HISTORY OF FUNICULARITY

The history of construction could be read through the paths followed by the loads.

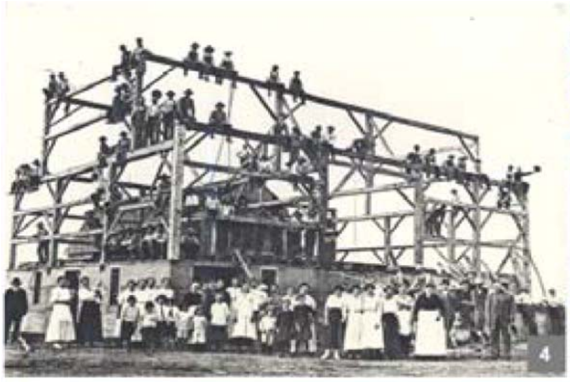
1 Stepped Pyramid of Djoser at Saqqara (3rd Dynasty, ca. 2667 to 2648 BC). Beginning more than 4000 years before Christ, buildings were made of masses of bricks or stone. Usable space was kept to a minimum. Openings and roofs were spanned by lintels and loads flowed almost directly from every point in the structure to the foundations.

2 Stone dome. The ancient Romans introduced or extended the use of arches, vaults and domes, enlarging considerably the useful space. Loads flowed through flat or curved planes and openings were resolved with the use of arches. Enormous amounts of material were saved because most of the volume of these buildings was not built mass and their shape favoured compression, the strength most characteristic of bricks, stone and concrete.

3 Saint Pierre de Beauvais Cathedral, S XIII-XVI. Gothic structures improved the Roman scheme by directing loads through lines. The architectonic identification of the load paths was brought to its culmination and the self-weight, for a material under compression, was kept to a minimum. Space and openings are freed by arches, buttresses, clustered piers and ribs.

Wood, iron and steel bars enabled the next step to take place in surpassing the limits of masonry. For the first time, bending and tension were allowed in the structure and breaking stresses were increased. In the construction of 18th century factories, load paths were identified with lines and refined up to the one-layer space frames of the second half of the 20th century.

4 Barn raising, farm of Jacob Roher, Massillon, 1888. Structures of barns were lightweight skeletons based on lines of wood taking advantage of bending.



5 Steel goes even further thanks to its isotropy and high resistance to all stresses (tension, compression, shear, torsion and bending). The single-layer lattice grid, for example, optimizes the vault by putting material only where it is necessary.

6 J.Strauss, 1937: Golden Gate Bridge, San Francisco Bay. Next step is given by tensile structures that are loaded mainly in tension where the material strength is used optimally as the entire cross-section of the structure is completely stressed up to the breaking load. (Compression needs over-sizing to prevent the buckling and bending only stresses the edge fibres and produces deflection).

In membrane structures all primary forces are arranged to be in tension through the double curved prestressed surface. As a result, the self weight drops dramatically to values close to 1 kp/m^2. Note, however, that the form is dependent on the membrane (threads, structure and coating), orientation of warp and weft, geometry and flexibility of supports and boundaries, loads and pre-stress, temperature and humidity, creep and yielding. Equilibrium is achieved with a particular geometry, loads and reactions. The geometry is nor free. It is defined by its internal equilibrium of prestress within a predetermined boundary system of support.

7 Ringling Bross, Barnum & Bailey circus tent (about 1900).

8 SBA Architekten with Knippers Helbig, 2010: Central Axis, Expo Shanghai.

The last step of the history of the load paths is the concealment that has occurred with the advent of the so-called free-forms.

9 F.Gehry, 1997: Guggenheim Museum, Bilbao. So-called free-forms require a steel framework. The load paths are hidden.

Liberty Enlightenning the World (F.A.Bartholdi with E.Viollet-le-Duc and A.G.Eiffel, 1886): an antecedent of hiding load paths.