

MILESTONES OF BUILDING CONSTRUCTION TECHNOLOGY

Theory of elasticity formulated by Claude-Louis Navier in a mathematically usable form and established the elastic modulus as a property of materials allowing engineers to understand both structural behavior and structural materials. In his lessons of 1826 he explored a great range of different structural theory, and was the first to highlight that the role of a structural engineer is not to understand the final, failed state of a structure, but to prevent that failure in the first place

Portland cement was patented by the engineer Joseph Aspdin as "*a superior cement resembling Portland Stone*" and were in common usage in Europe from the 1750s, commonly available, cheap materials, making concrete construction an economical possibility.

Ferrocement introduced with the construction of a rowing boat built of ferrocement in 1848 - the forerunner of modern reinforced concrete by Joseph-Louis Lambot, developments in concrete continued.

Monier system of Reinforced structures, the first use of steel reinforcement bars located in areas of tension in the structure when a reinforced concrete planting tub was patented by Joseph Monier in Paris, using steel mesh reinforcement. Monier took the idea forward, filing several patents for tubs, slabs and beams, leading eventually to the Monier system of reinforced structures.

Steel construction was first made possible when Henry Bessemer developed the Bessemer process to produce steel. He gained patents for the process in 1855 and 1856 and successfully completed the conversion of cast iron into cast steel in 1858. Eventually mild steel would replace both wrought iron and cast iron as the preferred metal for construction.

Use of Interior iron frame in 1797 for Ditherington Flax Mill in Shrewsbury was the first building in the world with an interior iron frame, designed by Charles Bage.

Fireproofed building succeeded when fireproof mill built at Belper in Derby (Belper West Mill), using cast iron columns and timber beams within the depths of brick arches that formed the floors. The exposed beam soffits were protected against fire by plaster. This mill at Belper was the world's first attempt to construct fireproof buildings, and is the first example of fire engineering. This was later improved upon with the construction of Belper North Mill, collaboration between Strutt and Bage, which by using a full cast iron frame represented the world's first "fire proofed" building.

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Landmark in bridge design, Forth Bridge was built by Benjamin Baker, Sir John Fowler and William Arrol in 1889, using steel, after the original design for the bridge by Thomas Bouch was rejected following the collapse of his Tay Rail Bridge.

The wrought-iron Eiffel Tower was built by Gustave Eiffel and Maurice Koechlin, demonstrating the potential of construction using iron, despite the fact that steel construction was already being used elsewhere.

Analysis methods developed for tensile structures, thin-shell structures, lattice shell structures and new structural geometries such as hyperboloid structures by Russian structural engineer Vladimir Shukhov.

Reinforced concrete design taken forward from 1892 onwards by François Hennebique's firm used his patented reinforced concrete system to build thousands of structures throughout Europe.

Reinforced concrete bridges entered between 1890 and 1897 when the firm *AG für Monierbauten* constructed 200 reinforced concrete bridges in Germany.

Understanding concrete behavior by Robert Maillart, correctly believed that if the concrete was cracked, it was not contributing to the strength, as many concrete bridge structures were significantly cracked, this resulted in the revolutionary Salginatobel Bridge design.

Truss theory for the shear design of reinforced concrete beams in 1899, Wilhelm Ritter formulated, and Emil Mörsch improved this in 1902. He went on to demonstrate that treating concrete in compression as a linear-elastic material was a conservative approximation of its behavior.

Prestressed concrete, pioneered by Eugène Freyssinet with a patent in 1928, gave a novel approach in overcoming the weakness of concrete structures in tension. Freyssinet constructed an experimental prestressed arch in 1908 and later used the technology in a limited form in the Plougastel Bridge in France in 1930. He went on to build six prestressed concrete bridges across the Marne River, firmly establishing the technology.

Moment distribution method developed in 1930 by Professor Hardy Cross allowing the real stresses of many complex structures to be approximated quickly and accurately.

Plasticity theory of structures developed in the mid 20th century by John Fleetwood Baker, providing a powerful tool for the safe design of steel structures.

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High-rise design and construction, Fazlur Khan designed structural systems that remain fundamental to many modern high rise constructions and which he employed in his structural designs for the John Hancock Center in 1969 and Sears Tower in 1973.

Skyscraper design and construction, Khan's central innovation in skyscraper design and construction was the idea of the "tube" and "bundled tube" structural systems for tall buildings. He defined the framed tube structure as "a three dimensional space structure composed of three, four, or possibly more frames, braced frames, or shear walls, joined at or near their edges to form a vertical tube-like structural system capable of resisting lateral forces in any direction by cantilevering from the foundation". Closely spaced interconnected exterior columns form the tube. Horizontal loads, for example wind, are supported by the structure as a whole. About half the exterior surface is available for windows. Framed tubes allow fewer interior columns, and so create more usable floor space. Where larger openings like garage doors are required, the tube frame must be interrupted, with transfer girders used to maintain structural integrity. The first building to apply the tube-frame construction was in the DeWitt-Chestnut Apartment Building which Khan designed in Chicago. This laid the foundations for the tube structures used in later skyscraper constructions, including the construction of the World Trade Center.

Concept of X-bracing was another innovation that Fazlur Khan developed, which reduced the lateral load on the building by transferring the load into the exterior columns. This allowed for a reduced need for interior columns thus creating more floor space, and can be seen in the John Hancock Center. The first sky lobby was also designed by Khan for the John Hancock Center in 1969. Later buildings with sky lobbies include the World Trade Center, Petronas Twin Towers and Taipei 101.

Analysis of complex concrete geometries, Jörg Schlaich and Kurt Schafer published the culmination of almost ten years of work on the strut and tie method for concrete analysis - a tool to design structures with discontinuities such as corners and joints, providing another powerful tool for the analysis of complex concrete geometries in 1987.

Powerful computers powered finite element analysis in the late 20th and early 21st centuries to become a significant tool for structural analysis and design. The development of finite element programs has led to the ability to accurately predict the stresses in complex structures, and allowed great advances in structural engineering design and architecture. In the 1960s and 70s computational analysis was used in a significant way for the first time on the design of the Sydney Opera House roof. Many modern structures could not be understood and designed without the use of computational analysis.

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Developments in the understanding of materials and structural behavior in

the latter part of the 20th century have been significant, with detailed understanding being developed of topics such as fracture mechanics, earthquake engineering, composite materials, temperature effects on materials, dynamics and vibration control, fatigue, creep and others. The depth and breadth of knowledge now available in structural engineering, and the increasing range of different structures and the increasing complexity of those structures has led to increasing specialization of structural engineers.

Nanotechnology, the recent development in the scientific technology, traditionally has been concerned in the developments in the fields of medicines, electronics, material sciences etc. Nanotechnology can be used for design and construction processes in many areas since nanotechnology generated products have many unique characteristics. These include products that are for: Lighter structure; Stronger structural composites; Low maintenance coating ; Improving pipe joining materials and techniques ; Better properties of cementitious materials ; Reducing the thermal transfer rate of fire retardant and insulation ; Increasing the sound absorption of acoustic absorber ; Increasing the reflectivity of glass.

References :

- Wikipedia free encyclopedia
- International Journal of Recent Trends in Engineering, Vol 1, No. 4, May 2009.

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