Bridging River's Edge Sports Complex

A STUDY IN STRUCTURE

BY
ROBERT L. THOMAS
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APPROVED BY:

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Paul Clark, Chairman

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Mario Cortes

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Bill Green

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Introduction

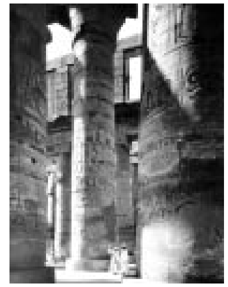
I think that a great step towards a new, true, structural architecture will have been made as soon as designers are convinced that every part of a structure has - in itself, and in its relationship to the materials of which it is built and to its specific static functions - a potential, intrinsic, formal richness, and that the essence of a structural project and the widest field for the manifestation of personal sensitivity consists in accepting, interpreting and rendering visible these objective requirements.

-Pier Luigi Nervi

Between the size of the house and that of the tower or the bridge lie the buildings on which most architects focus their attention. At that in-between scale, whether or not structure is expressed, is a function of the architect's personal morality of form . . . (However), when the span is large or the building high, the flow of forces insists to be recognized.

-Peter McCleary

In the past, the structure of the building was more evident: unobstructed columns revealed the amount of force being carried through their degree of slenderness; flying buttresses counteracted the lateral force of a specific load; even the load bearing walls indicated the pressures being withstood by their varying thicknesses. Today many architects have disguised their buildings with an all encompassing curtain wall facade that hides its structural composition. The trend to mask structure in the work of architecture overlooks the potential of structure to add to a building's design. Louis Kahn believed "the artist instinctively keeps the marks which reveal how a thing is done." There is an innate human desire to understand the function and stability of a building, and the clarity of the structural design is a foundation for this understanding. When asked a question concerning the role of structure in architecture, Pier Luigi Nervi stated, "Structural correctness . . . is identical with functional, technical and economic truthfulness and is a necessary and sufficient condition of satisfactory aesthetic results."



Massive unobstructed columns in the Hypostye Hall of the great temple complex at Karnak, Egypt.

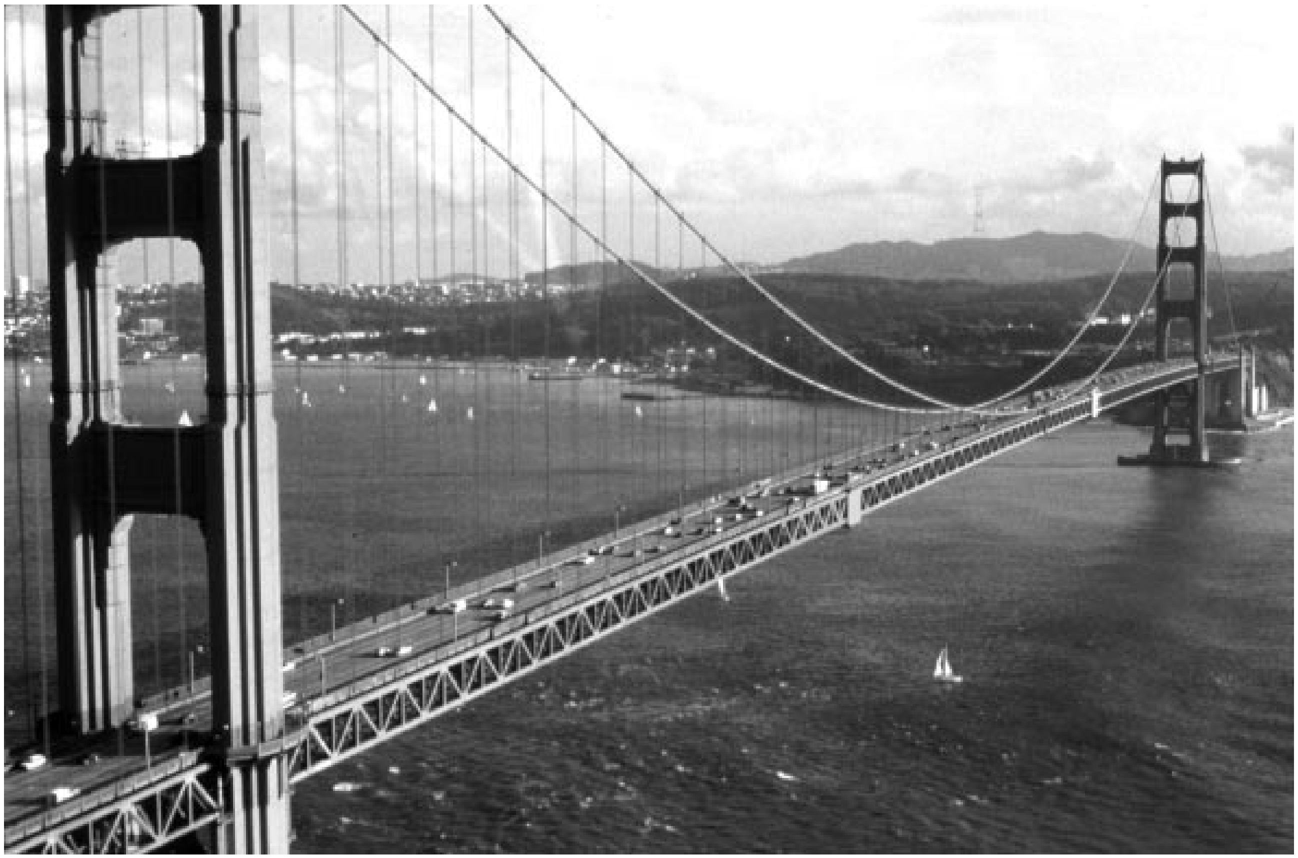
At Notre Dame Cathedral in Paris, France, flying buttresses elegantly resist the lateral forces of the roof.

Notice the window depths in the load bearing walls of the Monadnock Building in Chicago. The walls vary from 18 inches at the top to 6 feet at the base.

