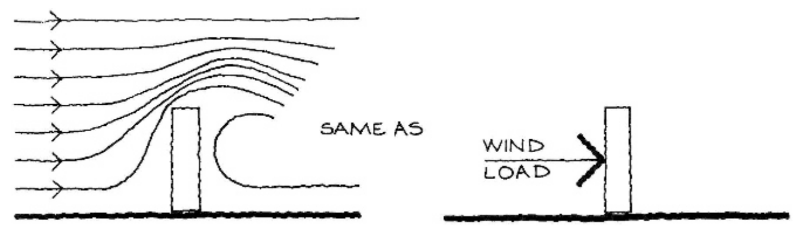


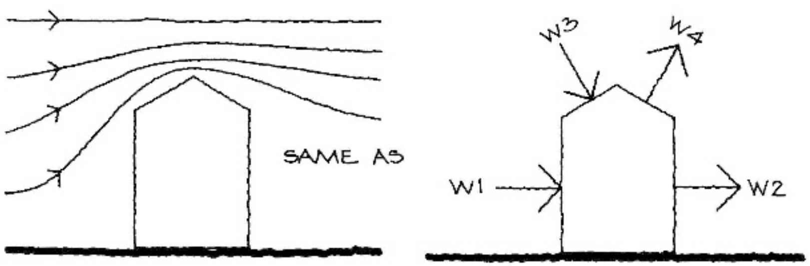


Wind load



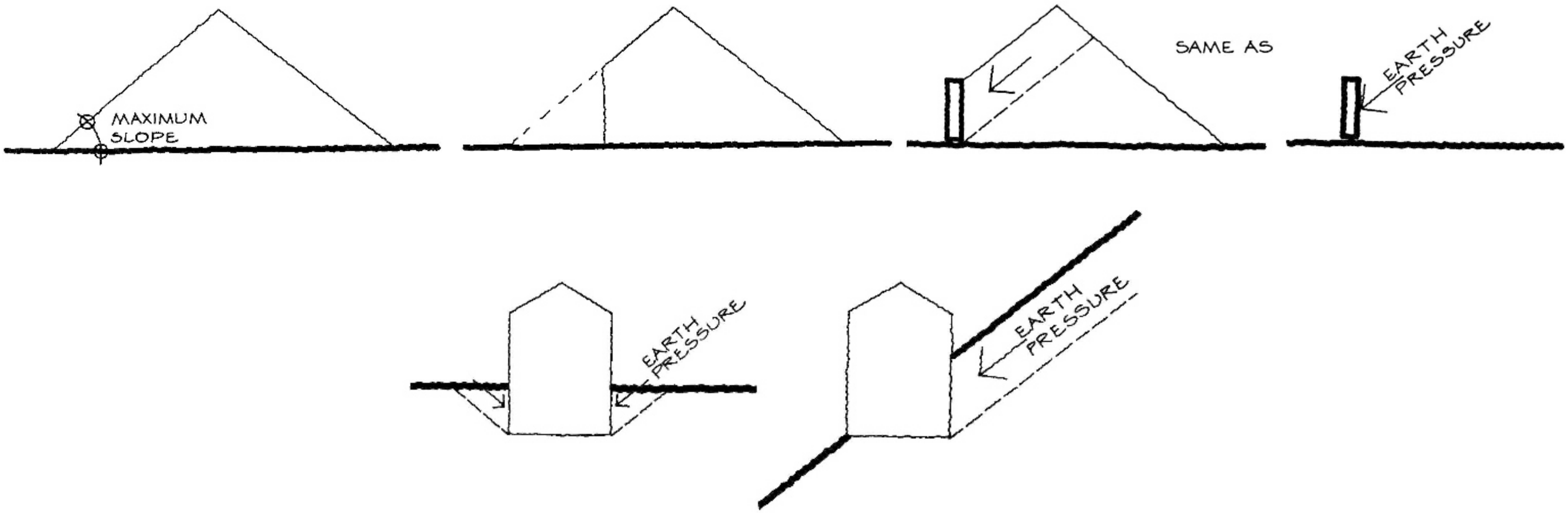




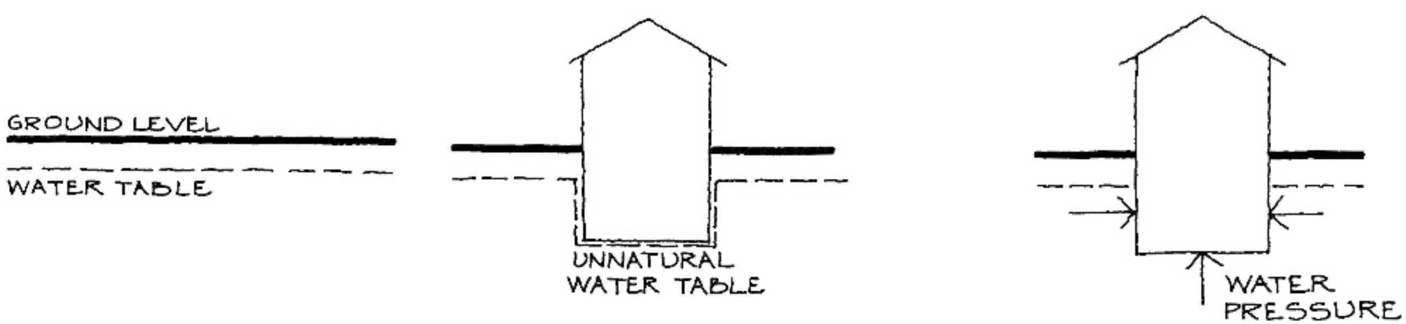


Natural loads

Earth pressure

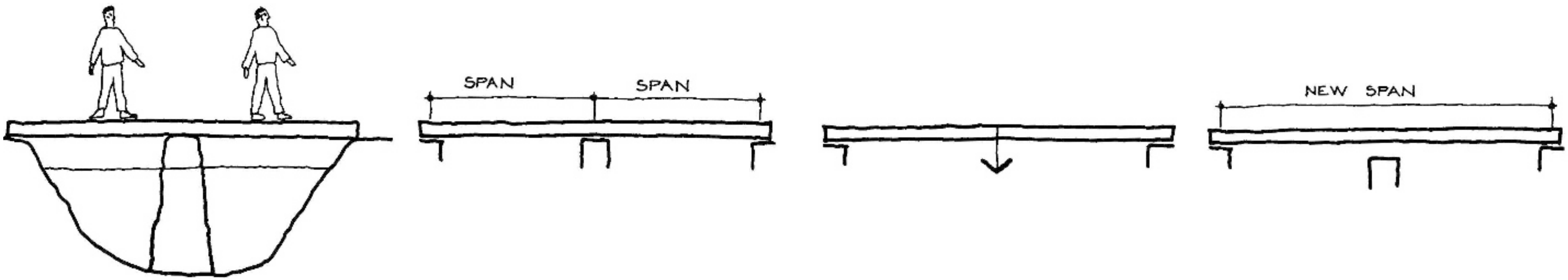


Water pressure

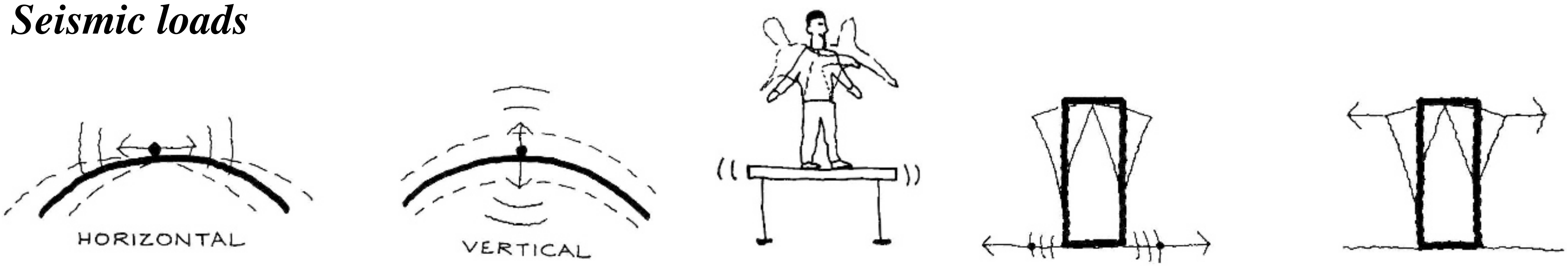


Natural loads

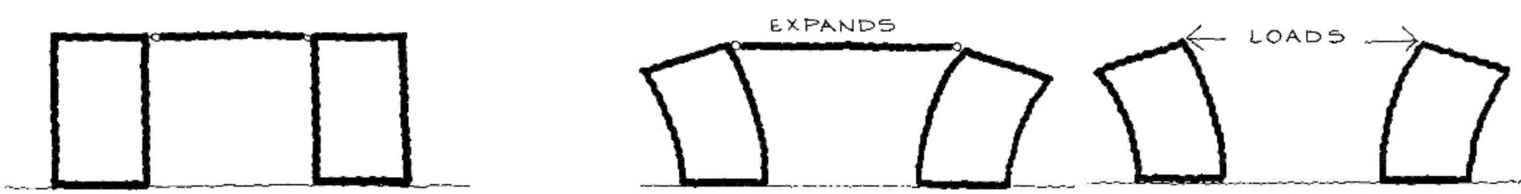
Ground movements (constraint failure)



