Chapter 6:

REINFORCED CONCRETE:

DEFINITIONS:

Concrete:

A composite material which consists essentially of a binding medium within which are embedded particles or fragments of aggregate; in Portland cement concrete, the binder is a mixture of Portland cement and water; a proportional mix of cement, water, large aggregates and small aggregates.

Cement:

A material or mixture of materials (without aggregate) which, when in a plastic state, possesses adhesive and cohesive properties and hardens in place. Frequently the term is used incorrectly for concrete.

Reinforced concrete:

(Beton Arme, ferroconcrete, steel concrete) Concrete containing reinforcement designed on the assumption that the concrete and reinforcement act together in resisting forces. Concrete, like stone, is very good at resisting compression forces, but virtually useless at resisting tensile forces. The steel reinforcing is placed within the concrete at areas where the member will be subjected to tensile forces. The rebars must have a cover of concrete in the range of 25 to 75 mm to protect them from water. Where the structure will be exposed to great amounts of water and salt, epoxy coated (green coloured) rebars are used to resist corrosion.

Reinforcement:

In reinforced concrete, metal bars, rods or wires, or other slender members that are embedded in concrete in such a manner that the metal and the concrete act together in resisting forces (the concrete, compression and the steel, tension).

DEVELOPMENT OF THE MATERIAL:

Origins of Concrete and Cement: up to 1700 (Italy)

Concrete is the oldest **synthetic** material used in the building process, however, its use was lost for a period of about thirteen centuries. Of the four primary ingredients of concrete, the sand and gravel (aggregate) are inert, and the cement and water are the active ingredients in the complex **chemical reactions** that transforms the wet plastic into a rigid and durable substance.

Romans made two important discoveries: firstly, that ordinary cement will set under water if the lime is previously mixed with a small quantity of a volcanic earth now called **pozzolana** (after the town of Pozzuoli, Italy). Secondly, that if hydraulic lime, sand and water are mixed with an aggregate of broken stones or bricks and allowed to set, the resulting product is a strong and durable stonelike substance that will harden in water as well as in air.

Vitruvius: 100 BC: mentions the components of concrete in the dissertations on materials. **Sand, lime and pozzolana.** On pozzolana: "This substance, when mixed with lime and rubble, not only lends strength to buildings of other kinds, but even when piers of it are constructed in the sea, they set hard under water." Also, by trial and error, had found that lime worked better as a component if it had been burned.

Even the **Coliseum** is noted as having some of its structure as composed of "concrete" (faced with fine stone as the concrete of this sort was very irregular in its finish).

Development of Concrete: Europe (England and France)

The art was lost until the sixteenth century when English builders began importing pozzolana and lime mixtures from Italy. That the ingredients had to be imported from Italy impeded the spread of use of concrete in construction.

The development of concrete, specifically hydraulic cement, during the 18th century may be attributed to needs posed by shipping. Much concrete was used in the construction of bridges, canals and harbor works. **Hydraulic cement** is a cement that is capable of setting and hardening under water, owing to interaction of the water and the constituents of the cement.

1774, John Smeaton, used a concrete compound of quicklime, clay, sand, and crushed iron slag, to construct the base of his Eddystone Lighthouse.

In 1811 James Frost and Louis Vicat had invented a way of artificially preparing the ingredients for the cement mixture.

The creation of **Portland Cement in 1824 by Joseph Apsdin** for use as imitation stone, seemed to be the high point of British advances in concrete technology for the time being, and further developments were carried out in France. The cement was called Portland as it bore resemblance to the limestone around the Portland area of England. Apsdin took out a patent for this artificially created cement, prepared by calcining a mixture of chalk and clay at a high enough temperature to vitrify the mixture, which was then ground to a powder. This produced a cement superior in quality and more reliable than others.