In the present project, I explore this issue of revealing the structural integrity of a building through the design of a recreational sports facility. The designated site for this sports facility is the River's Edge Sports Complex located in Roanoke, Virginia. A unique setting because the Roanoke River nearly cuts through the center of this site dividing the northern half with the existing football stadium, Victory Stadium, the National Guard Reserve Armory, and Maher Baseball Field from the southern portion containing athletic fields, tennis courts, and a playground. In order to consolidate the facilities into one sports complex, I propose a number of interventions including a bridge building, observation tower, coliseum, natatorium, racquetball courts, and exercise rooms. The goal of providing a smooth unifying path over the river, while creating a unique setting, presents an intriguing architectural challenge. The investigation focuses on the appropriate architectural expressions and structural possibilities of the long spanning bridge building since it is the central unifying element of the sports complex.

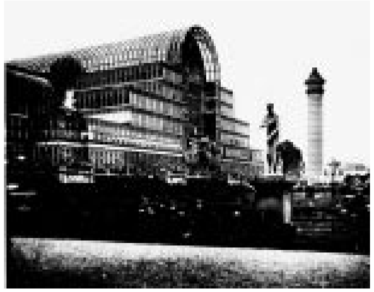
Modern Structural History

AN ARCHITECTURAL LOOK AT SPAN AND HEIGHT



Considered an international symbol because of its architectural excellence, the Golden Gate Bridge also has the tallest towers of any bridge, and one of the longest spans in the world.

Modern structural architecture was born 146 years ago in London, England with the construction of William Paxton's celebrated Crystal Palace (see figure). Although it was a very large building with significant spans, the Crystal Palace was assembled and dismantled with unheard of efficiency due to its modular design and use of prefabricated components. Also, unlike the masonry buildings of its time, only an iron lattice work supported the uniform sheets of glass in wood used throughout the building. This famous glass and iron building presaged the prefabrication and demountability of metal frame construction which has totally altered the structure and design of architecture in the twentieth century. The design of the Crystal Palace was so revolutionary that it remained at the forefront of building progress until the erection of Eiffel's timeless tower in Paris in 1889.



Crystal Palace

When the Eiffel Tower was completed it soared nearly twice as high as the Washington Monument, the tallest structure during that time. Through his knowledge gained from building high railroad viaducts through the windy valleys of the Massif Central, Eiffel designed the nearly transparent structure with graceful tapering lines to resist the force of wind (see figure). This tower was not only the first truly large-scale industrialized construction project, but also exemplified harmonious integration of architecture and engineering. For the first time in history the design of a large public project was not dictated by formalistic preconceptions, but was truly an abstract form rooted in the laws of physics. Eiffel's ingenuity also made possible the physical construction of this project. All the sections were prefabricated off-site because of time constraints and the enormous size of the structure. Additionally, hydraulic jacks were placed at the base of each leg so the tower could be raised or lowered into perfect alignment - an invaluable idea since two and a half million rivets, locking 12,000 pieces together, needed to line up perfectly.

Eiffel Tower

In the United States, bridge construction pushed the envelope of structural knowledge with singular daring: the most famous during this time being John and Washington Roebling's Brooklyn Bridge, another engineering triumph and work of art. Hailed as the eighth wonder of the world when completed, the Brooklyn Bridge was the world's longest suspension bridge with a span of 1600 feet. Its two massive Gothic towers soared 276 feet above the river, and the four main cables suspended from these towers were an enormous 16 inches in diameter. One of John Roebling's many innovations, the slanted cable or "stay", was used along with the suspension cables to help keep the roadway steady in high winds (see figure). He also invented a "traveling-wheel" rig for this project which enabled

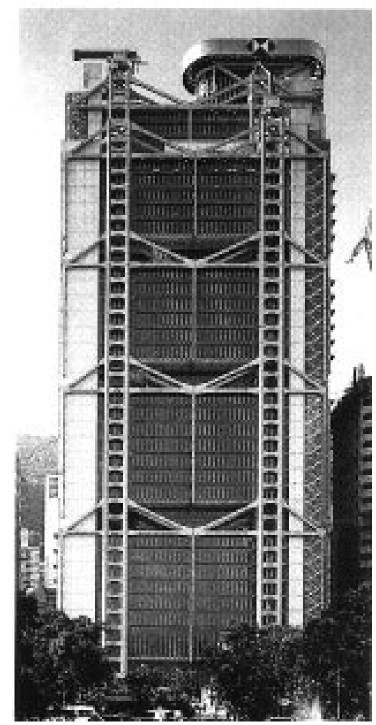
Brooklyn Bridge

workers to lay looped cable wire one loop at a time - a method continued by bridge engineers to this day. This invention eliminated the necessity of hoisting heavy cable, and the possible harm inflicted on the towers due to hoisting.

The experiments and calculations of the bridge engineers led logically to the evolution of the contemporary steel-framed skyscraper - a unique American development centered in Chicago in the 1880's. There were several factors which led to the development of the skyscraper. Elisha's Otis's invention of a reliably safe elevator, and the soaring cost of land in the large metropolitan areas were two prominent ones, but the heights of the modern skyscrapers would not have been possible without the evolution of engineering knowledge with respect to the new materials iron and steel. Beginning with William LeBaron Jenney's Home Insurance Building in 1885 (see figure), a building's design incorporated an internal steel frame to carry its weight. Earlier cast-iron and wrought iron frames had been used successfully with masonry walls; however, it was the lighter internal steel skeleton, with significantly higher compression and tensile strengths, that made tall buildings practical, changing the urban skyline throughout the world.

Home Insurance Building

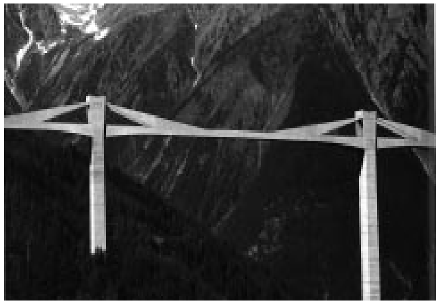
Bridges and towers have continued to be on the forefront of technology and architecture in the area of structural steel design. One of the first people who understood the significance of this new engineering, and used it artistically was Louis Sullivan around the turn of the century. He raised the technical achievement of the skyscraper to the level of great architecture. The 1920's gave us the elegant Chrysler Building, while the Empire State Building and the Golden Gate Bridge were completed in the 1930's. All are known for their architectural greatness, and each broke the record for height and span respectively. Mies van der Rohe designed the Seagram Building in 1958, the prototype of the glass-and-metal, flat-topped, high rise. The awe-inspiring Verrazano Narrows Bridge, completed in 1964, is currently the record holder for the longest span in the world. The exterior x-braced John Hancock Center, designed by Fazlur Khan and Bruce Graham, was finished in 1968, and set the precedent for the 1980's exterior braced Hongkong Bank (see figure) by Norman Foster and Shanghai Bank designed by I.M. Pei.



