

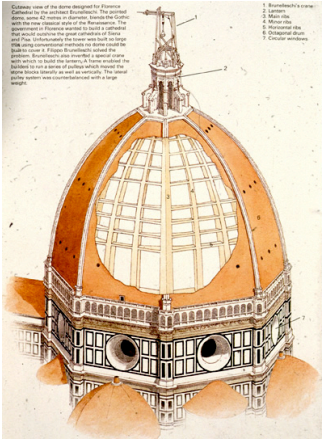


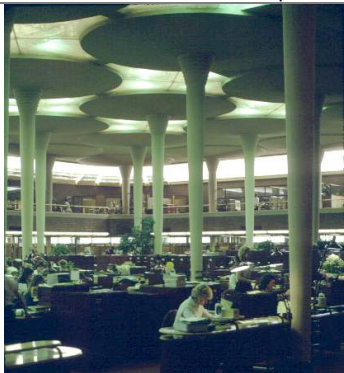

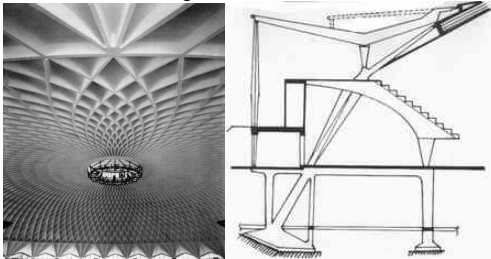



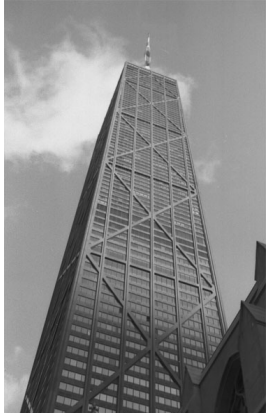


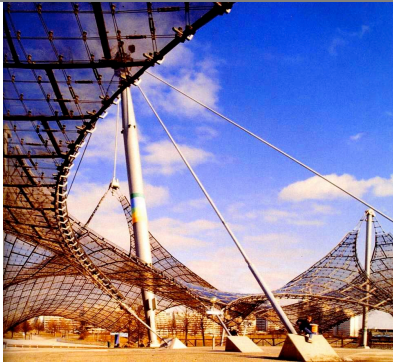






Building Architect/Engineer Date	Structural Description	Picture
<p><u>Pantheon</u> Romans, Year 123 AD</p> <p><i>Concrete Dome = Compression on top, Tension on bottom.</i></p>	<p>Its architects understood intuitively the nature of the stresses in a concrete dome, which the lower part tends to crack because of circumferential tensile stresses. Since they had no material that were strong in tension, their solution was to make the dome walls about 20 feet thick at the bottom, in order to keep the unit tensile stresses low enough to be resisted by the concrete. To reduce the weight of the dome, its underside was coffered.</p>	 <p>Arch, dome, and vault of site cast concrete. Long span.</p>
<p><u>Hagia Sophia, Turkey</u> Anthemius &amp; Isidorus, 537 AD</p> <p><i>Shallow dome supported on pillars, reconstructed after several earthquakes, iron tie around base added in 1847 (tension)</i></p>	<p>Its main dome was shallow and supported by four pillars, through pendentives and arches that rose from the pillars. The arches resisted both vertical forces and outward thrust from the dome; unfortunately, however, the arches did not provide sufficient buttressing, and a portion of the dome collapse in 558 AD. In 1847 an iron tie was placed around base of the dome to resist in tension the outward thrust.</p>	
<p><u>Dome of the Florence Cathedral</u> Filippo Brunelleschi, 1436</p> <p><i>Two masonry domes, thicker inside shell, thinner outside shell, tension rings on bottom. Some was constructed without any centering.</i></p>	<p>There are actually two masonry domes: a thick inner shell and a thinner outer shell. Brunelleschi understood that a dome tends to spread a part, and build in a series of circumferential iron chains to act as tension rings and hold the dome in equilibrium.</p>	
<p><u>Crystal Palace, London</u> Joseph Paxton, 1851</p> <p><i>Steel Frame Construction.</i></p>	<p>Prefabricated Glass and cast iron structure. Fabricated and erected in 6 months.</p>	