In France, the economic restrictions that followed the Revolution of 1789, the synthesis of hydraulic cement by L. J. Vicat around 1800, and the tradition of building in pise (**Pise** is a building whose walls are made of compressed earth, usually stiff clay formed and rammed in a movable frame or formwork. Pise is the building material itself, i.e., stiff earth or clay, rammed until it becomes firm; used to form walls and floors) The facts combined to create the optimum circumstances for the invention of reinforced concrete.

Concrete, in as much as it was used to imitate stone structurally, **exhibits the same structural characteristics as stone,** that is, that it is **strong in compression but weak in tension.** The use of plain concrete was then limited to compression members, the form of structures resembling those constructed of stone (columns, short lintels or floor spans, vaulting). It was recognized in stone construction that there were advantages in the use of iron to reinforce stone against tensile cracking and local stresses. The **Duomo** in Firenze, designed by Brunelleschi was reinforced with iron chains to control some of the outward thrust.

That stone was not strong in 'tension' was often noted after cracking had occurred, as in the dome of **St. Peter's** at the Vatican, and reinforcing in the form of added stone or iron had to be carried out to prevent further cracking and eventual collapse.

This recognition of the value of iron as tensile reinforcing is visible in the detailing of **Ste. Genevieve by Jacques Germaine Soufflot, c. 1776,** as well as in the detailing of the tie rods and cramps in the **Place de la Concorde,** Paris, by Ange-Jacques Gabriel, 1763. It was to take almost 75 years before these principles were to be seriously applied to concrete in the nature of reinforcing.

Development of Reinforced Concrete: (England, France and America)

In **1854 William Wilkinson** of England obtained a patent for embedding a grid of wire rope in a concrete slab.

Francois Coignet in 1861 developed a technique for strengthening concrete with metal mesh, and on the basis of this, established the first limited company to specialize in ferroconcrete construction. He worked in Paris under Haussmann's direction, building sewers and other public structures in ferroconcrete, including in 1867, a series of six storey apartment blocks. He held a patent on this process, but failing to uphold his patent, had to dissolve his company by the end of the Second Empire.

Joseph Monier was a French gardener who produced wire mesh reinforced concrete flower pots in 1850. He turned his success to the use of concrete in building, and between 1867 and 1878 took out a series of patents for metal reinforced applications. These rights were sold to the engineers Schuster and Wayss in 1880 and to the firm of Freytag in 1884. Wayss and Freytag (German) joined partnership, and published important theoretical studies on this method of ferroconcrete, called 'Monierbau', in 1887. The studies centered on differential stress in reinforced concrete.

Reinforced Concrete Framing: (America)

William E. Wards, 1873, in his reinforced concrete home on the Hudson River, became the first builder to take full advantage of the tensile strength of steel by situating bars below the neutral axis of the beam.

> "The incident which led the writer to the invention of iron with beton concrete occurred in England in 1867, when his attention was called to the difficulty of some laborers on a quay trying to remove cement from their tools. The adhesion of the cement to the iron was so firm that the cleavage generally appeared in the cement rather than between the cement and the iron.... the utility of both iron and beton could be greatly increased for building purposes through a properly adjusted combination of their special physical properties, and very much greater efficiency be reached through their combination that could possibly be realized by the exclusive use of either material separately, in the same or in equal quantity."

Ward designed the floor slabs with such a generous margin of safety that one would suppose he had intended them for bridge loading. He first laid down a thin slab of concrete directly on the supporting beams; on this he placed a grid of iron rods laid in two courses at right angles; he then poured a 2 inch top slab over the grid and carefully tamped the wet concrete around and under the rods. For a finished floor he added a 1/2 inch coat of cement and beach sand, placed after the main slab had set.

