Architecture of Workplaces 1. Lecture 1

History of Industrial Architecture 1.
(1860) 1900-1945

23. reliable drive – constant drive

26. The mixed iron steel production process was a patent of Henry Cort in 1784. It was a flame oven in which the melted row iron contacted smoke gas. The iron bed was constantly mixed with long steel bars. It was later displaced by the Bessemer and Siemens-Martin process.

28. The Bessemer wind blowing steel production process was a patent of Henry Bessemer in 1855. The melted row iron was cast/poured in a pear-form converter and air was blown through the iron from below. Due to the oxigen of the air coal, silicon and manganese will be burnt. The main advantage is it doesn't need fuel.

29. The Siemens-Martin process was a patent of Émile Martin and Pierre Martin in 1864. It enables the use of melting row iron and scrap-iron. This was the process enabling the production of various kinds of amalgam steel. There are two steps of the production process; the refreshing (oxidation) and the finishing (reduction) phase. For example the alloyment happens in the reduction phase.

31. The first bridge made totally out of iron with a span of 30 meters. Assembled of prefabricated iron elements cast in Darby's local foundry. A pressed arch construction that follows the principle of brick arches.

32. Telford was a Scottish civil engineer, architect and stonemason, and a noted road, bridge and canal builder.
The bridges, viaducts, factories and warehouses of the eighteenth and nineteenth century were on the whole the work of practical men and engineers. Architects as such didn't deal of such mundane work. Their work had often been limited to adorning/ decorating an engineered building.

33. Design and construction of the Shrewsbury Canal. One of Telford's achievements on this project was the design of the **cast-iron aqueduct** at Longdon-on-Tern, pre-dating that at Pontcysyllte, and substantially bigger than the UK's first cast-iron aqueduct.

34. In 1793 the detailed design and construction of the Ellesmere Canal. Telford used a new method of construction consisting of **trough**s made from **cast iron plates and fixed in masonry**. He had to invent new techniques, such as using boiling sugar and lead as a sealant on the iron connections.

35. Extending for over 300 m with an altitude of 38 m above the valley floor, the Pontcysyllte Aqueduct consists of nineteen arches, each with a forty-five foot span.

37. The sample of pressed arch construction of Coalbrookdale bridge was followed by a number of iron bridges assembled of cast iron elements.

38. With the expansion of **cotton industry** in England (Lancashire), the demand for **industrialized production**, so for mechanized mill has arisen. Workshops changed to mills, mills changed to factories.
Factories were settled on river banks as the water was necessary to drive the partly mechanized production process. The invention of the steam engine and then the use of electricity as energy source enabled the location of production sites independent of naturally supplied drive propulsion.

39. Based on the experiences in bridge-building, iron came into use in factory-building. An inner skeleton structure of round cast-iron columns supporting cast-iron beams enclosed by bearing brick walls.

40. Continuing the same principle: Spinning Mill in Salford (near Manchester) 1799-1801, George Lee, Boulton and Watt - **the building type of the multi-storey factory**. The slabs are made of brick vaults instead of wood, (fire protection!) span of the beams: 4,27m. The first industrial building with gas-lighting.
In such warehouse buildings the iron structure was contained within and remained partially supported by an outer load bearing wall. This remained the **most common construction of mills** and warehouses through the **nineteenth century**.

41. At the same time in France: the Royal Salt Works the production is mantled with an aesthetics of monumentality.

The work is an important example of an early Enlightenment project in which the architect based his design on a **philosophy** that favoured arranging buildings according to a **rational geometry and a hierarchical relation** between the parts of the project.
Ledoux designed the semicircular complex to reflect a hierarchical organization of work. The complete plan included the building of an ideal city forming a perfect circle, like that of the sun. The city was never started, however. All that was completed was the diameter and a semicircle of buildings of the saltworks.

42. The first consequent **multi-storey skeleton structure** on the European Continent. One of the first multi-storey buildings with a **steel frame** construction. Extension over the Marne River. Over the massive bridge piers a multi-storey iron skeleton frame is constructed. The steel frame is filled with non-bearing walls made of hollow bricks.

43. A hall-like skeleton construction clad in sheet metal is the **first really consequent multi-storey skeleton structure**. It is a three-bay ensemble made up of two four-storey high storages and an empty glass-covered hall of the same height between them. The structure: **cast-iron** H-profile pillars and cross beams and secondary wooden beams of the intermediate floors.

44. The **steel skeleton** became a self-supporting structure leaving the **outer wall to be free of load bearing** constraints and allow the use of lightweight corrugated iron panels and large areas of glazing. So a quite **new facade system** was developed: cast-iron window-frames form **running-through stripes**, the parapet fields are corrugated iron panels.