<p><u>Fallingwater, PA</u> Frank Lloyd Wright, 1936</p> <p><i>3 story masonry structure. 6 concrete cantilevers over water.</i></p>	<p>3 story masonry structure. 6 concrete cantilevers over water.</p>	
<p><u>Nervi's Airplane Hangars Italy</u> Pier Luigi Nervi, 1936-1939</p> <p><i>Lamella roofs, short concrete pieces connected.</i></p>	<p>His airplane hangars built for the Italian Air Force, between 1936-1939, had lamella roofs formed by short prefabricated reinforced concrete members connected at their joints.</p>	 <p>Barrel shell or vault ribbed at Orvieto Airport.</p>
<p><u>Johnson Wax Building, WI</u> Frank Lloyd Wright, 1939</p> <p><i>Slender mushroom-like columns flare at top to support roof.</i></p>	<p>Perhaps the most interesting element of this building is a great work space with slender mushroom-shaped concrete columns that flare out at the top to support the roof. The structural columns, ceilings, and lighting form an integral design and provide space with virtually no sense of enclosure.</p>	
<p><u>Yale University Skating Rink, CT</u> Eero Saarinen, 1958</p> <p><i>Steel cables hung from a central reinforced concrete arch, wood roof partially stabilized by cables.</i></p>	<p>Steel cables in tension are the essential structural element. Steel cables are hung from central reinforced concrete arch. The outer ends of the cables are anchored to heavy curved perimeter walls. The roof is wood, the weight of which partially stabilizes the cables.</p>	





<p><u>Palazzetto Dello Sport, Rome</u> Pier Luigi Nervi, 1960</p> <p><i>Ribbed concrete shell dome, supported on 36 Y-shaped buttresses.</i></p>	<p>Its roof, a ribbed concrete shell dome, is supported on 36 Y-shaped concrete buttresses which resist the forces at the edge of the shell.</p> 	 <p>Site cast concrete. Long span. A domed sport arena.</p>
<p><u>Dulles Int. Airport, Washington</u> Eero Saarinen, 1962</p> <p><i>Concrete roofs supported on steel cables, which are suspended from concrete columns, that lean outwards to balance inward pull of cables.</i></p>	<p>The concrete roof is supported by steel cables that are suspended between huge concrete columns, that lean outwards to balance the inward pull of the cables.</p>	
<p><u>CBS Building, NY</u> Eero Saarinen, 1964</p> <p><i>42 story structure, resist loads inner core and perimeter walls, piers are granite clad.</i></p>	<p>This 42 story structure, resist lateral forces by both inner core and perimeter walls, which consist of concrete piers five feet long apart.</p>	