The inherent structural advantage of this was almost immediately confirmed through the concrete beam experiments conducted in England by Thaddeus Hyatt and Thomas Rickets, whose results were published in 1877**.**

Francois Hennebique, was a self educated builder, and first used concrete in 1879. He conducted an extensive program of private research before patenting his own system in 1892. His system revolutionized reinforced concrete construction. Before Hennebique's invention, the key problem in reinforced concrete construction had been provision of a **monolithic joint.** Hennebique overcame this difficulty through the use of cylindrical reinforcing rods which could be bent round and hooked together. Integral to his system alone was the cranking up of reinforcing bars and the joints with stirrup hoops to resist local stresses. Now that the joint had been perfected, the monolithic frame could be realized.

In **Tourcoign and Lille,** Hennebique built three spinning mills in 1896. His partner L. G. Mouchel brought the system to England, building the first concrete road bridge in 1901 and a spectacular freestanding helical stair at the exhibition in 1908.

The Hennebique firm published a magazine **"Le Beton Arme"** which served to spread the influence of the ferroconcrete method.

In 1904 he built his own reinforced concrete villa at Bourg-la-Reine, complete with roof garden and minaret. Its solid walls were formed out of ferroconcrete poured in place between permanent precast concrete shuttering. The facade was almost totally glazed, and cantilevered out from the main plane of the building. His monopoly over the system began to wane at the beginning of the century although his patents had a few years left to run.

The use of concrete was impaired in the Americas due to the dependence on England for the importation of Portland Cement, as there were insufficient natural hydraulic lime deposits to be found. In 1871, David 0. Saylor patented an American equivalent to Portland cement and set up to manufacture it in Pennsylvania. Scientists were also starting to study the physical properties and structural behavior of concrete, although did not understand the chemical processes involved in setting at this time.

Concrete was widely used in the construction of **dams and bridges** as it was capable of withstanding large amounts of water pressure, and the adaptation of masonry arch forms to concrete was suitable for the construction of bridges. Its applicability to buildings subjected to hurricanes and earthquakes was taken advantage of, and its widespread use in areas subjected to these natural forces helped to put concrete and reinforced concrete construction into everyday use.

Between 1886 and 1888 the New York firm of Carrere and Hastings constructed a hotel in St. Augustine, Florida of poured plain concrete. Recognizing the limitations of the material, that is its ability to withstand large compressive forces but not tensile, the concrete was poured as footings, foundations, exterior walls and interior partitions only.

Ernest L. Ransome (1884-1911) pioneered the application of reinforced concrete building in the San Francisco area, because of its ability to withstand earthquakes.

Frank Lloyd Wright used concrete construction in the Unity Temple of Chicago (Oak Park) in 1905.

The first **skyscraper** was designed and built in 1902-3 by Elzner and Anderson. The Ingalls Transit Building in Cincinatti was 16 stories tall, and the reinforcing was based on Ransome's method.

Claude A. P. Turner invented a new kind of reinforcing in 1902 which eliminated the need for beams to support the floor slabs. Instead the floor slab was thickened and reinforced at the columns to resist punching shear, the shear being accommodated by mushroom capitals. This was patented as the Turner system and was used in 1908-9 in the Lindeke-Warner Building in St. Paul Minnesota.

Robert Maillart (1872-1940) developed his own flat slab system in Switzerland in 1900, independently of Turner, and criticized Turner's later system for over concentration of the reinforcing bars at the column, thereby placing some of the bars in the compression range of the concrete and not in a useful position.

Development of Prestressing Concrete:

The full advantages of reinforced concrete construction were only realized with the invention of **prestressing.** In prestressing the steel rods which are to be embedded in the concrete are stretched, the concrete placed around them and allowed to harden, and then the steel rods relaxed, shrinking, therefore placing the concrete in compression before it is loaded. Pope had invented something similar to this as early as 1811, however it was not to be widely used until much later.

Eugene Freyssinet (1879-1962) pioneered much of the development of prestressing, as well as technology involved in hinged arch construction during the 1920's.