Seismic loads

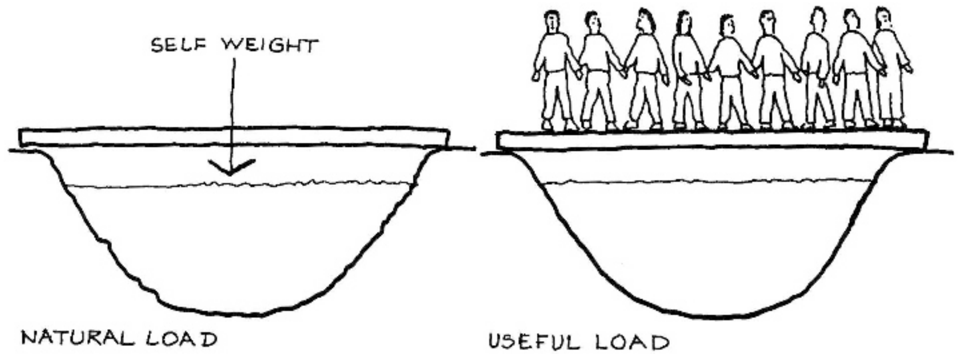


Temperature variation

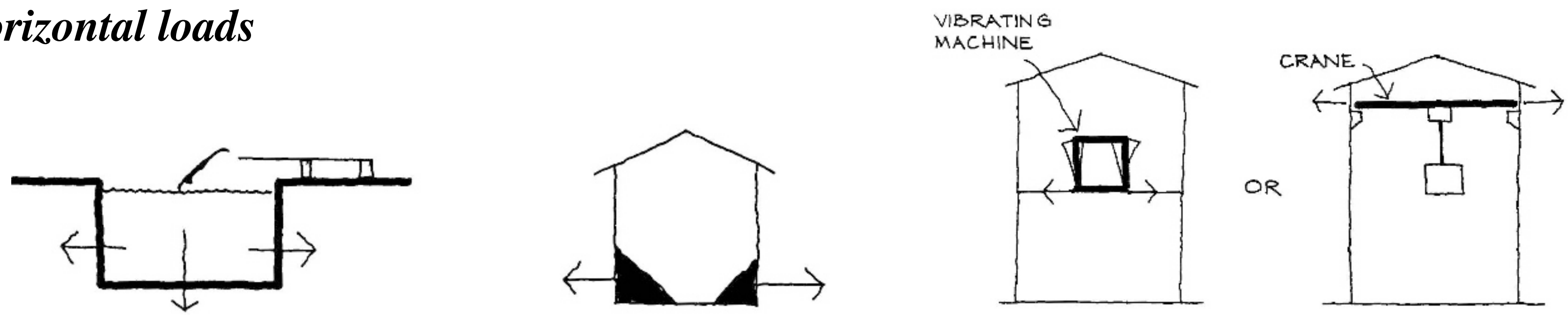


Useful loads

Vertical loads

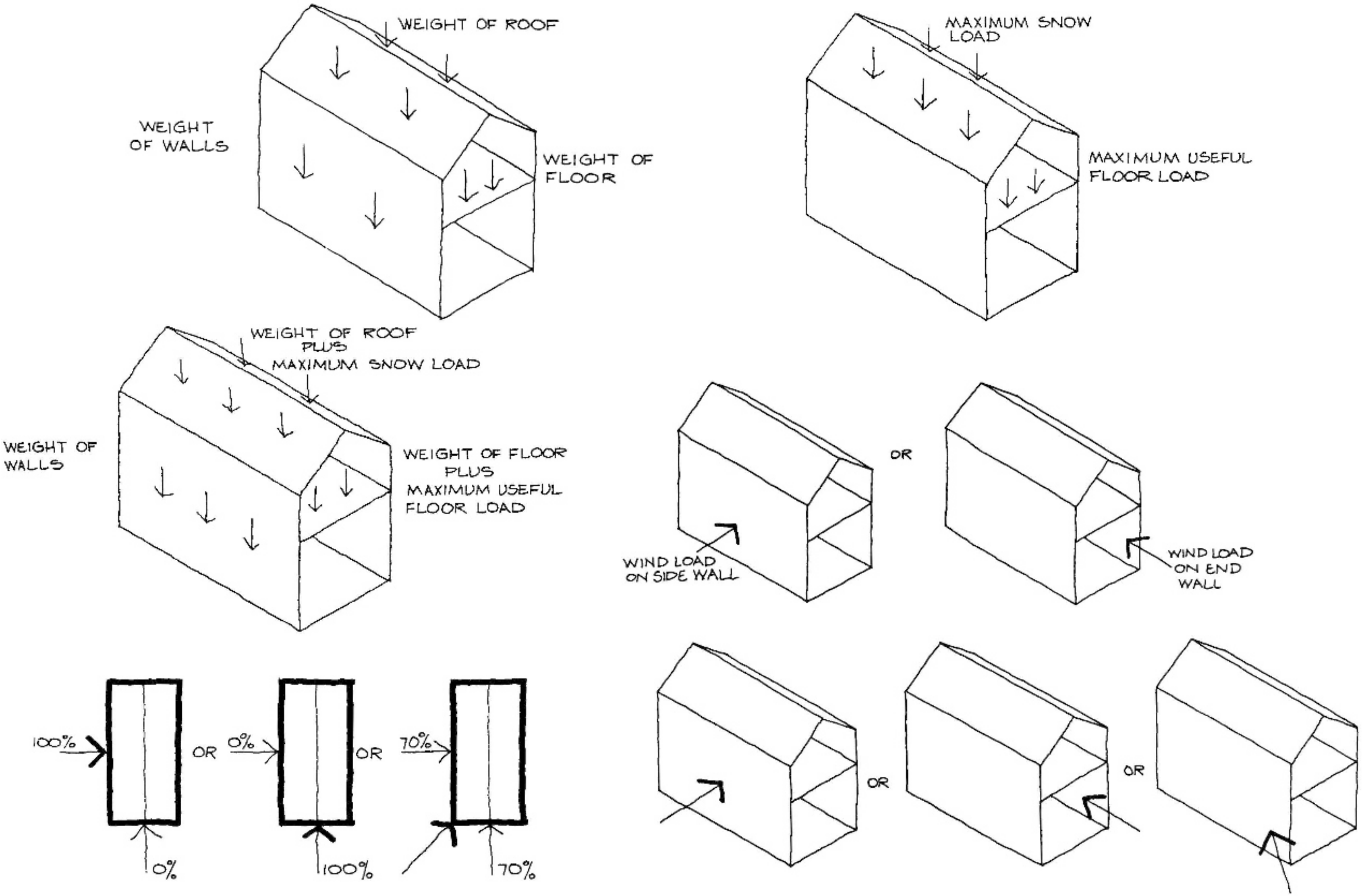


Horizontal loads



Load combinations

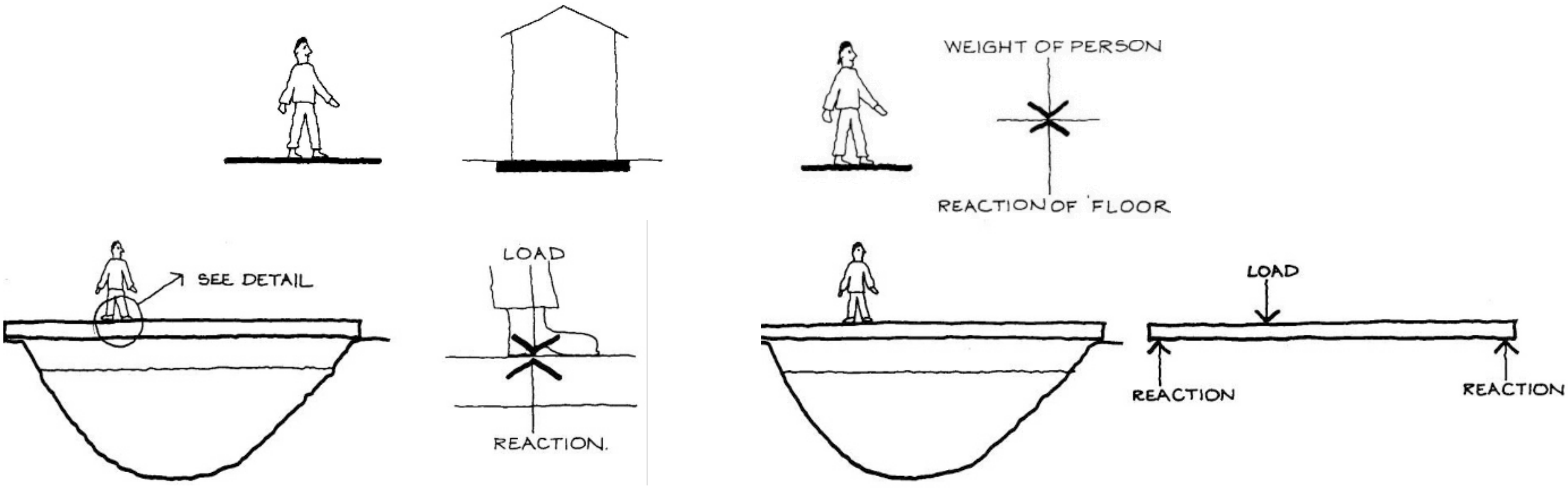
Load combinations (worst load case)