Hongkong Bank

The iron and steel frame changed the world or architecture by significantly increasing the limits of height and span possible, but when steel bars were embedded in concrete to form reinforced concrete, a radical new style and structure was born. Concrete alone had been used by Roman builders to enclose large open spaces. The most famous example of this being the concrete dome of the Pantheon, which had a span of 144 feet. Notwithstanding, reinforced concrete's unparalleled strength and unique monolithic nature made possible the enclosure of space with unprecedented spans. These spans could be achieved by methods such as thin-shelled vaults and free-curving shapes impossible to the traditional post and beam construction. Through the work of architects like Nervi, Candela, Saarinen, and Calatrava reinforced concrete has shown its true potential, and has been lifted to a great architectural form of its own. A building which exemplifies reinforced concrete's unique architectural form is Pier Luigi Nervi's Palazzetto dello Sport (see figure), whose considerable span is supported by striking y-shaped columns along the entire perimeter of the roof. Ganter Bridge in Switzerland (see figure) shows the potential of reinforced concrete for bridge design and other industrial projects.

Palazzetto dello Sport



Ganter Bridge

Throughout the ages technology has continued to enable new and fascinating possibilities for architects and engineers. Normally the potential of a new innovation is not realized in its early stages. The reasons for this are mainly two-fold: the designers need time to fully understand the new technology, and our natural resistance to change requires some time be allowed for adjustment. Many Parisian's felt the Eiffel Tower was an eye sore when it was first completed, and critics initially called the new structures using reinforced concrete "unsubstantial and aesthetically unsatisfactory." The complete readjustments of structural depth, in relation to the loads and stresses made possible by steel and reinforced concrete, offended traditional sensibilities.

Changes in building technology have increased dramatically in the years since the dawn of the Crystal Palace. People have adjusted themselves to accept change more willingly because it is so common. In fact many would argue that one now has to be willing to accept change to survive. Even though new materials prompt original structures, the architecture of a building will always be based on the solidity of the design and attention to detail. Pier Luigi Nervi stated it eloquently, "Today no one doubts that a work of architecture must be a stable, unified, enduring organism, in accordance with its surroundings and the functions that it must satisfy, balanced in all parts, sincere in its supporting structure and technical elements, and at the same time capable of giving that indefinable emotion that we call beauty. . . and that this result can be achieved with a liberty of means unsuspected yesterday."