REINFORCED CONCRETE AND THE MODERN FORM OF ARCHITECTURE:

The invention of reinforced concrete had immense design ramifications during the onset of the Modern Movement in Architecture at the beginning of this century. The material and structural capabilities of reinforced concrete facilitated a type of design that would not otherwise have been possible using the existing materials of steel, stone and timber. Concrete’s primary point of deviation from the design and structural attributes of steel and timber lay in its monolithic and plastic nature, versus the elemental and modular nature of steel and timber. Whereas steel design required considerations of modularity, repetition and elemental design, reinforced concrete could be sculptural and freeform. The adoption of reinforced concrete into the mentality of modern conceptual design allowed for former “visionary” styles of architecture to become realizable.

The fire resistant nature of reinforced concrete, coupled with a proliferation of major fires and high rise related fire disasters during the latter part of the 1800’s, assisted in promoting the use of reinforced concrete over steel for many building types.

VISIONARY ARCHITECTURE:

The French Revolution during the latter part of the 18th century brought an abrupt end to the building careers of many French Architects who were associated with the French aristocracy. "Paper Architecture" replaced building for those affected. Such designs were created whose intellectual musings were far reaching, in spite of being based in the Neo-Classical style of the period. Often these designs were of a scale so grand to be far beyond the capabilities of materials currently available -- simple iron reinforced concrete or timber. Had reinforced concrete been invented 100 years earlier than it was, we may have seen the construction of some of these visionary projects... They served, instead, to inspire many of the Architects of the modern movement by initiating precedents in conceptual design.

The task of integrating the new Neo-Classical theory into architectural education, a theory that was reactionary to the previous Rococo Style of the Ancient French Regime, fell to Jacques-Francois Blondel, who after opening his architectural school in 1743, became the master of the "visionary" generation of architects, including Etienne-Louis Boullee, Jean-Baptiste Rondelet, and Claude-Nicholas Ledoux. J. F. Blondel's teachings were based on extrapolations of theories professed by Claude Perrault, architect of the East Facade of the Louvre, Francois Blondel, and the Abbe Cordemoy (later followed by Abbe Laugier and the theories of the Rustic hut and the origins of the Greek orders). The concern was now with Appropriate use of the orders, appropriate formal expression and with a differentiated physiognomy to accord with the varying social character of different building types. It was Cordemoy who had introduced the notion of "fitness" and warned against the inappropriate application of Classical or honorific elements to utilitarian or commercial structures. Much of this belief tended to simplify the ornamentaion previously accepted in traditional design, and conditioned taste to accept the simplified, sometimes brutal or plain appearance of reinforced concrete construction.

Etienne-Louis Boullee (1728-1799):

Boullee was born and died in Paris and although the record of his personal life is sketchy, is reputed never to have traveled to Italy or England, and rarely out of Paris. At the age of 18 or 19 he was made a teacher at the Ecole des Ponts et Chaussees, and he later held an authoritative position in the Academie d'Architecture of which he became a second class member in 1762 and a first class member in 1780. Boullee had studied under J. F. Blondel at the Academic, prior to his induction as a professor. He assisted in setting the programs for the competitions and projects at the Academie, which included largely civic buildings such as hospitals, lighthouses, prisons, medical schools and museums. One of his pupils includes Jean-Nicholas-Louis Durand (1760-1834) who at the age of 16 became Boullee's private pupil before entering the Academie for more formal teaching.

The character of Boullee's style is linked to his early ambitions to become a painter, an ambition that was thwarted by his father who held a position of architect in the "Batiments du Roi" and insisted Boullee follow the same profession. His painterly ideas assisted in his synthesizing painting and architecture in his novel effects of light and shadow, which were new to his time.

His contribution to theory and architecture is clear -- that of light and shadow as a means of heightening architectural expression. He was inspired by the simplicity and austerity of the dwellings of the poorer classes. He saw in bare walls and unbroken surfaces a means of aesthetic expression, which although based on cheap and humble habitations, could be adapted to palaces and civic buildings. (Anti-Rococo). Out of this grew a preference for simpler forms, a clear precise style with few embellishments. A use of the platonic solids, with a clear preference for the sphere, and frequent use of flat roofs gave many of his structures a modern appearance. The concepts of regularity and symmetry were borrowed from Vitruvius as equivalent to proportion.