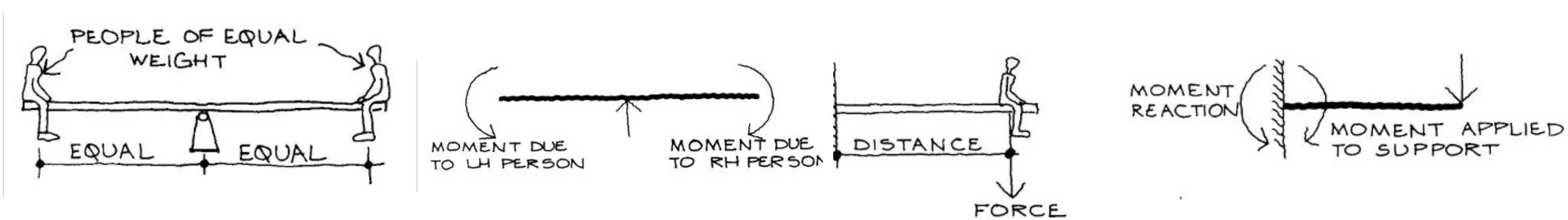
Reaction loads

Third Newton's law: to every action there is always an equal and opposite reaction

Vertical reactions

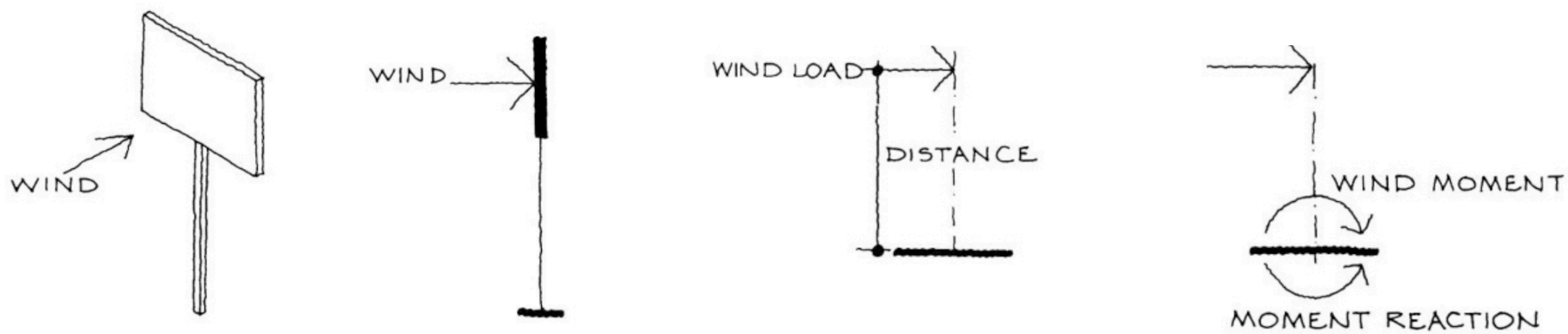


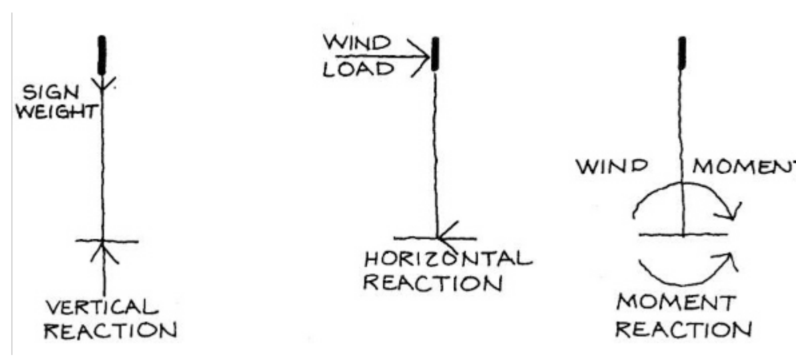
Moment reactions *(a moment is a force times a distance)*



