

A brief history of the World Trade Center Towers

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Abstract

The history of the World Trade Center can now be fully written. The buildings no longer exist, the site has been cleared and plans are beginning to emerge for the next manifestation of buildings and open space for the area bounded by Vesey, Liberty, Church and West Streets. The complete redevelopment of this area was brought about through the influence and interest of the Rockefeller brothers in the 1960s, and its utter destruction accomplished through the insanity of fanatical devotion to a radical and wealthy Saudi. The scorched site now seems to possess a great deal more past than any clearly imaginable future, despite the many proposals for redevelopment already being offered. While the morning of September 11, 2001 still echoes in our memories, these wounded acres of Manhattan Island are now no more and no less than what will be envisioned by the people of New York City. This chapter offers a brief history of the place, the process of development, design and construction and an introduction to several key figures in the making of the World Trade Center - as we once knew it.

Conception

Lower Manhattan has served as the original anchor for the settlement of New York City and continues to be the perpetual symbolic frontier for expectant immigrants and global financial power alike. Lower Manhattan has become the steadfast prow of a business machine that has taken the form of one of the most inspiring and frenetic cities ever built. The glass and metal wall of the financial fortress that lines the island in Upper New York Bay and extends from the Brooklyn Bridge on the East River down and west through Battery Park and up beyond the towers of the World Financial Center and extending to Chambers Street is one of the most imposing and awe-inspiring walls of office towers anywhere in the world. This piece of Manhattan, jutting out into New York Harbor, has also been the location for massive civic renewal through publicly funded real estate investment and commercial office development of extremely high densities. With the birth of the idea in 1946 for a large office development on the lower Hudson, a World Trade Center, New York City was once again launching forth a remaking of itself. In that year, the New York State Legislature articulated a vision of a vast trade, commercial, hotel and convention facility that would complement the growing

international center of finance that Wall Street had become. The project was initiated in the early 1960s through the influence of David Rockefeller in part to reclaim a part of the city that had fallen on hard times. The vision was meant to use the trade facility and urban renewal as tools to clear and revitalize what had become a “commercial slum”. The construction of the towers yielded not only a new frontier for business but also the landfill for a new shore on the banks of the Hudson. Since the early 1980s, the World Trade Center Towers, 110 stories each, were the most prominent mark of the proven success of this vision for the revived future of trade and finance on the island. Until recently, this renewal had seemed a permanent part of New York City, as unmovable and steady as the towers themselves - a clear and indelible binary landmark on the confident skyline of American capitalism. No one expected these buildings to last a mere 30 years.

The World Trade Center project, as it was eventually realized, was the idea of David and Nelson Rockefeller. Consideration of such a center was active since after World War II, but the planning for the development of the lower Manhattan site only began in 1960 when the Downtown-Lower Manhattan Development Association proposed a renewal of the area. Long known for its many electronics stores, the displacement and improvement of “radio row” now became a pet project of the Rockefeller brothers. At the time Nelson was serving as governor of New York State and his brother David was Chairman of Chase Manhattan Bank. When the towers were completed they were nicknamed “David” and “Nelson”. David had also founded the development group and was intent on bringing about a renewal of Lower Manhattan that was of a scale never before seen in New York City, nor anywhere else. The process was long and often bitter and included the demolition of 164 buildings on sixteen blocks and the closing of five streets. The area had been known as a seedy and variously industrial part of the waterfront in Lower Manhattan. Numerous warehouses, retail and repair stores, distribution houses and other small-scale enterprises formed the fabric for a down and out, dark and dangerous part of town. However, the area had its supporters and the negative aspects of urban renewal were beginning to be articulated. With the publishing of “The Life and Death of Great American Cities” Jane Jacobs questioned the real effects of the new planning strategy of urban renewal and stated, “Our present urban renewal laws are an attempt to break this particular linkage in the vicious circles by forthrightly wiping away slums and their populations, and replacing them with projects intended to produce higher tax yields, or to lure back easier populations with less expensive public requirements. The method fails. At best, it merely shifts slums from here to there, adding its own tincture of extra hardship and disruption. At worst, it destroys neighborhoods where constructive and improving communities exist and where the situation calls for encouragement rather than destruction.” [1].