Although much of the architecture of his time has been classed as Romanticism, Boullee is clearly not of this category. His individualism was based on a reasoned appreciation of function and ruled by the recognition of the laws of nature, founded on Newton's theories. Boullee had no desire to "improve" nature, he was no follower of contemporary thought in this respect. In his eyes the architect's task was to reproduce, by his own means and in a structural idiom, the ennobling impression which nature makes on the spectator.

To attain this end the architect first has to select from natural forms, under the guidance of a concept of regularity, based on Platonic traditions. Accordingly the sphere is the most perfect of bodies. Secondly, the painterly approach is nourished by the different hues appearing during the seasons, leading to the desire of emulating nature. This is achieved by emphasizing the emotional impact of natural and structural settings, by stressing the purpose of the building, when of a moral character, and by appealing to the emotions of sorrow and joy. In these terms Boullee envisaged what he termed "architectural character". Thus it is always the essential that was Boullee's aim, and this concern with absolute form gives him his timeless character.

> "Circular bodies please our senses because of their smooth contours; angular bodies are displeasing because of the harshness of their forms; bodies that crawl over the ground sadden us; those that rise into the sky delight us and those that stretch across the horizon are noble and majestic."

Although Boullee had a very fruitful practice in Paris during the 1700's, much of his designed architecture of great importance is in the means of visionary drawings for projects never intended to be built. This can be partly attributed to the lack of building after the Revolution of 1789. Boullee was appointed in 1778 as General Controller of Buildings at the Hotel des Invalides, and at that time ceased to take private clients in the hopes of attaining "official" commissions which were much more prestigious. The work Boullee did in the years 1762-1774 provided him with a valuable fund of experience in which he founded many themes which were to become central to his later visionary works.

The foremost theme is that of overhead lighting. In his eyes, skylights had the great advantage of leaving him free to design the facades without worrying about the distribution of windows. "I have tried to avoid that thinness of effect which comes of having too many openings. These make the piers too narrow, so that the house is reduced to a kind of lantern of an intolerable monotony." He accordingly eliminated windows from the upper floor of the main facade and soon came to make all his facades blind. He became a master of lighting effects of these skylights on the interior, not using the simply oculus as on the Pantheon in Rome.

Boullee's ideas and theories are most clearly expressed in his "Architecture, Essai sur l'Art", a collection of notes speculated never intended for publishing, that were published in the middle of the 19th century, well after his death, and which are kept in the Biblioteque Nationale in Paris.

"What is Architecture? Shall I join Vitruvius in defining it as the art of building? Indeed no, for there is a flagrant error in this definition. Vitruvius mistakes the effect for the cause.

In order to execute, it is first necessary to conceive. our earliest ancestors built their huts only when they had a picture of them in their minds. It is this product of the mind, this process of creation, that constitutes architecture and which can consequently be defined as the art of designing and bringing to perfection any building whatsoever. Thus, the art of construction is merely an auxiliary art that, in our opinion, could appropriately be called the scientific side of architecture.

Art, in the true sense of the work, and science, these we believe have their place in architecture."

"In my search to discover the properties of volumes and their analogy with the human organism, I began by studying the nature of some irregular volumes.

What I saw were masses with convex, concave, angular or planimetric planes, etc. Next I realized that the various contours of the planes of these volumes defined their shape and determined their form. I also perceived in them the confusion (I cannot say variety) engendered by the number and complexity of their irregular planes.

Weary of the mute sterility of irregular volumes, I proceeded to study regular volumes. What I first noted was their regularity, their symmetry and their variety; and I perceived that that was what constituted their shape and their form. What is more, I realized that regularity alone had given man a clear conception of the shape of volumes, and so he gave them a definition which, as we shall see, resulted not only from their regularity and symmetry but also from their variety.