Reaction loads

Moment reactions

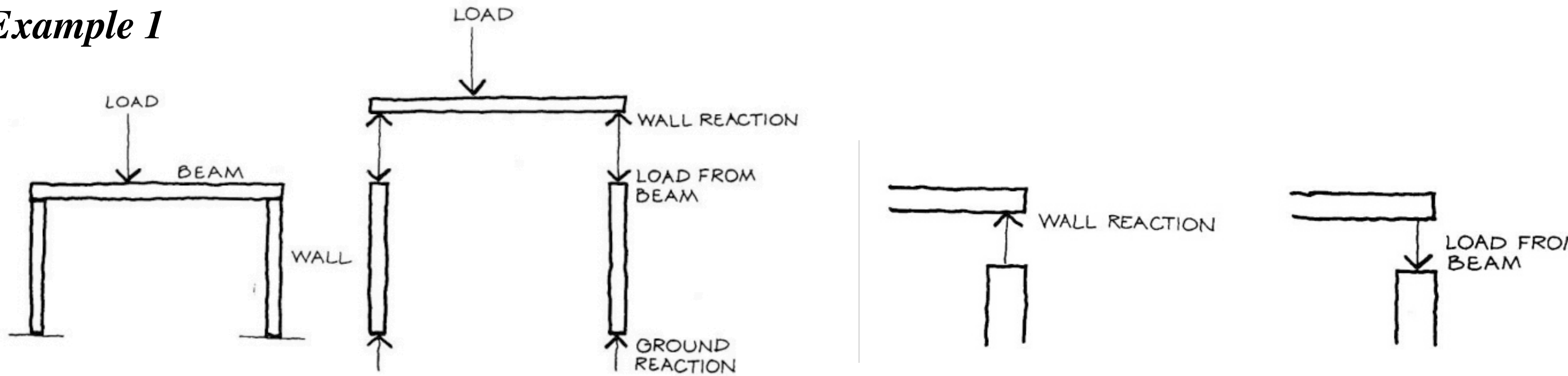




Load paths 1/2

The load path is basically a sequence of loads and reactions between structural elements.

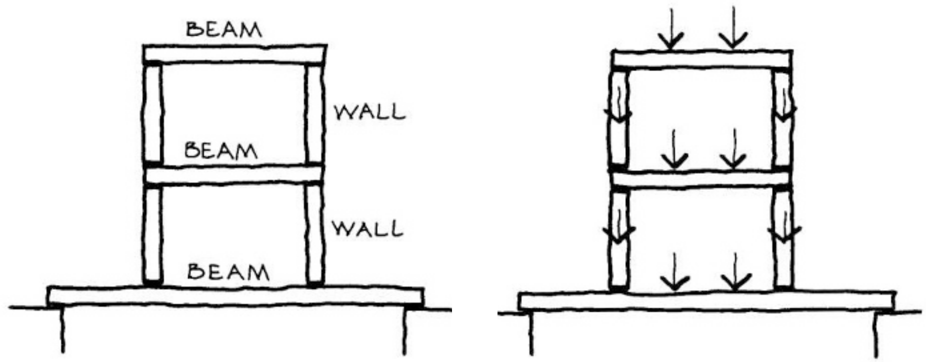
Example 1

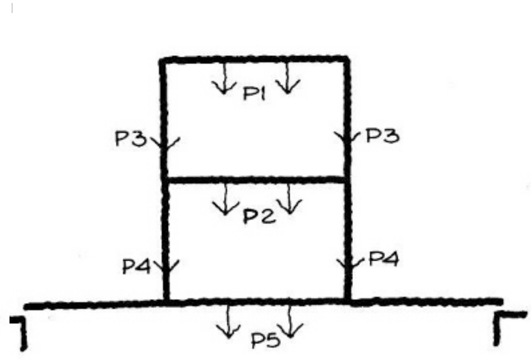


The important point here is one element's reaction to the next element's load. For the simple example of a beam on two walls, the reactions of the beam *cause* loads on the walls.

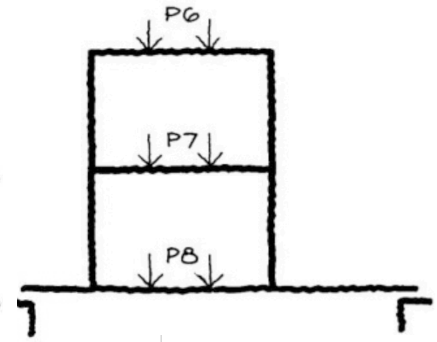
Load paths

Example 2

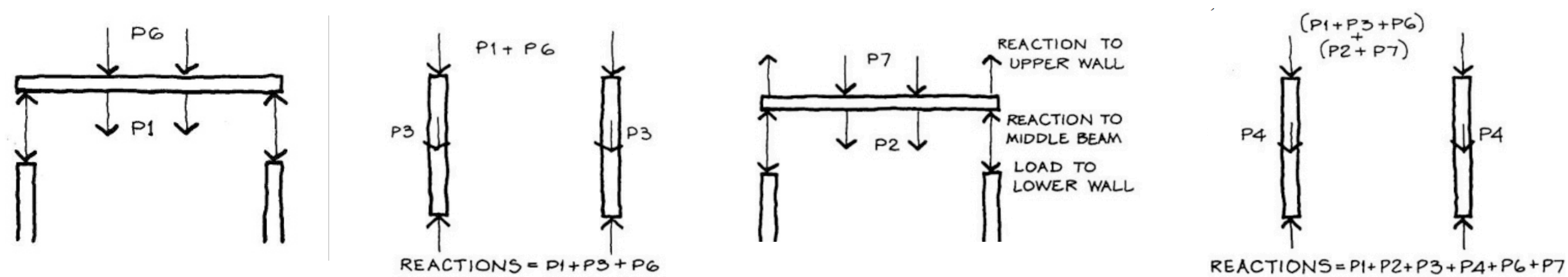


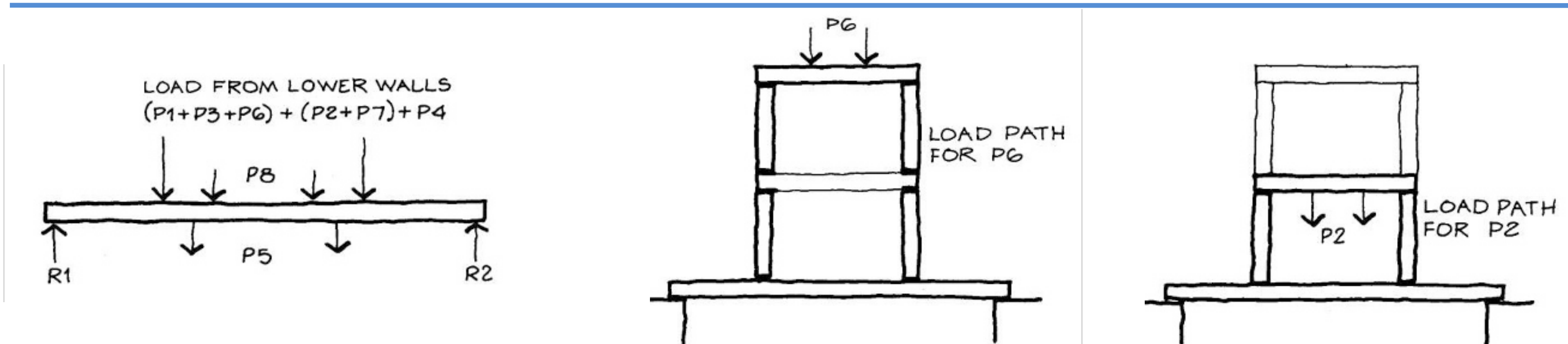


Self weight



Useful weight





5 – Forze interne

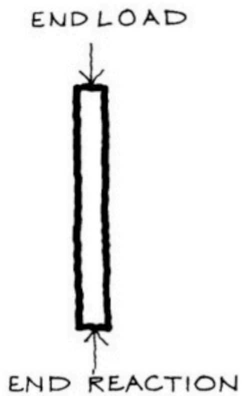
(Rev 02/2020)