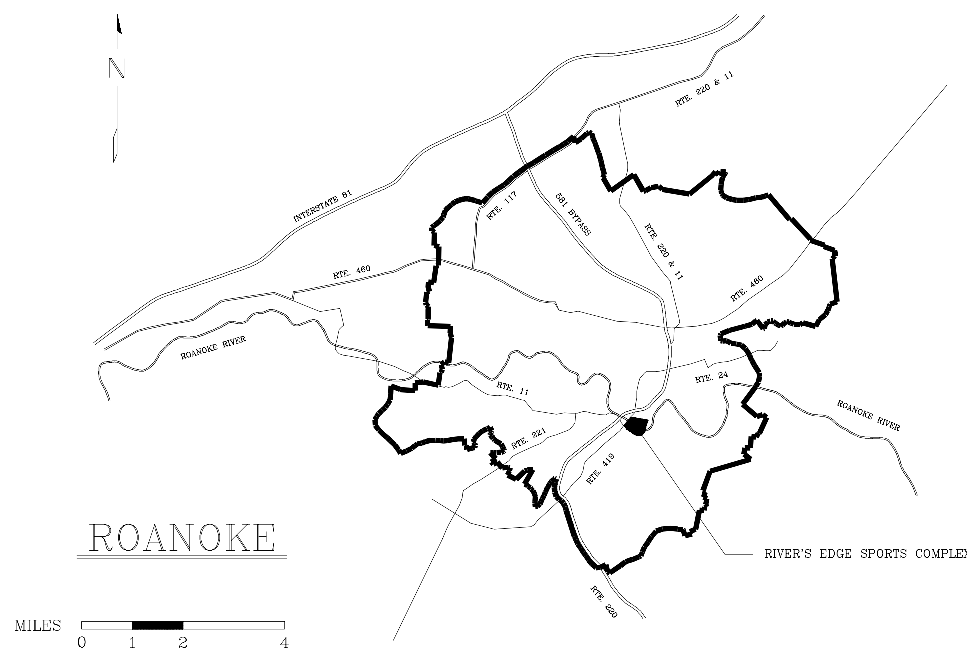
River's Edge Sports Complex

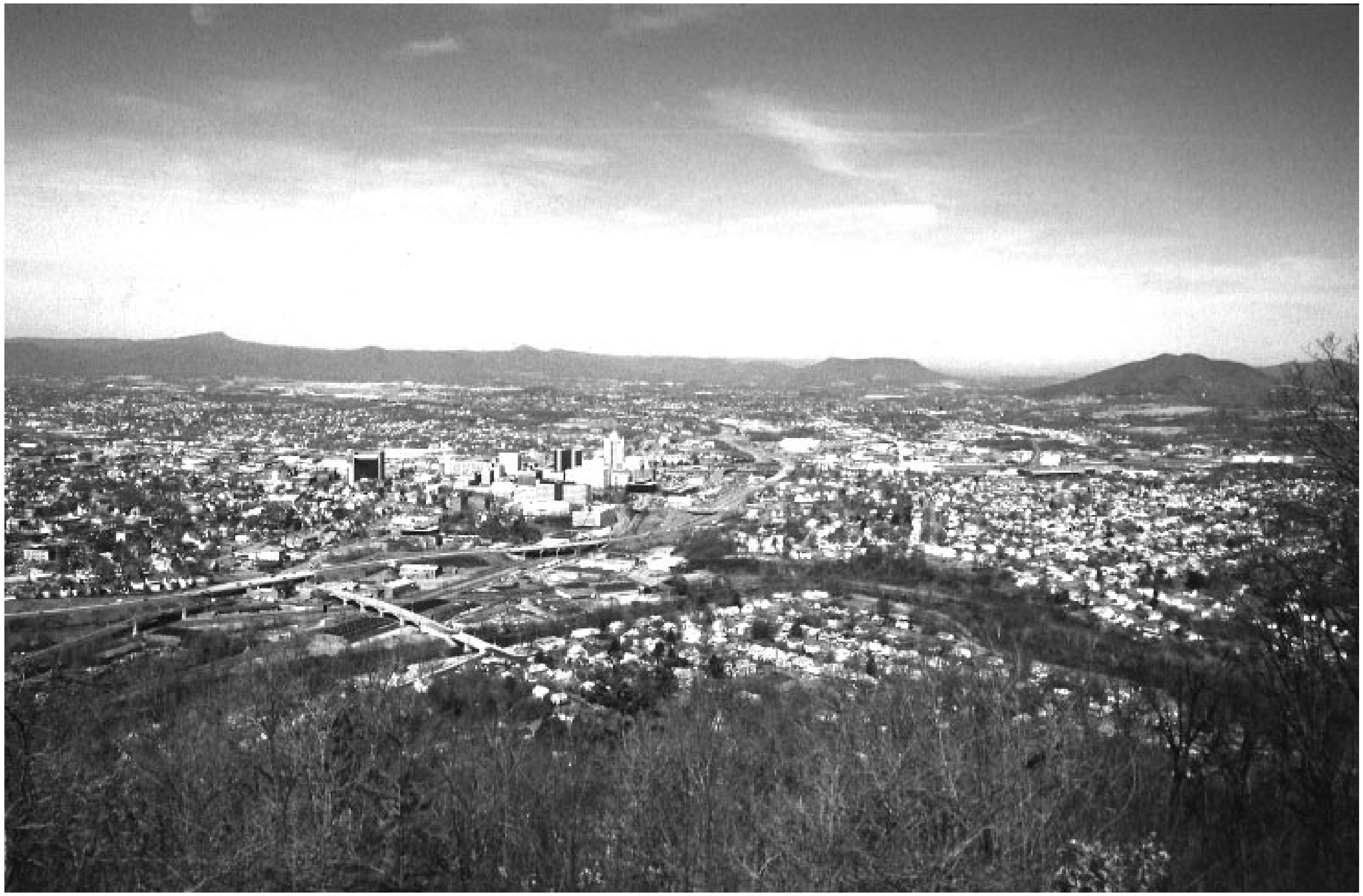
THE EXISTING SITE CONDITIONS

Looking west over the River's Edge Sports Complex from Roanoke Memorial Hospital

The River's Edge Sports Complex is located in southwest Virginia, a relatively temperate climate with long pleasant spring and falls. Winters are cold with normal lows in the mid 20's Fahrenheit. Snow is common, the average annual snow fall in Roanoke is 23 inches, but amounts vary greatly depending on location. Summers are hot and humid with the normal highs reaching nearly 90 degrees Fahrenheit. According to BOCA, the wind speed used for design is 70 m.p.h., and the average yearly precipitation is around 40 inches.

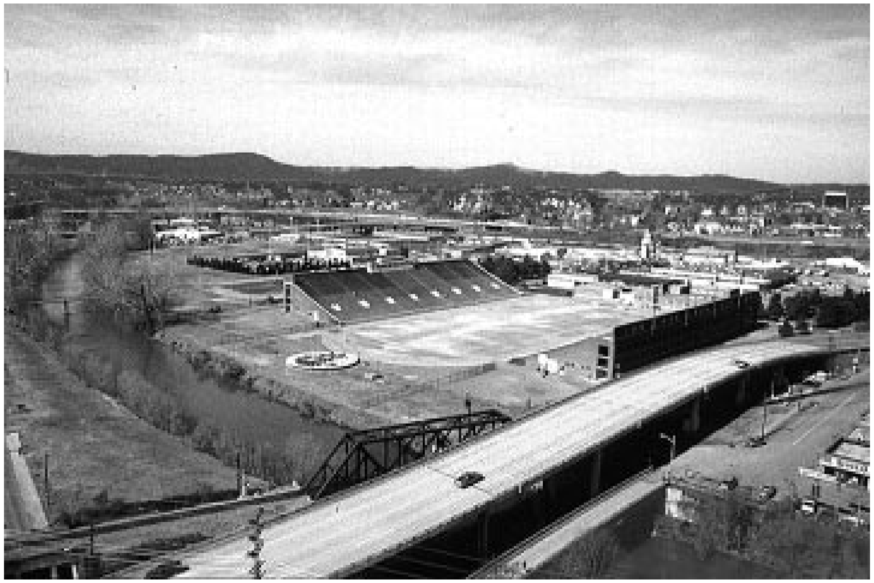
Roanoke is the largest city in Virginia west of Richmond with a population of nearly 100,000. It is the center of the Roanoke Valley, a 270,000 population area also comprised of Roanoke, Craig and Botetourt counties, the Town of Vinton and City of Salem. Relative to the middle of downtown Roanoke, the River's Edge Sports Complex is located slightly to the southeast, just off the 581 bypass and Route 220. An important geological feature of this city and the complex is the Roanoke River, which flows through the heart of each.