45. The extension of the Sayner Hütte foundry, founded 1769-1770. The new casting house was built in 1828-30 in form of a three-naved basilica borrowed from the church architecture. Traditional form for new purpose: the old scheme of the basilica ensures optimal, natural lighting for manufacturing. A real **skeleton structure of cast iron elements**, the solid, heavy longitudinal brick walls stand without any bearing function. All elements from structure to window-frames are made of cast-iron. As 1844 the hall was extended: the complete west front was dissembled and again assembled four axes to the west - perfect sample of prefabrication.

46. Round hollow iron columns supporting the three-centre arch lattice girders and crane-track in the middle nave. An **industrial building** constructed with **industrially prefabricated iron elements**.

47-48. Richard Turner (1798–1881) was an Irish iron founder and manufacturer of glasshouses.
His works included the Palm House at Kew Gardens, the glasshouse in the Winter Gardens at Regent's Park in London, the Palm House at Belfast Botanic Gardens and the Curvilinear Range at the Irish National Botanic Gardens, Glasnevin, Ireland. He was **a pioneer in the structural use of wrought iron**. The glasshouses which he designed were sophisticated and innovative, as the use of wrought and cast iron was at the leading edge of building technology at the time. He used **standardised** components and **prefabricated elements manufactured off-site** for later assembly, together with curved glass in long lengths.
Turner entered the initial competition for designs for the London International Exhibition of 1851 and out of 233 entries was jointly awarded the second prize along with an entry by Hector Horeau. The final built design was "The Crystal Palace" by Joseph Paxton.

49-50. The very first example of **industrialized construction** is not a real industrial building, it is a huge exhibition hall for industrial products. It was built for the 1st World Exhibition and is the main representative of **cast iron architecture**. Competition for designs for the London International Exhibition of 1851.
Paxton was neither an architect, nor an engineer, but he was the chief gardener of a prince. Joseph Paxton as a learned gardener had used experiences of greenhouse-building. He planted and carried out several palm houses according his own design. The Crystal Palace had a construction made of cast iron, covering surface totally made of glass, a 92 000 m2 basic area.

51. The construction had a basylical system with several bays. Paxton utilized bravely the **constructional and formal opportunities** hiding in the new material: **iron and glass**. He built a **semi-transparent glass-hall** with walls rising fast weightless. Looking out from the enterieur the boarder becomes indistinct between inside and outside. The **massive wall architecture lost its validity** from here on. The example had an **effect of a revolution**.

52. The demand for planning and erecting a huge exhibition hall within less then twelve months(!) required **new methods** for production and assembly. It was the first time that **standardized elements were prefabricated in series production**. Certain groups of workers were responsible only for certain work phases, as an early sample of **organization of work**.
Paxton **moduled the dimensions**. He planned according to a module which was convenient with the dimensions of the glass boards in English industry. So he reached that the production works of the building could be divided between several

factories and the whole work was finished in 6 months. He demonstrated that the methods of mass production are useful in architecture too.

53. Later the Crystal Palace was settled on a new place, where it existed until 1937, then it was burnt.
The series of exhibition halls started with Paxton's Chrystal Palace.

54. Creators of cast-iron architecture in the United States - "the first person who practically used Iron for the building material of an exterior„
Badger set up the Architectural Iron Works for producing prefabricated cast-iron elements.

55. Round 1800 the **better quality** of iron enables the production of **wrought-iron elements** that can be used for **tensile force**. So the possibility of **chain bridges**, like the bridge Conway, Wales 1826. Conwy Suspension Bridge, was one of the first road suspension bridges in the world.

56. English mechanical and civil engineer, the most determining engineer of the 19th century. His designs revolutionised public transport and modern engineering.

57. The Clifton bridge is an important trendsetting example of suspension bridge-building, the longest span of any bridge in the world at the time of construction.
Roller-mounted "saddles" at the top of each tower allow movement of the three independent **wrought iron chains** on each side when loads pass over the bridge. The bridge deck is suspended by 162 **vertical wrought-iron rods** in 81 matching pairs.

58. The bridge (of bowstring girder or tied arch construction) consists of two main spans of 139 m, 30 m above mean high spring tide, plus 17 much shorter approach spans.

59. Today still is a mainline station, was the London terminus of the Great Western Railway. Brunel astonished Britain by proposing to extend the Great Western Railway westward to North America by building steam-powered iron-hulled ships. He designed and built three ships that revolutionised naval engineering.