An irregular volume is composed of a multitude of planes, each of them different and, as I have observed above, it lies beyond our grasp. The number and complexity of the planes have nothing distinct about them and give a confused impression.

How is it that we can recognize the shape of a regular volume at a glance? It is because it is simple in form, its planes are regular and it repeats itself. But since we gauge the impression that objects make on us by their clarity, what makes us single out regular volumes in particular is the fact that their regularity and their symmetry represent order, and order is clarity."

Boullee's designs for a Metropole, Museum, Opera, all reflect his desire for grand proportions, plain exterior surfaces and painterly lighting.

Boullee's design of a Biblioteque Nationale is one of his most noted pieces. He writes of it:

> "If there is one project that should please an Architect, and at the same time, fire his Genius, it is a Public Library. In addition to giving him an opportunity to develop his talent, it has the precious advantage of enabling him to devote it to the men who have made their age illustrious.
>
> The masterpieces of these great men evoke a desire to follow in their footsteps and inevitable give rise to lofty thoughts; one experiences then those noble transports, that sublime impetus that seem to draw forth soul from body; one believes oneself inspired by the shades of these famous men.
>
> "I was deeply impressed by Raphael's sublime design for the School of Athens and I have tried to execute it; doubtless I owe what success I have had to this idea."

Boullee's design of a Cenotaph sets out a building type that is rich in the potential for iconographic meaning. This he readily associates with pure geometric form, heralding from his Masonic connections and beliefs.

> "It is obvious that the goal one sets oneself when erecting this kind of Monument, is the perpetuation of the memory of those to whom it is dedicated. These monuments should therefore be designed to withstand the ravages of time.
>
> The Egyptians have left us some celebrated examples. Their Pyramids are truly characteristic in that they conjure up the melancholy image of arid mountains and immutability."

Boullee's design for a Cenotaph for Newton optimizes the manifestation of his architectural pedagogy, and served as a precedent for many famous modern architects in their use of reinforced concrete. Note the similarity between the apertures cut through the shell and the design of the windows by Le Corbusier for the Chapel at Ronchamps.

> "Sublime mind! Prodigious and profound genius! Divine being! Newton! Deing to accept the homage of my feeble talents! Ah! If I dare to make it public, it is because I am persuaded that I have surpassed myself in the project that I shall discuss.
>
> 0 Newton! With the range of your intelligence and the sublime nature of your Genius, you have defined the shape of the earth; I have conceived the idea of enveloping you with your discovery. That is as it were to envelop you in your own self. How can I find outside you anything worthy of you? It was these ideas that make me want to make the sepulcher in the shape of the earth. In imitation of the ancients and to pay homage to you I have surrounded it with flowers and cypress trees."...
>
> "I will not bore you by continuing to describe my goals. I would advise those who intend to take up architecture to study attentively what I have to say, to study my designs scrupulously, to ponder on them and on my writings, before coming to any

conclusion; then, to do as I have done with regard to the ancients, that is to respect their designs when they are good, but not to follow them slavishly; but to become rather the slave of nature which is an inexhaustible spring where all of us, however many we are, should draw continuously."

REINFORCED CONCRETE AS STRUCTURAL TYPOLOGY:

Conceptual design has linked itself very strongly with the structural typoloy of reinforced concrete. Building design can be seen which clearly aligns with the structural properties and construction methods of reinforced concrete -- the most notable examples of which clearly take full advantage of the potential of the material. Reinforced concrete could not be replaced with any other material without serious detriment to the conceptual design and project parti.

The material became a central component of the modern architecture of Le Corbusier. His vision of the technological advances of the 20th century adopted concrete as the material of this new architecture. Le Corbusier's parti revolved around a platform called "Five Points Towards a New Architecture". He felt that all buildings should have a free plan, free facade, be built on pilottis, have horizontal strip windows and a roof garden (to replace the green space lost at grade by the building footprint). The monolithic, free form nature of concrete facilitated this vision. No building of Le Corbusier's expressed this better than the Villa Savoye.