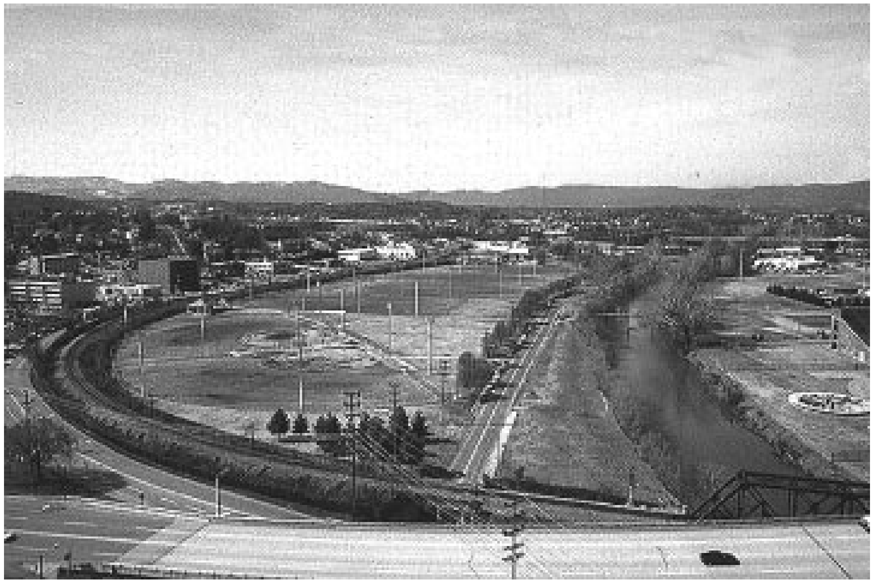


Roanoke is a beautiful city nestled in the Appalachian mountains. Many refer to Roanoke as "The Star City" because of its most visible attraction, a 100 foot high star shaped illuminated structure. This picture of Roanoke was taken at the base of this star which lies on the top of Mill Mountain.

A view of the River's Edge Sports Complex north of the Roanoke River. The main structure in this section is Victory Stadium, with the National Guard Reserve Armory at its northern end and a fountain to its south. Behind the west stands is the stadium's unpaved parking lot. West of this is the Parks and Recreation Building, with its parking lot surrounded by trees. Maher Baseball Field is on the other side of this parking lot, while the School Department is the building still further to the west.

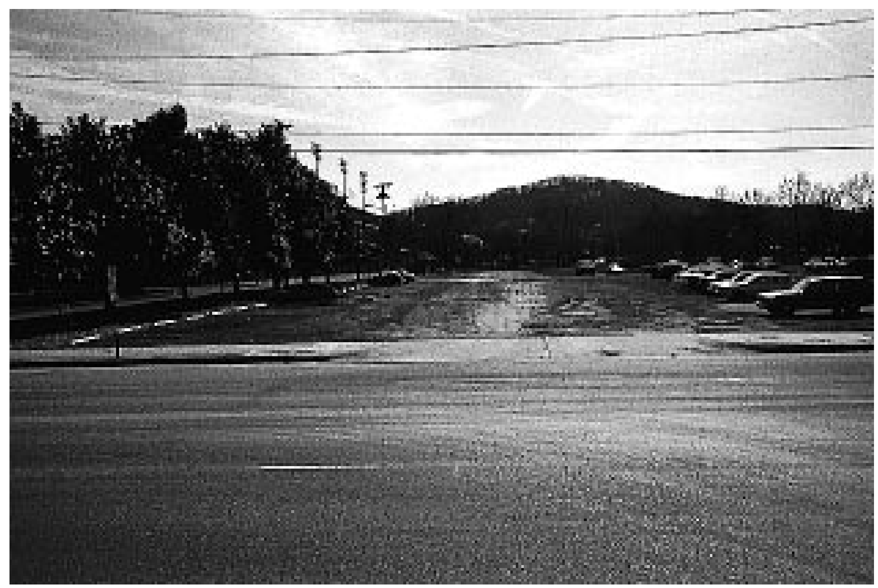


A view of the southern part of the River's Edge Sports Complex. The southern and eastern limits are marked by the railroad tracks. Wiley Drive runs along its northern end with tree shaded parking accessible on the southern side of the road. Looking east to west, there are two practice baseball fields with rest rooms and an eating area just to their southwest. Next are several soccer/football fields with large light poles, and barely visible are the tennis courts in the distance.



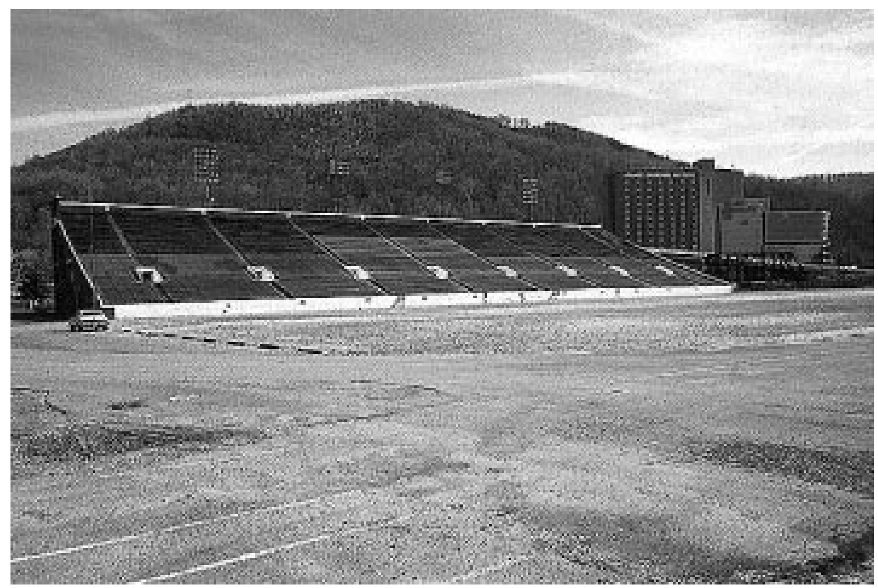
The existing service entrance to Victory Stadium, which is very similar to the entrance condition for the proposed facility (the major difference being the rows of trees would be twice as long.) At the end of this existing procession of trees is a gate surrounding the stadium. Once past this gate, service vehicles can continue straight, traveling between the West Stands and the exterior fence, or make an immediate left. By turning left, vehicles can continue past another set of gates and onto the football field.

The procession of trees for the service entrance to Victory Stadium can be seen here on the left. This picture shows the location of the proposed northern entrance to the new facility. This entrance will be lined with trees on both sides for most of its length, except for two places which allow cars to turn right into the main parking lot. The visitor will have the option of turning into this parking lot, or dropping passengers off first at a turnaround which will terminate the procession of trees.