61. The series of exhibition halls started with Paxton's Crystal Palace. The World Exhibitions in the second half on the nineteenth century promoted the development of steel structure halls, the largest example of which was the Galerie des Machines in Paris of Contamin and Dutert, built for the World Exhibition Paris, 1889.
That time experiments were made with the new materiel: steel. The Machine-hall, Paris represents the results achieved.
The Galerie des machines formed a huge glass and metal hall with an area of 115 by 420 metres and a height of 48.324 metres, it was free of internal supports. The framework consisted of twenty trusses. The structure incorporated the **three-pin hinged arch**, developed for bridge building.

62. The biggest span achievable had been round 40 m in architecture so far. (Pantheon, later the domes of Dom in Florence and S. Pietro in Rome) This dimension was not altered, exceeded by cast iron constructions either. But here the span of **three-pin frame of trussed arches with a span of 115m**! (48 m high). Even the shape of the frames was estonishing, quite new.
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63. Following the static principle, the trussed arches were **tapered at the supports**. In traditional stone architecture the law was common that the load bearing support thickers smoothly dawn-wards, according to the net weight. Here the section of the construction was –vica versa- the smallest at the support – so gaining a feeling that it spans the huge distance without effort, without load. Most part of roof and facade were glazed.
This example helped architecture **to get rid of historical forms** an make a step forward to modernism.

64. Inventor of the **separation of the bearer** (columns, beams, arches) into structures assembled of small elements, creating **three-dimensional space constructions**.

66. The world's longest steel arch bridge in 1877 in Oporto, Portugal.

67. The largest and highest railway arch bridge in the world at the time of its completion in 1884. 124 meters high, 165 meter span, two-hinged arch bridge.

69.	Construction: a wrought iron lattice tower. Constructed in 1889 as the entrance to the 1889 World's Fair, it was initially criticized by some of France's leading artists and intellectuals for its design, but has become a global cultural icon of France and one of the most recognisable structures in the world. The tower is the tallest structure in Paris and the most-visited paid monument in the world.
The tower is 324 metres high – about the same height as an 81-storey building. Eiffel and his engineers, as experienced bridge builders, understood the importance of wind forces, and knew that if they were going to build the tallest structure in the world, they had to be sure it could withstand them. Eiffel used empirical and graphical methods to account for the effects of wind rather than a specific mathematical formula. Careful examination of the tower reveals a basically exponential shape. The tower sways by only 6–7 cm in the wind.

71.	The Forth Bridge is a cantilever railway bridge over the Firth of Forth. It was the longest single cantilever bridge span in the world until 1917 when the Quebec Bridge in Canada was completed. It continues to be the world's second-longest single cantilever span.
It is 2,467.05 m in length, and the double track is elevated 45.72 m above the water level at high tide. It consists of two main spans of 518.16 m, two side spans of 207.3 m, and 15 approach spans of 51.2 m. Each main span consists of two 207.3 m cantilever arms supporting a central 106.7 m span truss.
The bridge was the first major structure in Britain to be constructed of steel. (The Eiffel Tower was built of wrought iron.) Large amounts of steel had become available after the invention of the Bessemer process in 1855.

72.	Illustration of the cantilever principle. In order to illustrate the use of tension and compression in the bridge, a demonstration in 1887 had the Japanese engineer Kaichi Watanabe supported between Fowler and Baker sitting in chairs. Fowler and Baker represent the cantilevers, with their arms in tension and the sticks under compression, and the bricks the cantilever end piers which are weighted with cast iron.

73.	The use of steel cables enabled significant increase of the bridges' span. Wire rope suspension bridge designs have begun.
Transportation between eastern industrial hubs and frontier farming markets had become a matter of both national and popular interest. Many transportation projects were underway. Roebling's first engineering work in America was devoted to improving river navigation and canal building. Roebling began **producing wire rope** at Saxonburg in 1841. At that time canal boats from Philadelphia were transported over the Allegheny Mountains on railroad cars to access waterways on the other side of the mountains, so that the boats could continue to Pittsburgh. The railroad cars were pulled up and down the inclines by a long loop of thick hemp rope, up to 7 cm thick. The hemp ropes were expensive and had to be replaced frequently. Roebling remembered an article he read about wire ropes. Soon after, he started developing a 7-strand wire rope at a ropewalk that he built on his farm.

74-75.	Architect renowned for his pioneering works on new methods of analysis for structural engineering that led to breakthroughs in industrial design of world's first hyperboloid structures, diagrid shell structures, tensile structures, gridshell structures, oil reservoirs, pipelines, boilers, ships and barges.
Shukhov was the inventor of a new family of doubly curved structural forms.