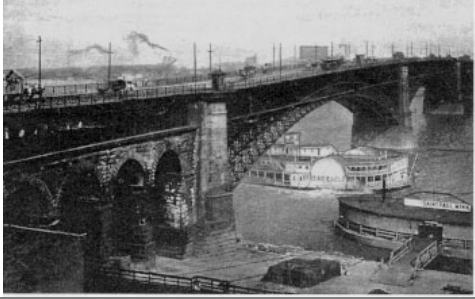

<p><u>Toronto City Hall</u> Viljo Revell 1965</p> <p><i>Two curved office slabs surround a low circular city council chamber. Each wall is a curve that inherently resists overturning.</i></p>	<p>Each office tower is a huge curved shell that provides strength and rigidity against overturning forces caused by wind or earthquake.</p>	
<p><u>Houston Astrodome</u> 1965</p> <p><i>9.5 acre steel lattice dome, 710' diameter weight is only 30 PSF.</i></p>	<p>First of such structure: domes enclosing stadiums. It weights less than 30 PSF, one twentieth of the weight of Brunelleschi's inner dome in Florence.</p>	
<p><u>First National Bank, Chicago, IL</u> Perkins &amp; Will, 1966</p> <p><i>Superframe (rigid frame) stiff horizontal trusses connected to massive exterior column, slender profile tapers gracefully to wider column at ground.</i></p>	<p>This building has a slender profile that tapers gracefully to a wider base in order to resist wind overturning forces more effectively. It utilizes a special type of rigid frame called super-frame or mega-frame. This consists of a very deep, stiff horizontal truss or girder wherever a mechanical floor occurs, about 15 to 20 stories apart, connected at each end to a large exterior column. The interior column and horizontal girders at the other levels form a secondary rigid frame.</p>	
<p><u>John Hancock Building, Chicago</u> SOM Skifmore, Owings and Merrill, 1968</p> <p><i>100 story, tapered form, large exterior X bracing trussed tube system.</i></p>	<p>"Big John" is a gigantic trussed tube, which is very efficient in resisting wind forces. The overall dimension of the building is utilized to resist overturning forces, while the truss members resist shear by direct stress, rather than bending.</p>	




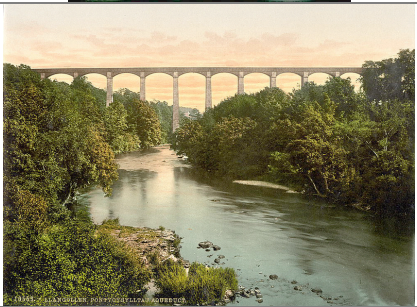
<p><u>Knights of Columbus Building</u> Roche &amp; Dinkeloo, 1969</p> <p><i>26 story, 4 corner concrete towers that supports 80' steel girders that support steel floor structure. Corner towers resist lateral forces as circular cantilevers from the foundation.</i></p>	<p>Its four corner tower constructed of concrete with dark brick ... support the main 80 foot long horizontal st... girders, which in turn support the steel fl... structure. The towers also resists horizontal .... Or earthquake forces by acting as huge circular tubes which cantilever from the foundation.</p>	
<p><u>US Pavillion at Expo 70, Japan</u> David Geiger, 1970</p> <p><i>Inflatable roof, vinyl membrane, w/stiffening steel cables anchored to concrete compression ring. Roof resists air pressure inside and wind outside.</i></p>	<p>An incredible 100,000 square foot inflatable roof made of a special vinyl membrane, with stiffening steel cables anchored to a concrete compression ring around the perimeter. The roof was designed to resist wind forces, as well as the air pressure inside the pavilion. This building was a pioneering effort by engineer David Geiger in the field of pneumatic structure.</p>	 <p>David Geiger = Designer of pneumatic structures.</p>
<p><u>Munich Olympic Stadium</u> Frei Otto, 1972</p> <p><i>Series of steel cable nets stretched between steel masts anchored to the ground with steel cables. Plexiglas covers net surface.</i></p>	<p>It is an immense high-tech tent! A tensile structure. A series of steel cable nets was stretched between steel masts that were anchored to the ground by steel cables. The net surfaces, covered with Plexiglas, were shapes of double curvature for stability.</p>	
<p><u>Federal Reserve Bank Building, Minneapolis</u> Gunnar Birkets, 1972</p> <p><i>Two sets of cables are catenary shape.</i></p>	<p>Two sets of <u>cables</u>, draped in the shape of a <u>catenary</u>, supports the building's vertical loads and are anchored to 2 concrete towers (275' span)</p> <p><b>Catenary = funicular shape for an unloaded cable, determined &amp; dictated by the weight of the cable. More Sag &gt; Less Thrust.</b></p>	