As a result of these and many other written words and mobilization of local community groups, the project began its life with substantial controversy that evolved into a persistent notion that the buildings themselves were out of place and not appropriate to the island of Manhattan and the rest of the city. The architectural and urban design critics were generally not happy with the sheer scale of the buildings, the new impersonal urban relationships created and the conservative aesthetics of the building design itself. Much of the criticism lay at the feet of the designer of the towers, the architect Minoru Yamasaki. Ada Louise Huxtable, wrote that Yamasaki, “has developed a curiously unsettled style, which involves decorative tracteries of exotic extraction applied over structure or worked into it. His choice of delicate detail on massive construction as a means of reconciling modern structural scale to the human scale of the viewer is often more disturbing than reassuring... Here we have the world’s daintiest architecture for the world’s biggest buildings.” [2]. Other critics also lamented the size; a scale that seemed alien to the character of New York City streets. This question of scale and the application of historicist ornamentation was to be an enduring criticism of many of the larger buildings designed by Yamasaki.

Design

After a search that engaged dozens architects and many months, Yamasaki's firm, of Troy Michigan, was chosen as the design architect and Emery Roth & Sons as associate architects for the assemblage of buildings that were to comprise 5 of the buildings within the World Trade Center complex, including both towers. These five buildings were completed at different points between 1970 and 1977. In addition, Skidmore Owings and Merrill designed the Marriot Hotel at 3 World Trade Center and 7 World trade Center was designed by Emery Roth & Sons as lead designer and built in 1987.

Table 1: World Trade Center Buildings

Building	Completed	Height (floors)	Floor plate sizes (sq. feet)	Elevators
1 World Trade North Tower	1970	110	45,000-50,000	97 passenger 6 freight
2 World Trade South Tower	1972	110	45,000-50,000	97 passenger 6 freight
3 World Trade	1980	22	21,000	8 passenger 3 freight
4 World Trade	1977	9	84,500	12 passenger 4 freight
5 World Trade	1972	9	108,400	9 passenger
6 World Trade	1975	8	80,400	8 passenger 4 freight
7 World Trade	1987	47	40,000	30 passenger 2 freight

The complex of buildings, and the two towers especially, were the most important commissions for the architect. At the time, Yamasaki was part of a loose grouping of architects that attended to the needs of the new ideas of urban renewal and mixed-use megadevelopment. His use of primary forms and simple ornamentation allowed for the functional needs of the new and often very large forms of low-income housing projects and the new and ever larger office buildings being commissioned by American and multi-national corporations. He was well enough known in 1963 to be chosen for the cover of Time magazine. At the same moment, he was much criticized for his almost servile attendance to the needs of large corporations. And yet, Yamasaki brought a certain sensitivity of material and form that had been missing from previous proposals for the World Trade Center site. His words were often self-deprecating, humorous and displayed an interest in pursuing a personal vision for a new architecture; even amid the gigantic scale of the forms he was designing. While Yamasaki espoused a conservative architecture of uncompromising modernism, his aesthetic was neither overly harsh nor dogmatic. He favored materials of a softer, gentler feel; woods, smooth and painted concrete, stainless steels and anodized aluminum plate. His buildings often bore the hints of a renewed interest in ornament and figurative form as part of a new modernism.

At the time of his selection as lead architect of the project, Yamasaki's career was progressing very well. His firm had completed important buildings across the United States including; the Saint Louis Airport Terminal, completed 1956, the Michigan Consolidated Gas Company Headquarters, completed in 1963, the Dhahran Air Terminal in Saudi Arabia, completed in 1961, the Woodrow Wilson School of Public and International Affairs at Princeton University, completed in 1965 and the IBM Office Building in Seattle Washington, completed in 1964 among others [3]. After the opening of the World Trade Center, Yamasaki's place in modern architecture was assured and his firm went on to design several more important buildings, many of them towers for corporate clients. And yet, historical perspective has yielded an overall impression of Yamasaki's work as deeply problematic. Many of the most important commissions were greeted with official adulation and followed with sustained yet generally polite criticism. Clearly, here was a man whose life was dedicated to his craft and yet the buildings themselves displayed very little creative fervor while refusing to imply a greater vision for modern architecture. The work was restrained to the point of equivocation not so much in its essential forms, which were boldly modern and abstract, but in the relationships formed with the surrounding context and the building's inhabitants themselves. The buildings, which were rarely modulated by the setting in which they were placed, held themselves apart from streets, adjacent buildings and other physical links to the city. While Yamasaki himself states his keen interest in nature and the environmental context of his work, the buildings themselves seem oddly aloof [3]. This reserve permeated the Trade Center towers. The critics were quick to point to this weakness in his craft while the corporate world, from IBM to Alcoa, were quick to embrace it. The restraint and formality of Yamasaki's ornamental modernism was just what corporate and governmental clients were looking for; a bold *and* polite modernist vision.