Le seguenti ‘slides’ costituiscono solo una base per lo sviluppo delle lezioni e, pertanto, non sostituiscono i testi consigliati

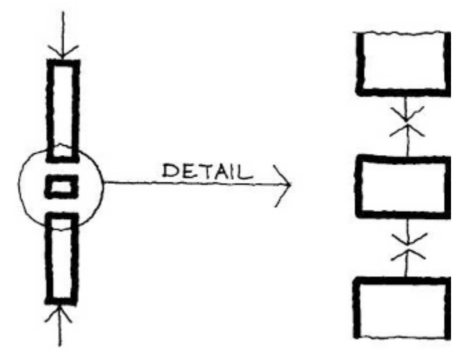
Internal forces

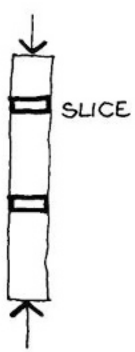
The structure transfers loads by **forces** that are **in the structure** and these forces cause **stresses** in the structural material. The structure also deforms under the effect of the loads, and the size of the deformation depends on the **stiffness** of the structure.

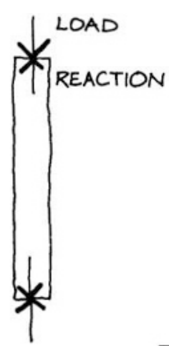
Axial forces = forces that stretch or compress elements in the direction of their longitudinal axis



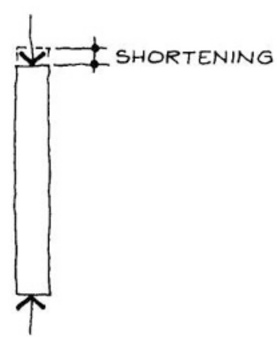
What happens to a typical slice of the column?



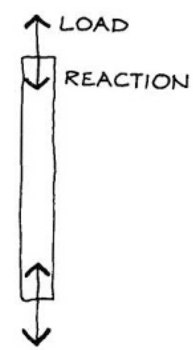




All slices are compressed and the column **is compression**



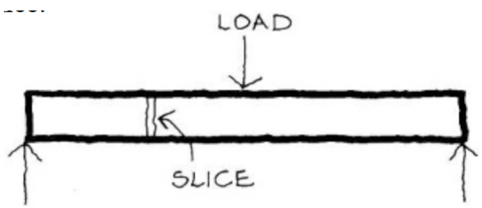
The column deforms by **shortening**

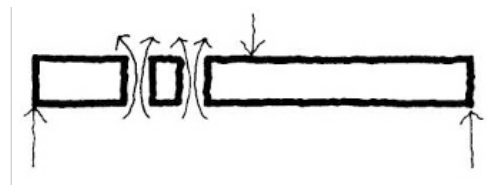


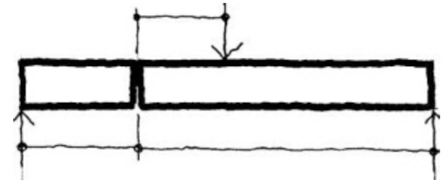
If the direction of the load is reversed, the column is **in tension**

Bending moments and shear forces

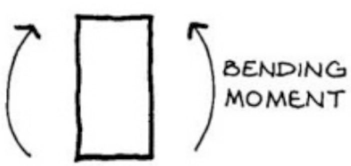
Beams transfer loads to supports by a combination of bending moments and shear forces. Although bending moments and shear forces act together, conceptually they can be considered separately. To understand what is happening to the beam it helps to see what happens to a slice. Each side of the slice is being bent by a moment.



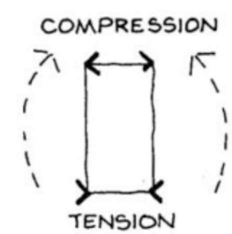


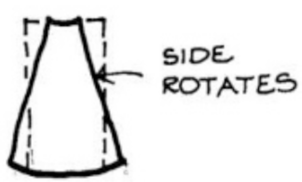


Moment = forces multiplied their distance from the slice

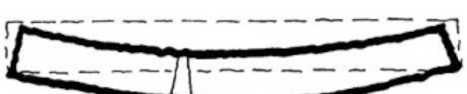


A pair of bending moments is bending the slice. This causes the slice to be compressed at the top and stretched at the bottom: the **top** of the beam is in **compression** and the **bottom** in **tension**.





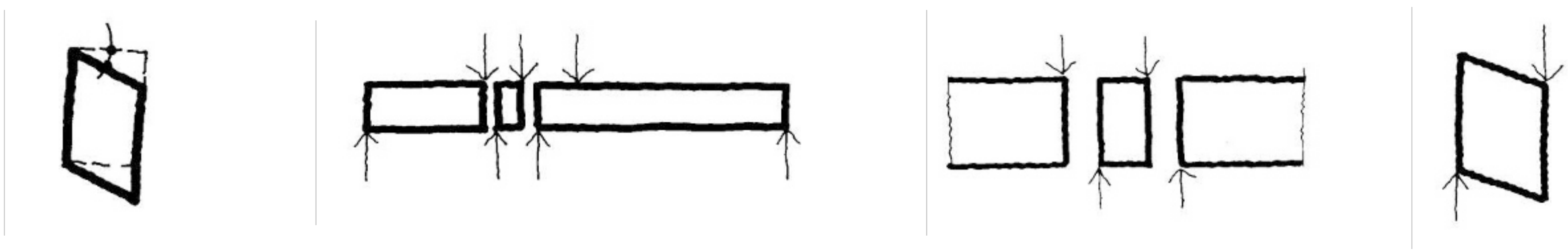
Because the top is in compression it **shortens**, and because the bottom is in tension it **lengthens**. These effects cause the sides to **rotate**.



Because each slice changes shape, the beam takes up a bent shape.