<p><u>World Trade Center, NY</u> Minoru Yamasaki, 1972</p> <p><i>110 stories each tower, exterior columns at 3' o.c. connected by spandrels.</i></p>	<p>The structure system comprised exterior columns only three feet apart connected by deep spandrels, so that the entire tower became an immense hollow cantilever tube.</p>	
<p><u>Sears Tower, IL</u> SOM, Skifmore, Owings and Merrill 1976</p> <p><i>Bundle of 9 tubes, each tower is a cantilevered tube.</i></p>	<p>Is Bundle of 9 tubes, each tower is a cantilevered tube.</p>	
<p><b>Notable Engineer</b> <b>Date</b></p>	<p><b>Structural Description</b></p>	<p><b>Picture</b></p>
<p><u>Felix Candela 1910</u></p> <p><i>Thin shell concrete roofs.</i></p>	<p>Candella believed that strength should come from form not mass. This belief led to an extensive exploration of tensile shell structures. His nickname became "The Shell Builder" because of this structural favoritism.</p>	 <p>Oceanografic 1997. Site cast concrete. Long span. Hyperbolic Paraboloid.</p>

<p><u>Gustave Eiffel</u> 1832-1923</p> <p><i>Great strength and beauty.</i></p>	<p>Designer of Eiffel Tower.</p> <p>Eiffel was a master of elegantly constructed <u>wrought-iron lattices</u>, which formed the basis of his bridge constructions and led to his project for the Eiffel Tower. He was mainly recognized as an engineer and bridge builder.</p>	
<p><u>Eudene Freyssinet</u> 1879-1962</p> <p><i>Prestressed concrete.</i></p>	<p>He developed pre-stressed concrete. Considered the "<u>father of pre-stressed concrete</u>"</p> <p>Airship hangars at Orly Airport, France (1921) The skin has a corrugated cross section that allows efficient resistance to secondary bending moment.</p>	
<p><u>Fazlur Khan</u> 1930-1982 <i>SOM Engineer Structural ideas.</i></p>	<p>Known as "Einstein of Structural Engineering", designer of John Hancock Center and <u>Sears Tower</u>.</p>	<p>Refer to Sears Tower.</p>
<p><u>Robert Maillart</u> 1872-1940</p> <p><i>Reinforced concrete.</i></p>	<p>Known for his <u>radical use of reinforced concrete</u> which revolutionized masonry arch bridge design.</p> <p>Primarily an engineer, Maillart gained notoriety through his innovative bridge designs. Maillart utilized the structural strength and expressive potential of reinforced concrete to generate a modern form for his bridges. To avoid structural beams and arches, he established a structural form based on both flat and curved concrete slabs reinforced with steel.</p>	 <p>Salginatobel Bridge 1930.</p>

<p>Pier Luigi Nervi 1891-1979</p> <p><i>Lamella.</i></p>	<p>Internationally renowned for his design of <u>large-span structures built of reinforced concrete.</u></p> <p>Alcanzó su mayor desarrollo en el Palacio de Exposiciones de Turín (1948-1950).</p>	 <p>Exhibition Building, Turin 1949. Long span reinforced concrete.</p>
<p><u>John Roebling 1806-1869 and his son Washington Roebling 1837-1929</u></p> <p><i>Lightness with strength.</i></p>	<p>A pioneer in the <u>construction of suspension bridges.</u> Best known for building of <u>Brooklyn Bridge.</u></p> <p>In 1841 Roebling invented the twisted wire-rope cable, an invention which foreshadowed the use of wire cable supports for the decks of suspension bridges. Because the cable could support long spans and extremely heavy loads, Roebling quickly gained a reputation as a quality bridge engineer.</p>	 <p>Brooklyn Bridge</p>
<p><u>Eduardo Torroja 1899-1961</u></p> <p><i>Concrete shell structures.</i></p>	<p>Roof for the Zarzuela Hippodrome <b>1925.</b> Site cast concrete. Long span. Cantilevered concrete barrel Shell.</p>	 <p>Site cast concrete. Long span. Cantilevered concrete barrel Shell.</p>
<p><b>Others:</b></p>		
<p>Othmar Ammann</p>	<p>Master bridge engineer</p> <p><u>Bronx Whitestone Bridge</u> is a suspension bridge that crosses the East River and connects the boroughs of Queens and The Bronx. The bridge was opened to traffic with four lanes on April 29, <u>1939.</u></p>	