Minoru Yamasaki was born in Seattle in 1912 to Japanese immigrant parents from the island of Honshu. While his father worked several jobs to advance the fortunes of the family, Minoru grew up and became aware of the strong racial bias of the time against the Japanese in the Pacific Northwest. Yamasaki writes of these experiences in his book "A Life in Architecture" [3]. He was motivated to become an architect after his uncle, Koken Ito graduated from the University of California in architecture and then headed to Chicago. Yamasaki enrolled at the University of Seattle during the depression and completed his studies funded by spending the summers in fish canneries of Alaska. After graduating, he made his way to New York City, where he found work scarce and had to settle for odd jobs and temporary work in a series of architectural firms. One of his first steady jobs was in the firm of Shreve, Lamb and Harmon, architects of the Empire State Building. Between 1936 and 1943, Yamasaki worked primarily in the production of construction documents for the firm. In the few months before the war, he worked on several design projects for the Department of Defense. After the attack on Pearl Harbor, Yamasaki was investigated by the FBI, the Navy and the Army but was kept gainfully employed by Shreve and, as a result, out of the "relocation camps". His brother and parents also joined him in New York when many of their friends were being directed to leave for the camps.

In 1949, Yamasaki joined with partners George Hellmuth and Joseph Leinweber to establish a firm with offices in Saint Louis and Detroit. Years later, the firm was divided between the two cities and in 1959 Yamasaki struck out on his own forming Yamasaki & Associates in Detroit. Yamasaki died in 1986 at the age of 73.

The firm of Minoru Yamasaki & Associates continues to produce designs for buildings around the world. The firm is located in Rochester Hills, Michigan, a suburb of Detroit. Seven partners now administer the work of the firm.

Leslie Robertson, the other key figure in the design of the towers, was a young member of the the firm of Skilling, Helle, Jackson of Seattle Washington at the time of the design of the towers. Robertson was the most influential engineer on the project and assumed the position of lead structural designer of the towers. Robertson had as much influence on the form of the building as anyone apart from Yamasaki himself. In fact, it is not too strong to assert that the forms of the towers were primarily a combination of the real estate development targets established and possible structural engineering solutions. While the simple forms of the buildings provided many positive attributes for modern commercial offices, such as column-free space, the architectural restraint of the volumes was absolutely necessary for the realization of an efficient structural tube. Robertson understood his role as an innovator; for nothing short of real innovation would allow such a structure to stand and fulfill the space requirements of the client. He was involved in pioneering research regarding the dampening of lateral movement of the towers due to wind pressures. He was also primarily responsible for the lightness of the floor slabs and the rigidity of the tower from using these floors as structural diaphragms.

Construction, completion and occupation

The building of the towers was an endeavor at the scale of municipal infrastructure. Five streets were closed and clearance of the site provided 16 acres for the new project. Two subway lines on the site were kept running as the foundations and basements were built around them. Construction began in 1965 and it was formalized with a groundbreaking ceremony on August 5, 1966 and finally completed with the occupation of Tower One in 1970 and Tower Two in 1972. In total, the entire complex contributed to Lower Manhattan more than 10 million square feet of office space, several hundred hotel suites, the most successful retail center in the city, an extremely busy transportation hub and dozens of service and support businesses in seven buildings.

The construction of the towers was an unique engineering challenge from the very beginning [4][5][6]. With the excavation of the foundations, the construction team had to find solutions to problems never before encountered at such a scale. With the use of slurry walls, the first time this type of foundation wall was used in the US, the construction had to proceed through highly creative solutions of materials handling, erection sequencing, joint detailing, structural engineering and architectural design.