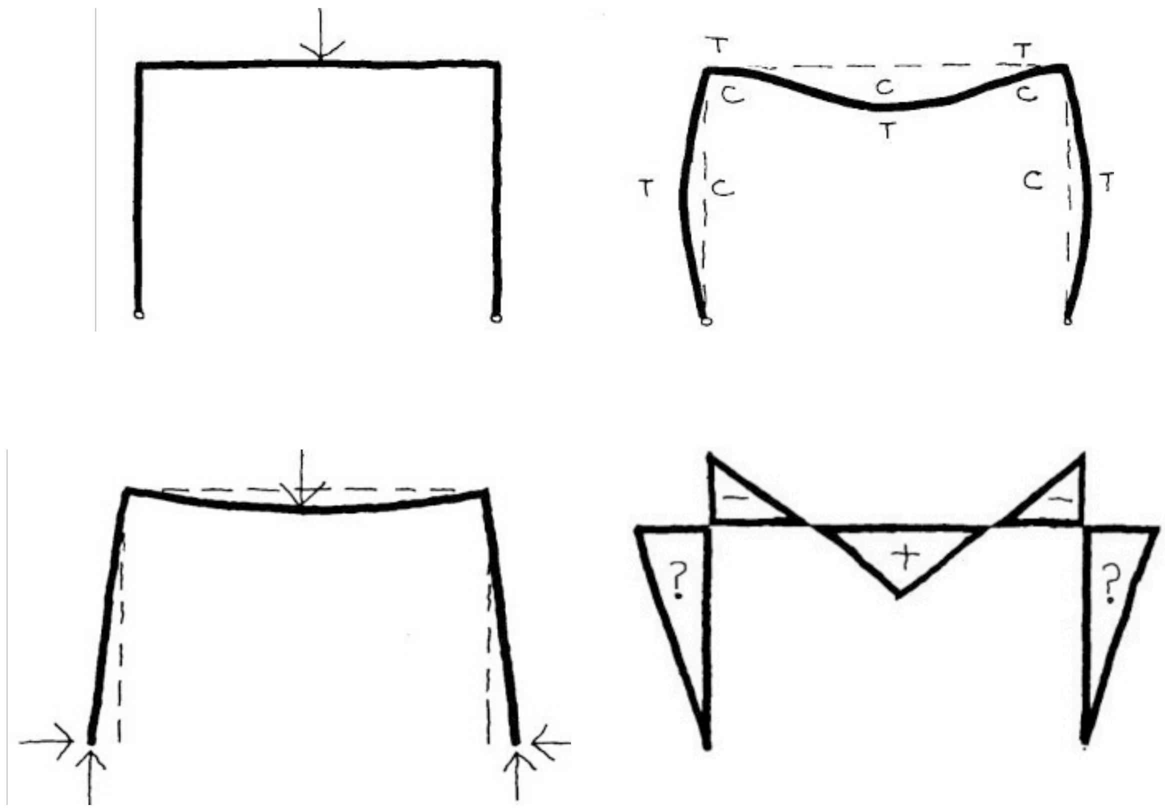
Bending moments and shear forces

Bending moments in a beam resist the effects of the moments caused by external loads, and reactions acting at different distances from each other. Bending moments do not resist the vertical effect of loads on beams; shear forces resist these. When a rectangle is distorted by an angular change into a parallelogram, it is sheared.

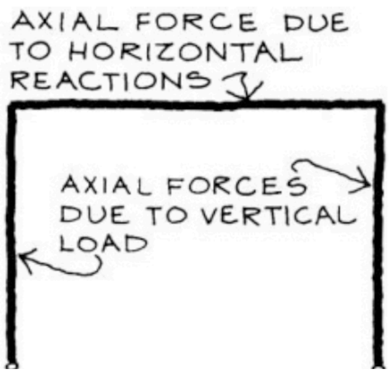


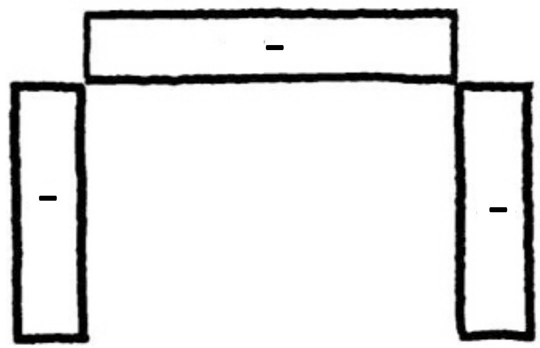
Not only does the slice has to transfer the bending moments from one face to the other, it also transfers the vertical load from one face to the other. These pairs of up and down forces are called **shear forces**, because their effect is to shear the slice.

The diagrams for a **portal frame** can be drawn showing what is happening inside the structure when it is loaded. Although there is only a vertical load, **horizontal reactions** exist because otherwise the legs would move apart at their bases. The deformed shape shows which sides of the legs and cross-bar are in tension and compression. Using this as a guide the bending moment diagram can be drawn.

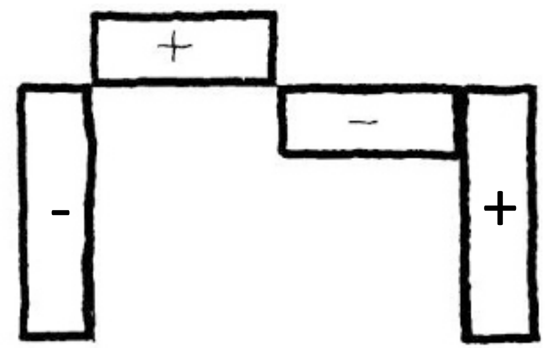


Not only will there be bending moments in the frame but there will also be axial forces and shear forces. There are axial forces in the legs due to the vertical load and an axial force in the cross-bar due to the horizontal reaction.