<p><u>Benjamin Baker</u></p>	<p>Designer of the <u>Forth Bridge</u> in Scotland.</p> <p>The main spans comprise two 680 feet cantilever arms supporting a central 350 ft span girder bridges. The three great four-tower cantilever structures are 340 ft (104 m) tall, each 70 ft diameter foot resting on separate foundations.</p>	
<p><u>Horst Berger and Frei Otto</u></p>	<p>Design of tent structures.</p> <p><u>Denver International Airport</u>. Tensile Architecture</p>	
<p><u>James Eads</u></p>	<p>Eads Bridge 1874 over the Mississippi, the <u>first major structure built of steel</u>.</p>	
<p><u>Buckminster Fuller</u></p> <p><i>geodesic dome</i></p>	<p>Inventor of the <u>geodesic dome</u>.</p> <p>A geodesic dome is an almost spherical structure based on a network of struts arranged on great circles (geodesics) lying on the surface of a sphere. The geodesics intersect to form triangular elements that create local triangular rigidity and distribute the stress. It is the only man made structure that gets stronger as it increases in size.</p>	 <p>The American Pavilion of Expo '67</p>

<p><u>TY Lin</u></p>	<p>Master of <u>prestressed concrete</u>.</p>	
<p><u>Elisha Graves Otis</u></p>	<p>Inventor of <u>passenger elevator</u>.</p>	
<p><u>Auguste Perret</u></p>	<p>Father of <u>reinforced concrete</u>.</p> <p>Notre Dame du Raincy, France 1922. Reinforced concrete. Shallow concrete vaulted ceilings and gossamer window walls.</p>	
<p><u>Thomas Telford</u></p>	<p>Engineer of iron bridges.</p> <p>Pont Cysyllte Aqueduct 1805. Masonry and cast iron. 1000 foot aqueduct with cast iron canal trough and tow path on 19 masonry piers 120' high.</p>	

Building Architect/Engineer Date	Structural Description	Picture
<p><u>Home Life Insurance Building, Chicago</u> William Le Baron Jenney, 1885 demolished (1931)</p> <p><i>Steel Frame Construction.</i></p>	<p>William Jenney = Designer of steel frame buildings.</p> <p>The Home Insurance Building was one first from an iron skeleton designed multistoried buildings, that with its ten floors over the height usual five to six projectiles exceeded. The steel framing was fireproofed with masonry, and the exterior masonry facings were supported on steel frame.</p>	<p>No Photo</p>
<p><u>Marshall Field Warehouse, Chicago</u> Harry Hobson Richardson, 1887</p> <p><i>Stone Masonry.</i></p>	<p><i>Building Type:</i> commercial warehouse <i>Construction System:</i> cut stone bearing masonry <i>Notes:</i> Block scale coherent ordering of facade creating a strong presence without use of historical detail.</p> <p>Richardson used the textured monochromatic surface of the granite and brownstone masonry to provide visual interest, supplemented only by a chamfer at the corners and an enriched terminal cornice.</p>	 <p>Rested on a two story base of red granite. Its upper walls were built of red sandstone, and its interior was framed with heavy timber.</p>
<p><u>Wainright Building, St. Louis</u> Louis Sullivan, 1891 (demolished 1931)</p>	<p><i>Building Type:</i> early skyscraper, commercial office tower <i>Construction System:</i> steel frame clad in masonry <i>Note:</i> An early tall building (10 stories) with an all steel frame. The Chicago School.</p>	

<p><u>Monadnock Building, Chicago</u> John Root, 1891</p> <p><i>Reinforced Brick Masonry.</i></p>	<p><i>Building Type:</i> early skyscraper, commercial office tower <i>Construction System:</i> bearing masonry</p> <p>In spite of Root's artistic achievement in making the tall building a unified, coherent statement, it was structurally traditional, employing cast iron and wrought iron framing only for window spandrels and the internal frame. Consequently the walls at ground level had to be six feet thick to carry the upper floors (18 inches thick at the top); this massive bulk then rested on an immense iron and reinforced concrete raft.</p>	
<p><u>Reliance Building, Chicago</u> CB Atwood, 1894</p>	<p><i>Building Type:</i> early skyscraper, commercial office tower <i>Construction System:</i> steel frame clad with terra cotta <i>Note:</i> A key precedent for the modern skyscraper.</p> <p>It consisted of a riveted steel-frame superstructure, hollow-tile flooring on steel joists, plaster fire-proofing, perimeter bay windows filled with plate glass, steel-trussed wind bracing and bedrock concrete caissons sometimes extending for as much as 125 feet beneath the footing.</p>	