The foundations for the towers reached down to bedrock an average of 70 feet below grade. With the excavation of 1.2 million cubic yards of earth, 23.5 acres of new land for Manhattan were created on the shores of the Hudson River. Eventually the office towers and wintergarden of the World Financial Center, designed by Cesar Pelli, and several apartment buildings were built on this new land.

The material expenditures on the towers were enormous; 192,000 tons of steel, 425,000 cubic yards of concrete, 43,600 windows with 572,000 square feet of glass, 1,143,000 square feet of aluminum sheet, 198 miles of ductwork and 12,000 miles of electrical cable. The towers also provided an extraordinary employment opportunity for the construction workers of the region. More than 3,500 people were employed continuously on site during construction. A total of 10,000 people were involved in its construction. Tragically, 60 people were killed during construction.

The history of the tower form can be conceived of as the history of the relation between several building systems and their ability to address the issues of circulation, fire and structural efficiency and integrity. In the early days of tall buildings, the dominant building

system relationship came between the exterior envelope and the structure. Later as towers reached higher into the sky, the mode of vertical circulation through elevators and the various systems used to monitor and suppress fires and the egress systems came to play extremely important roles as well.

The World Trade Center Towers used a type of perimeter tube structure along with an interior steel frame to resist the lateral shear and moment imposed on it by the accumulated wind pressure. Both the frame and the perimeter tube also contributed to transferring the internal loads of the building down to the foundations.

The inner steel frame housed the elevator cab shafts, mechanical shafts and other support spaces necessary on each floor. The outer tube served as the framework for the exterior wall and was made by bolting together hundreds of premanufactured 3-story tall rigid steel frames. These rigid frames carried both the internal dead and live loads from the floor plates as well as in-plane stresses. The designers were careful to alternate the height of adjacent rigid frames so that they avoided creating a continuous joint around the circumference of the tube. The elevator shafts were recruited during construction to serve double duty by being incorporated into the hydraulic lift system that secured and lifted the construction cranes.

The structure of the floors was a prefabricated unit of open web steel joists with an in-situ structural concrete slab. The floors tied together the exterior perimeter columns and the interior steel frame to resist twisting, or torsion, of the tower. The World Trade Center was one of the first structures to undergo a series of wind tunnel tests as an integral step of the structural design process.

Another innovation of the towers was the use of viscoelastic dampers to counteract oscillation of the building. This was accomplished at the bracing on the lower chord of the open web steel joists. Two layers of a high density polymer were sandwiched between steel plates that connected the joists with the perimeter box columns. These sandwiches absorbed the energy from the lateral force imposed upon the structure by the wind and released it, in the form of small amounts of heat, enabling the structure to delay the effect of the lateral load and “dampen” its resulting movement [7].

At completion the towers of the World Trade Center were the world’s tallest until the Sears Tower in Chicago gained that title in 1974.

The Towers in the life of the city

During their lifetimes the towers were host to the birth of 17 babies and 19 murders. Fifty thousand people called the towers their place of work and on many days tens of thousands visited.

In 1993, the towers were attacked by terrorists who entered an underground garage and detonated a bomb that did substantial damage to several floors of the garage but left the towers intact. The bomb was extremely powerful containing 1200 pounds of urea nitrate. Six people were killed. On September 11, 2001 terrorists attacked the towers using two airliners to crash into and cause the collapse of both buildings. Each building was struck at a different height and angle. Preliminary analysis seems to indicate that the two suffered damage in different areas of the exterior wall and core and, as a result, their individual progressive collapse mechanisms were also distinct. In the end, each tower was felled by the initiation of a critical progressive collapse that toppled each building in a near free-fall condition.

Some buildings in a city become daily landmarks, confirmations of place and physical constants by which to personally gauge the subtle changes of the city. The World Trade Center Towers were just such buildings. One example is the way in which residents of the city use

buildings to assess the daily weather. Is the top of the Empire State building obscured by clouds this evening? People who live in large cities are keenly aware of their environment; the particular spectrum of autumn light as it reflects off of aluminum panel and metal coated glass, the subtle changes in temperature as one passes the open doors of an office building's lobby, the clarity of the day as measured by the extent of one's view down an avenue. In this sense, the physical presence of the largest buildings in cities can lend a humanizing, reassuring anchor for one's place in a familiar environment. This intimacy with one's environment is exactly the opposite of what one might expect of living in a city. Yet, these personal measures are quickly acquired and easily processed from the physical context in which people live, whether it be the country or the city. They form one's daily mental construct of the context for living. Certain measures are at the scale of the street, the shop front, the corner deli. Others are at the scale of infrastructure, the large machine that is the city. And some are on the scale of infrastructure, the bridges, the subway trains, the tallest buildings. The World Trade Center was at the scale of infrastructure.