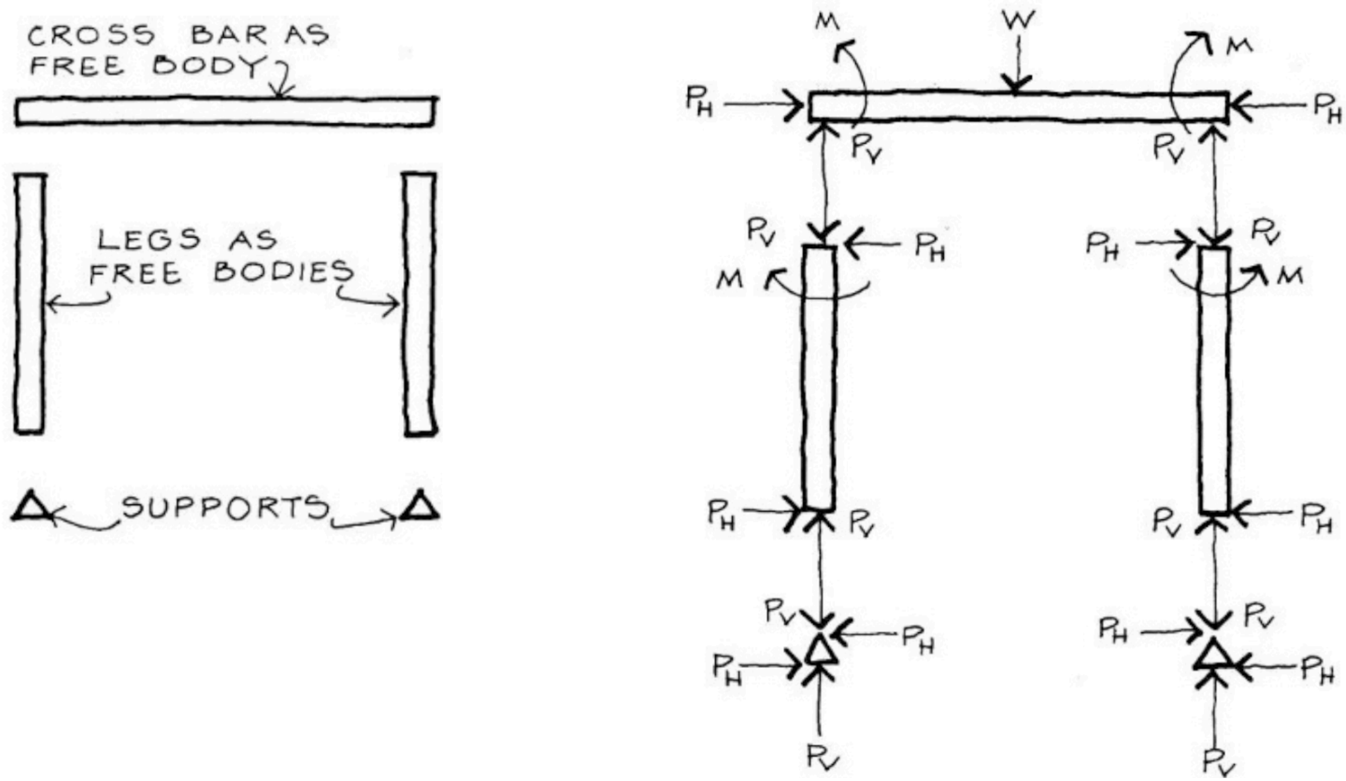


Axial force diagram

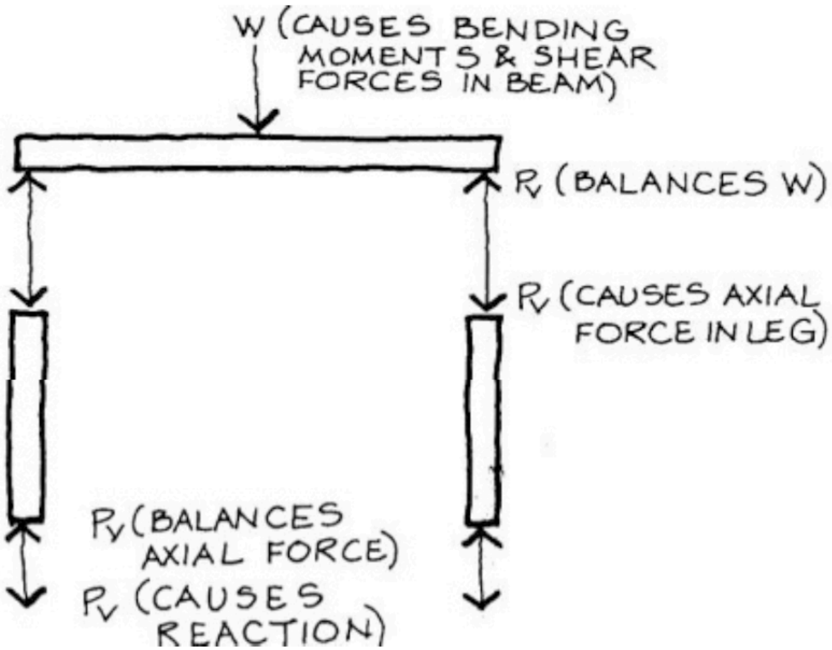


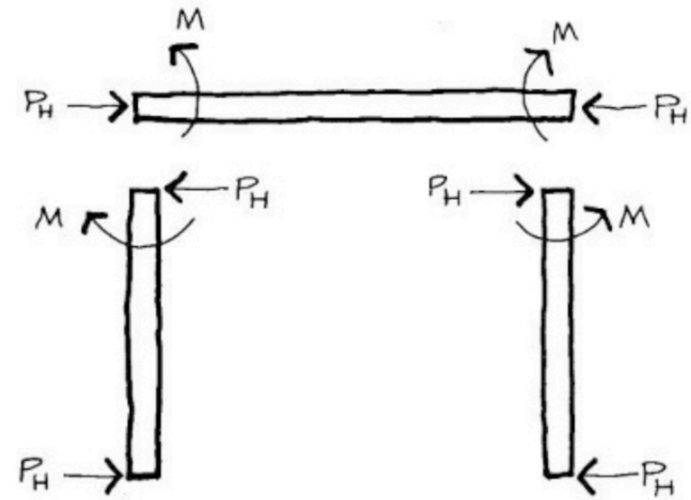
Shear force diagram

Further understanding of how the internal forces are acting on a structure can be obtained by considering the parts of a structure as **free bodies**. In the case of the portal frame, the free bodies are the beam and the two legs. The forces acting on these free bodies to keep them in equilibrium are shown in the following figure.



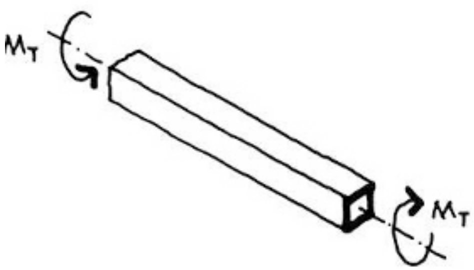
Structural diagrams: an example

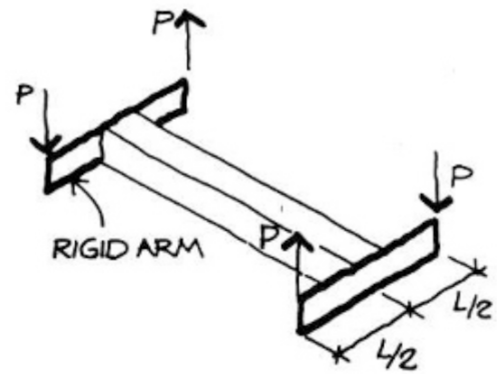


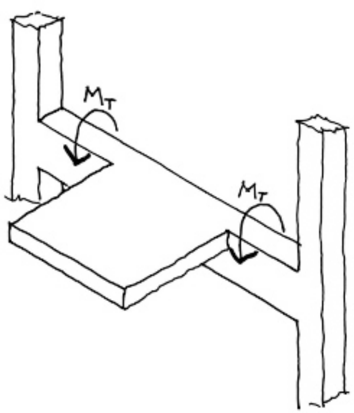


Twisting forces

The most common internal forces are axial forces, bending moments and shear forces. However, there is another internal force that **twists** a structural element about its longitudinal axis. This internal force is a moment and is called **torque** or, more commonly, **torsional moment**.



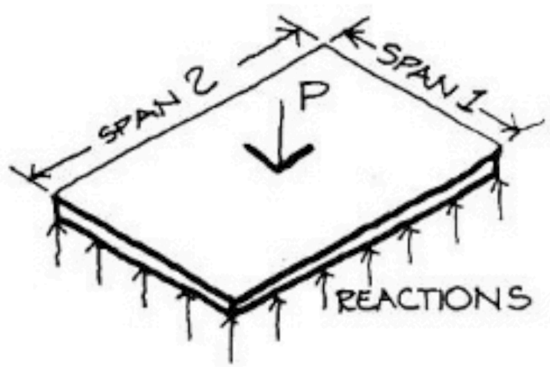


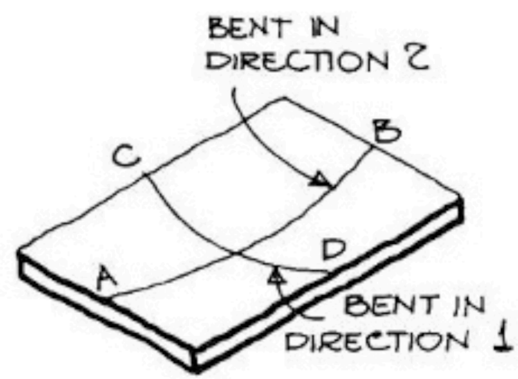


Torsional moments can occur as part of the primary load carrying systems in building structures: for example, a slab cantilevering from a beam that is spanning between two columns.