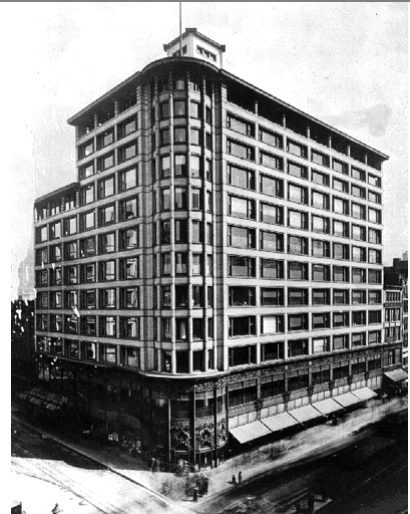
Guaranty Building,  
Buffalo  
Louis Sullivan,  
1895

The Guaranty Building stunningly illustrates Sullivan's famous statement that "form follows function." The building's intricate terra cotta ornamentation, for example, accentuates its structure. The piers between the windows form strong vertical lines that draw the eye upward to the dominant cornice. Yet, despite the technological advancements that made the skyscraper possible (such as structural steel and elevators), Sullivan strove to connect it with the natural world. His ornamentation for the Guaranty Building was inspired by flowers, seedpods, and even, at the top of the building, the spreading branches of a tree.



Carson, Pirie, Scott  
Department Store,  
Chicago  
Louis Sullivan,  
1904


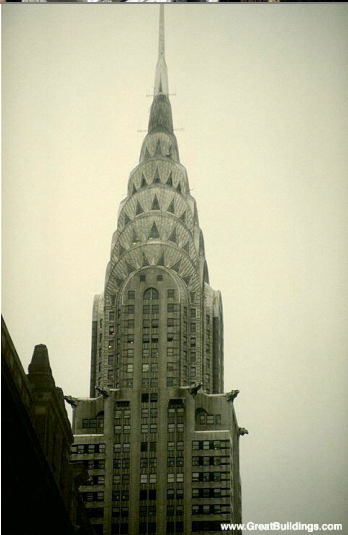

One of the most important structures in early modern architecture, famed for its influential modular construction and design. Visionary architect Louis Sullivan shaped this commercial building--originally built for the Schlesinger and Mayer department store--into a dramatically animated structure that inseparably merges beauty and function. The ornament of the lower two stories is frozen in cast iron, while at the same time giving the impression of being in fluid motion. It is an excellent example of Sullivan's genius for architectural ornament.






Metropolitan Life,  
NY  
Napoleon Le Brun  
& Son,  
1909

World's tallest building from 1909 - 1913



<p><u>Woolworth Building,</u>  <u>NY</u>  Cass Gilbert,  1913</p>	<p><i>Building Type:</i> corporate headquarters, early skyscraper  <i>Construction System:</i> terra cotta cladding  <i>Note:</i> 60 story tower with Gothic ornamentation.</p>	
<p><u>Chrisler Building,</u>  <u>NY</u>  William Van Allen,  1930</p>	<p><i>Building Type:</i> skyscraper, commercial office tower  <i>Construction System:</i> steel frame, metal cladding  <i>Notes:</i> Stainless steel metal ornamented top. Automobile-derived ornamental details. Elegant lobby.</p>	
<p><u>Daily News, NY</u>  Raymond Hood,  1930</p>	<p><i>Building Type:</i> Newspaper offices and printing plant  <i>Construction System:</i> steel frame, brick cladding</p>	