An exterior view of the west stands of Victory Stadium, a stadium which commemorates the veterans of World War I. Here was the battleground for the heated rivalry between VPI and VMI's football teams. This was considered by many the biggest event of the year in Roanoke, and was eagerly anticipated by fans and media alike. Although Victory Stadium no longer hosts this game, local high schools play football games at the stadium, and other events such as concerts are also performed here.

The location of Victory Stadium is quite unique. These are the east stands with Roanoke Memorial Hospital and Mill Mountain in the background. With the impressive mountain as a backdrop, and the Roanoke River flowing just past an interesting fountain south of the field (see next page), it is truly a beautiful setting for viewing an event. Unfortunately, the stadium has deteriorated and is in need of repair. Therefore, a renovation would coincide with the erection of the new sports facility.



Trees line both sides of the Roanoke River for its entire length until the stretch south of the stadium. This allows spectators a good view of the city's graceful namesake.

The trees lining the Roanoke River provide a naturally beautiful backdrop for many of the activities in which one could participate at the River's Edge Sports Complex. The proposed facility would cut across the Roanoke River at this location; an environmentally sensitive route which would require less chopping of trees than most paths would require.

These two magnificent poplar trees would stand like sentinels on either side of the proposed bridge building. These are just two of the many beautiful trees which constitute the vertical "walls" enshrouding the Roanoke River. This picture was taken from the small, very ordinary, pedestrian bridge which would be demolished and replaced by the "core building", the building which would bridge the river unifying the entire River's Edge Sports Complex.

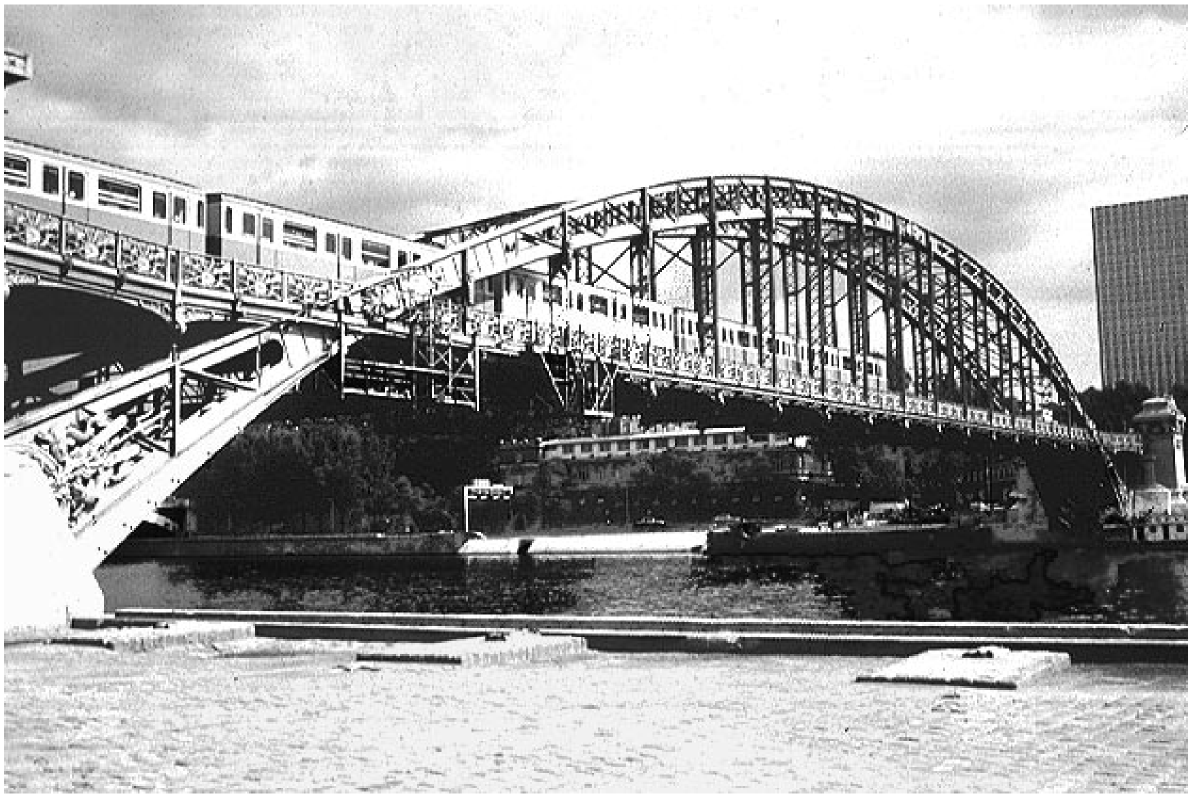
There are six tennis courts in superb condition which would remain untouched by the proposed layout for the entire complex. Local tournaments are held here as well as the tennis for the Commonwealth Games - a tournament which attracts players from all around the state. Most of the River's Edge Sports Complex is very flat, but this picture was taken from a nice shaded knoll where spectators could watch the tennis from an elevated position without sitting on the hot bleachers.

A backboard is located adjacent to the tennis courts which offers an excellent place to practice your groundstrokes. It is also used by the locals for a place to practice throwing and catching lacrosse balls. This masonry block wall has two practice areas on either side which are completely surrounded by a fence to keep stray balls from traveling too far. Some efflorescence caused by exposure to rain can be seen on the wall, but this does not affect the trajectories of the balls coming off it.

A gazebo is located south of the backboard, and to the west of the tennis courts. It provides a nice shelter from the sun for the tennis spectators, or for parents keeping watch over their children enjoying themselves on the playground. Since there is not a building nearby, the gazebo also offers a convenient place to wait out a short summer storm for people playing tennis. In addition to providing shelter, this gazebo has a picnic table inside so people can eat a lunch or snack in a pleasant environment.