From far uptown on the west side, the Towers' presence was a reminder of the extent of the island; a limiting parameter of the landmass within which was contained all of the neighborhoods of Tribeca, Chelsea, Times Square, Midtown. Their sheer scale and metal armor served in the way that distant mountain ranges delineate the extent of a valley.

Their presence was also a reminder of the role of the island. The commerce, the intensity of capital in flux, the streaming trade giving legitimacy to the haughty authority that the name, World Trade Center, so embodied when it was first built. In fact, the first few years after construction were difficult ones and the wisdom of its conception were, at the time, roundly questioned. The complex experienced persistent economic difficulty, especially at its opening and during the fiscal crisis and eventual bankruptcy of the city in the 1970s. The buildings, as a viable enterprise, struggled and only turned a corner when the Port Authority itself decided to partially justify its development by occupying parts of the towers. The initial severity of the simple form gave way to a no-nonsense presence. These were buildings that housed commerce, facilitated business and went about daily events within a restrained cage of steel. What was remarkable about the towers was their sheer scale. Arriving at the center from subway tunnels below the street, the stance of the two towers spoke of forces that were global in reach. It was as if the scale of the towers was of another world, a world beyond the expanse of the island itself. This is the scale that was marked for destruction, this global reach; symbols of a dominant power.

As Nathan Silver has written, buildings in cities "become constituent to the psyche" [8]. As much as the towers were criticized for their lack of connection to the old New York and their imperial stance, the fact that they were there at all meant that they had become a part of the city; that part of the city that New Yorkers, visitors and people around the world carried around as part of their psyches. With their absence, the loss is as much psychological as it is physical or economic. For this reason, their demise is all the more poignant. These towers, in the pride of scale that was uniquely their own, announced their confidence every morning with the rise of the sun. They displayed their metallic torsos with as much pride as a youthful athlete. They were unfazed by the decades of less than complimentary commentary. They were serving the business community well and, presumably, were here to stay.

During the attack, the ingenious engineering of the young Les Robertson kept them standing for a short, but critical period of time. Their simple forms were critically wounded and as we now know, the structural redundancy inherent in the tubular forms allowed hundreds to escape with their lives. The work of Minoru Yamasaki and Leslie Robertson allowed dozens to escape down the fire stairs and out through the lobbies and pedestrian bridges to safety. But the strikes had been too large, the aim of the terrorists too precise and soon afterwards the inconceivable collapse of each tower rendered an entire world transfixed in sadness. And yet

as buildings, their inability to fend off the strikes despite their size and bulk, made us deeply sad. These buildings, once seemingly indestructible, proved critically and tragically vulnerable. In the end, their confident occupation of the sky to heights never before achieved placed them in the deadly territory of hijacked airplanes. It had never occurred to anyone that this space could become deadly beyond comprehension through the simple replacement of a dedicated pilot with a determined terrorist. It never occurred to anyone. And as a result of this understandable lack of imagination for the horrific, these towers paid the price that no other modern skyscraper ever has, complete collapse.

Futures

Recently, ideas for a redevelopment of the site have been one of the passionate discussions surrounding the events of last September. In New York's past, optimistic and ultimately transformative periods of rebuilding have followed catastrophes, such as after the fires of 1835 [9]. And after the initial study presented to Congress by FEMA and ASCE, it is clear there is substantial work to be done, both in analyzing the events of the attack and in assessing current vulnerabilities [10].

Therefore, as anyone knows that has lived or continues to live in Manhattan, the loss is felt at every scale of experience, intellectually and physically, economically and socially. There is no aspect of the life of New York City that has not been touched by the destruction and now the powerful absence of these buildings. The negation of these buildings figures prominently in our minds and hearts. Only a renewal of effort, a rebuilding, and most importantly the passage of time will be enough to continue the history of the towers.

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