<p>Empire State Building, NY Shreve, Lamb / Harmon, 1931</p>	<p><i>Building Type:</i> commercial office tower, skyscraper <i>Construction System:</i> steel frame, stone cladding <i>Notes:</i> 102 floors, 1252 feet, 381 meters high. Effective use of setbacks to emphasize tower</p>	
<p>McGraw Hill, NY Raymond Hood, 1931</p>	<p><i>Building Type:</i> skyscraper, commercial office tower <i>Construction System:</i> terra cotta and glass cladding over steel frame <i>Note:</i> Unusual and attractive use of substantial color on the exterior of a significant skyscraper.</p>	
<p>Philadelphia Saving Fund Society, Philadelphia Howe &amp; Lescaze, 1932</p>	<p><i>Building Type:</i> corporate headquarters, skyscraper, commercial office tower <i>Construction System:</i> steel frame, granite, limestone, &amp; brick cladding <i>Note:</i> "Philadelphia Saving Fund Society". elegant, subtly sculpted slab masses. "a summation of European Modernism"</p>	

Rockefeller Center, NY  
Raymond Hood,  
1933

*Building Type:* skyscraper complex, commercial office towers  
*Construction System:* steel frame, stone cladding  
*Note:* Family of forms example, a fine urban ensemble, with a famous sunken plaza with outdoor skating rink. With others, including Wallace K. Harrison, Max Abramovitz, the firms of Reinhard & Hormeister and Corbett, Harrison, & MacMurray.



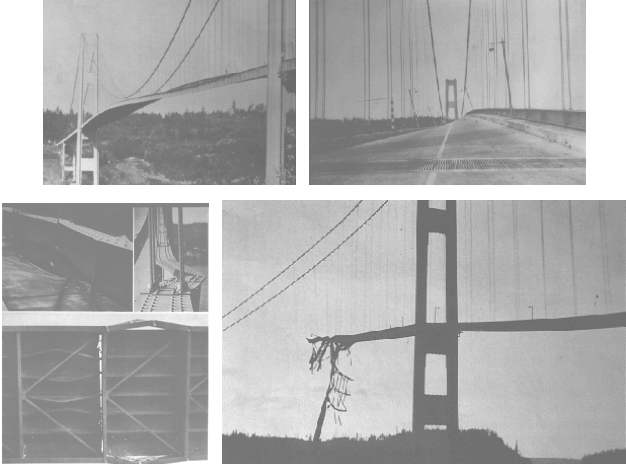
Paramount, San Francisco  
Pankow Residential Builders

*tallest precast concrete building*

The Paramount, located in the South Market area of downtown San Francisco, is the tallest precast concrete building in a high seismic zone in the United States. The striking 39-story residential apartment tower, completed in 2001 by Pankow Residential Builders II, L.P., includes 486 apartments and parking for 350 cars in a total of 660,000 square feet of building area. The Paramount is also the first significant application of the Precast Hybrid Moment Resistant Frame (PHMRF) System.

In simple terms, the make-up of the joint using the PHMRF system allows it to work like a shock absorber to accommodate and counter the seismic forces that cause a building to sway when an earthquake strikes.



Building Architect/Engineer Date	Structural <u>Failure</u> Description	Picture
<p><u>Tacoma Narrows Bridge Disaster</u> 1940</p> <p><i>Stiffening the deck laterally provides resistance to wind loads.</i></p>	<p>The bridge was an unusually light design, and, as engineers discovered, peculiarly sensitive to high winds. Rather than resist them, as most modern bridges do, the Tacoma Narrows tended to sway and vibrate. This progressively worsened due to harmonic phenomena.</p>	
<p><u>Hyatt Regency Hotel, Kansas</u> 1981</p>	<p>Two suspended walkways. 113 dead, 1981 injured. In terms of casualties, the most devastating structural collapse ever to take place un USA.</p> <p>Experts found that the design of critical connections in two walkways had been changed from the original plans and did not meet local building codes. Their findings led the American Society of Civil Engineers to adopt a document that for the first time assigned responsibility for various aspects of the construction process.</p>	