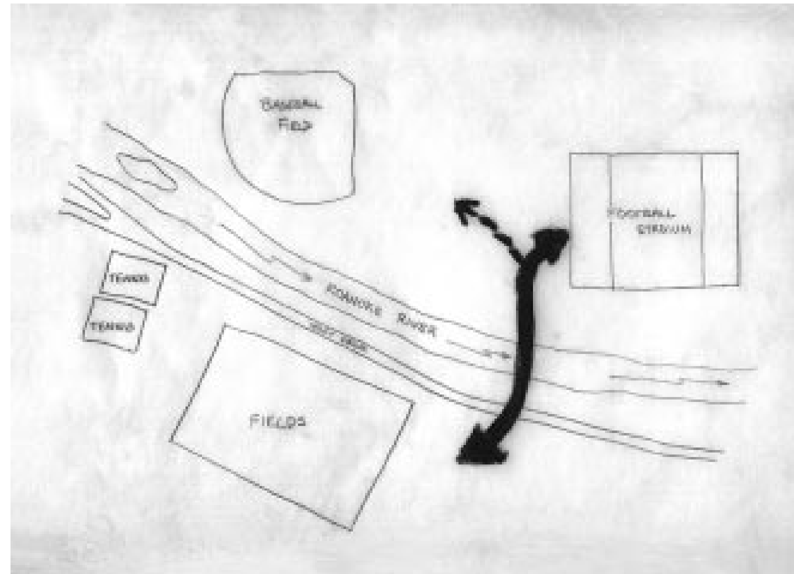
The playground located west of the tennis courts has a rope swing, several slides, and numerous climbing stations to keep young kids entertained for hours. This view also shows the quaint grove of trees in the background. This grove, which is just west of the backboard, provides a perfect spot for relaxing in the shade or having a picnic. The trees in the grove, along with the other trees surrounding the playground, effectively shelter this entire area from the traffic on Franklin Street.

Related Structures and Design Process

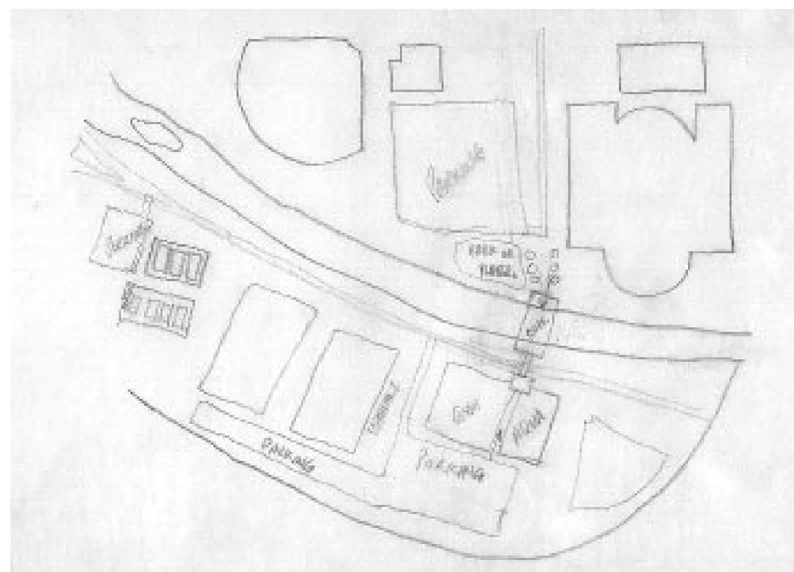


The original idea for this project was to have a bridge building "hung" by vertical cables connected to an arch similar to the Pont d'Austerlitz in Paris, France.

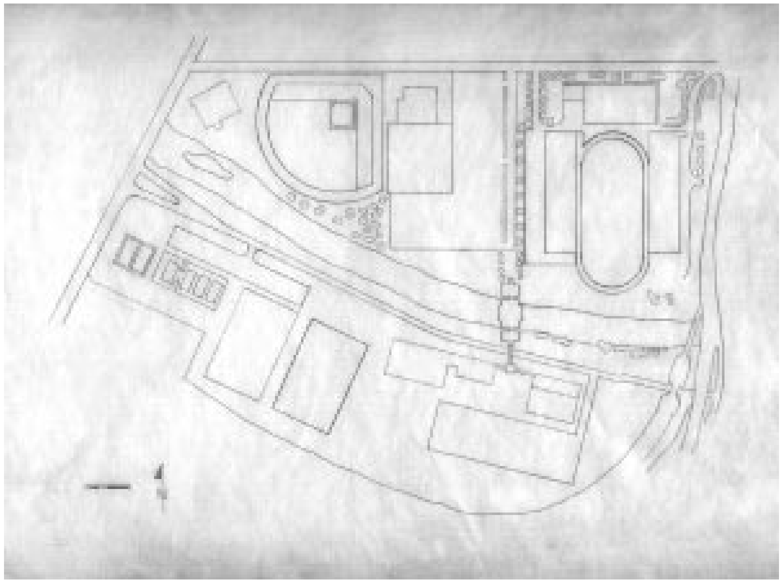
My originalconcept unified the two halves of the River's Edge Sports Complex by bridging over the Roanoke River and Wiley Drive. Unification and spanning were the driving forces behind the "core" part of the new facility. I envisioned a smooth flowing path between the football stadium and fields to accomodate the majority of the circulation. The bridge also enabled spectators to readily enjoy a baseball game, or watch the activities on the tennis courts located on the other side of the river.



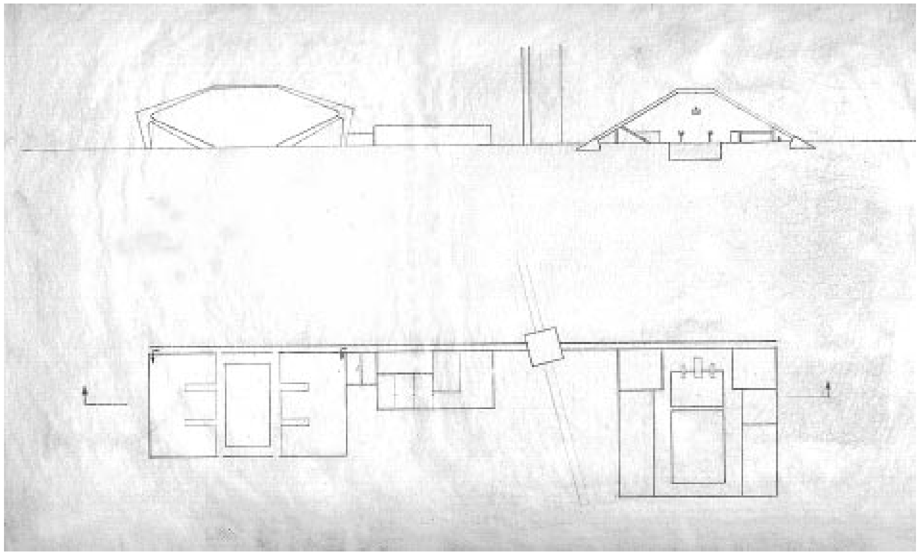
The first masterplan for the entire complex indicates the three primary components of the proposed facility: the core bridge building, a natatorium, and a basketball coliseum. The northern entrance to the new facility is a straight path from Reserve Avenue, allowing visitors an uninterrrupted view of the "core" building and tower from this road. The parking for football is located west of Victory Stadium, while the parking for the pool and basketball is positioned south of the gym and natatorium.