The concepts of bending moments, shear and axial forces are not confined to one-dimensional elements, such as beams and columns; they can be applied to all structural forms. For instance, a two-dimensional element such as a floor slab resists lateral loads by a system of internal bending moments and shear forces.

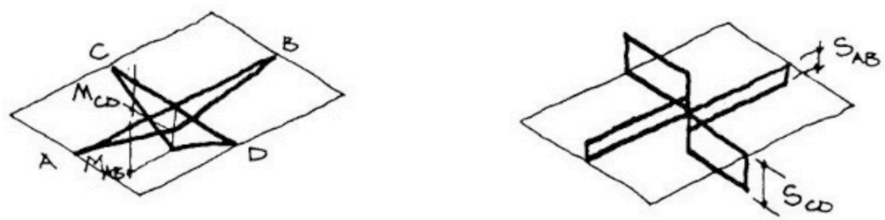
Because the slab is two dimensional, bending moments and shear forces can be considered as acting in two separate directions. For example a rectangular slab, supported on all sides and loaded by a central point load, will span in two directions.



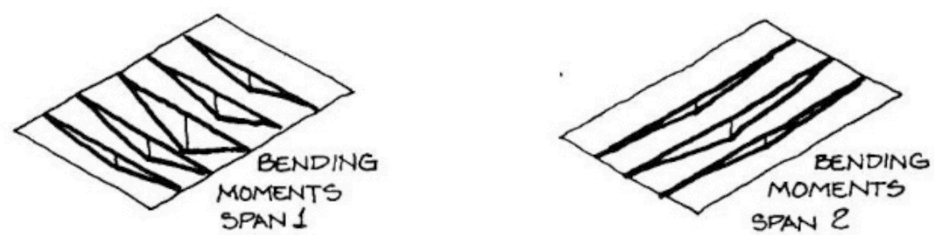


Slabs

A strip, AB, of the slab acts rather like a beam spanning from A to B. This strip will have bending moment and shear force distributions that can be represented by bending moment and shear force diagrams. Similarly with strip CD.



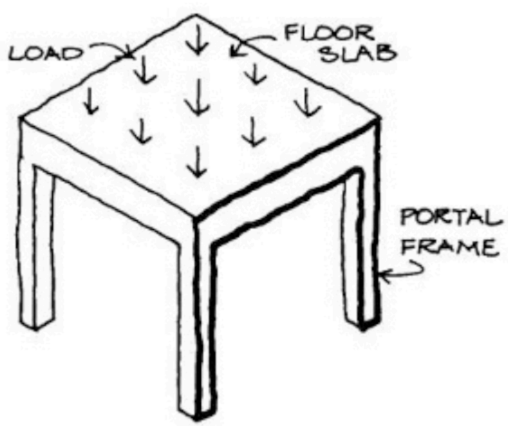
Bending moments and shear forces vary continuously throughout the slab. An idea can be given by drawing the diagrams for a series of strips. In the next diagram, bending moments are drawn for the two directions for a series of strips.

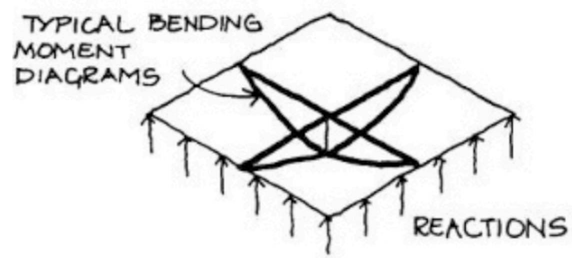


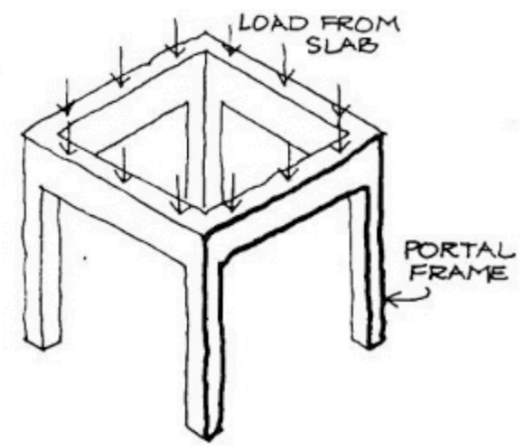
The structural action of load path

Often beams support the edges of floor slabs and columns support the beams. The slab spans two ways on to the beams and the beams, together with the columns, form a series of portal frames.

The slab carries the load to the beams by a system of bending moments and shear forces acting in two directions. At the edges of the slab there are vertical reactions that balance the load on the slab. In turn, these reactions cause loads on the portal frames.

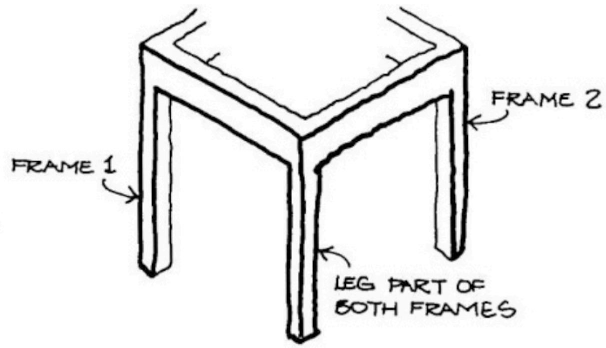


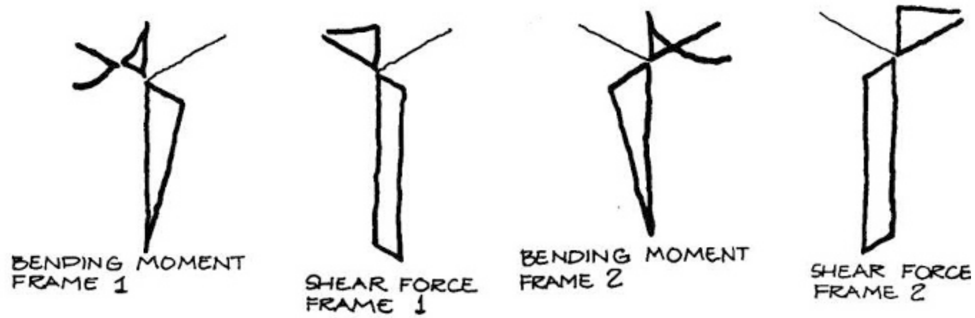


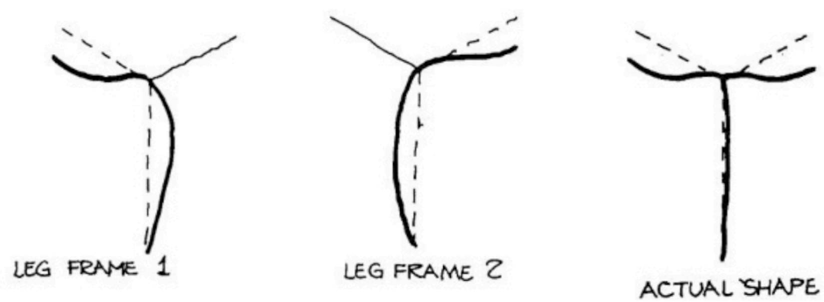


The structural action of load path 2/2

The portal frames resist these loads by internal bending moments, and shear and axial forces. These internal forces are distributed throughout the portal frames. The columns are now part of two portal frames.







In summary, two essential skills are required for the understanding of structures:

- Identifying the load path for each load (this is what carries the load)
- Identifying the sequence of structural actions in the load path (this is how the load is carried)