Monolithic Framing:

- August Perret [1874-1954] (Theatre des Champs Elysees 1913)
- Le Corbusier (Villa Savoye)
- Le Corbusier [1887-1965] (Unite d'Habitation 1947-52)
- Oscar Niemeyer [1907-1, Lucio Costa and Le Corbusier (Ministry of Education, Rio de Janeiro 1937-43)
- Skydome (1989) Robbie, Allen Architect and Engineer

Plasticity and Cantilevers:

- Pier Luigi Nervi (1891-1979) (Giovanni Berta Stadium, Firenze 1930-32)
- Eero Saarinen [1910-61, son of Eliel Saarinen 1873-19501 (Dulles Airport 1958-62 and TWA Airport 1956-62)
- Pier Luigi Nervi (Palazzo del Sport 1958-60)
- Le Corbusier (Chandigarh 1953-62, Ronchamps 1950-54)
- Frank Lloyd Wright [1867-19591 (S. C. Johnson 1947-50), Guggenheim Museum 1944-57)
- Bertrand Goldberg Associates (Marina City 1960-67)

Long Span:

- Robert Maillart [1872-1940] (Salginatobel Bridge 1929-30)
- Eugene Freyssinet [1879-19621 (Airship Hangers Orly 1916)
- General Bridge Construction

Precast (Assemblage Concrete):

Precast concrete clearly separates itself from normal reinforced concrete, and in design, must be viewed as a hybrid of the monolithic element, and the elemental and modular requirements of steel framing. The elements themselves may be sculptural or elaborately cast, but economy requisites the maximization of repetition of each element. Joints are very like to the hinge joints of steel construction; i.e. they are constructed of steel parts which are attached to or embedded in the concrete. These connections are then welded or bolted together. This places a structural limitation on the height of the precast concrete building, owing to a lack of rigidity as a result of the non-monolithic nature of the structure.

- Le Corbusier (Maison Domino 1914)
- James Stirling [1926-] (Prefabricated Housing after Domino 1951)
- Moshe Safdie [1938-] (Habitat Housing, Expo 67, Montreal)
- Crang and Boake (Eaton Centre Parking Garage, Guelph 1984)
- IKOY (Red River Community College 1984)
- Arthur Erickson (Anthropology Museum 1975)

REINFORCED CONCRETE 'STYLE':

Not only was reinforced concrete integrated into the conceptual design of the Modern Movement as a result of its structural attributes, requirements and potentials, but came to be closely associated as the material of certain “styles” of architecture -- the iconographic symbol of theory and design.

<u>Brutalism:</u>

- Le Corbusier (Maison Joule 1956, La Tourette 1955)
- Kallmann, McKinnell and Knowles (Boston City Hall 1962-67)
- Atelier 5 (Alder House 1958, Berne Housing 1960)
- Neave Brown (Alexandra Road Housing 1978)
- Patrick Hodgkinson (Brunswick Centre Housing 1968)
- John Andrews (Scarborough College 1964-65)
- Paul Rudolph [1918-] (Lower Manhattan Expressway Project 1970)
- Carlo Scarpa [1906-1978] (Cemetery Brion-Vega 1970-72)

<u>Futurism and Italian Rationalism:</u>

- Antonio Sant'Elia [1886-19161 (Sketch for a Lighthouse Tower 1914)
- Giuseppe and Attilio Terragni (Como War Memorial 1933)
- Giuseppe Terragni [1904-421 (Casa del Fascio 1934)
- the work of Mario Botta -- although in cast concrete modular units (like blocks), adopts the roughness of the material and the simple geometry
- Aldo Rossi [1931-] (Galaratese Housing 1969-76) - not presented, look it up
- reference the periodical Architectural Design on Futurism and Italian Rationalism