The masterplan is in the final stages of the design. The natatorium and exercise buildings are located far enough apart that the view of the unification path over the river is not compromised. Trees are aligned along both sides of the northern entrance to make an enticing promenade. The major problems which still need to be resolved are: the fields and tennis courts on their own axis do not fit well with the rest of the complex, and the parking lots still need further refinement.



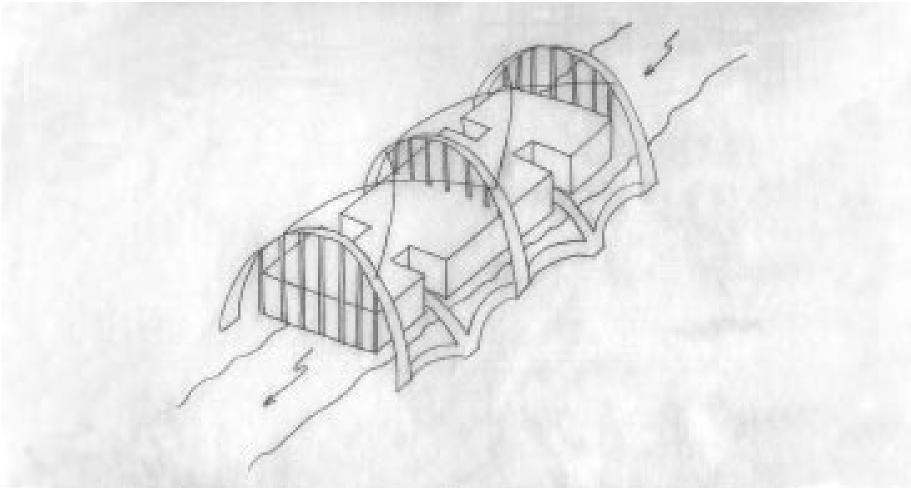
The forms of the coliseum, exercise building, and natatorium are to the point where they can be visualized, and the locations of their interior spaces are well developed. The structural systems of the two large buildings, the coliseum and natatorium, can be recognized. The observation tower is aligned with the bridge building and not the other facilities to distinguish them as the "core" section of the proposed sports complex. A thorough structural investigation of the bridge building is now needed.



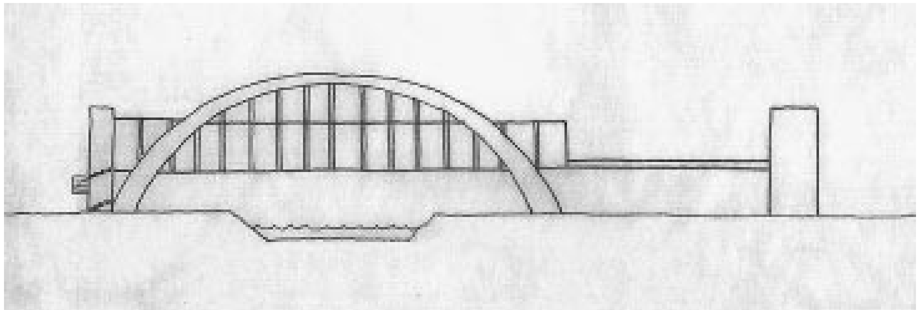
The notion of a building functioning as a bridge is unusual, but not unprecedented. One of the earliest, and perhaps the most famous, is London Bridge which began its construction in 1176 and took 33 years to complete. It was designed by Peter of Colechurch, a priest and engineer. This icon functioned as a 900 foot long bridge, as well as a place to live and shop, for over 600 years, despite misuse and neglect. The bridge had a draw, 19 pointed arches, and sturdy piers on pointed foundations to resist the tides.

An existing example of a bridge also functioning as a building is Ponte Vecchio in Florence, Italy. It is the oldest bridge in Florence and was reconstructed out of stone in 1345. After the previous wooden bridge was destroyed by a flood in 1333, Neri di Fioravante designed this stone bridge to have shops run along both sides. These shops were originally rented to butchers; however, they were later assigned to gold and silversmiths: a tradition that is still respected to a good extent today.

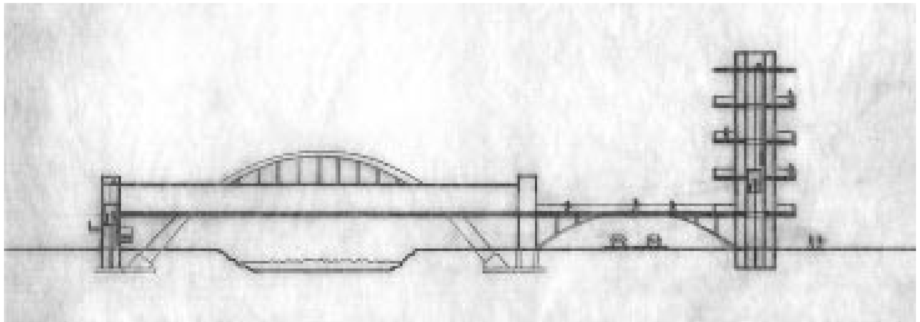
The original idea for the bridge building has it spanning width-wise over the Roanoke River. This concept enables people to cross the river, but it has several problems. Wiley Drive separates this building from the rest of the proposed facilities, and spectators have to traverse across its traffic. This orientation also necessitates an enormous suspended building which significantly increases the cost of the project.



Later versions orient the bridge building to span length-wise over the Roanoke River. A pedestrian bridge crosses over Wiley Drive, and a small observation tower allows visitors to either continue to the fields below, or an elevated view of the entire complex.



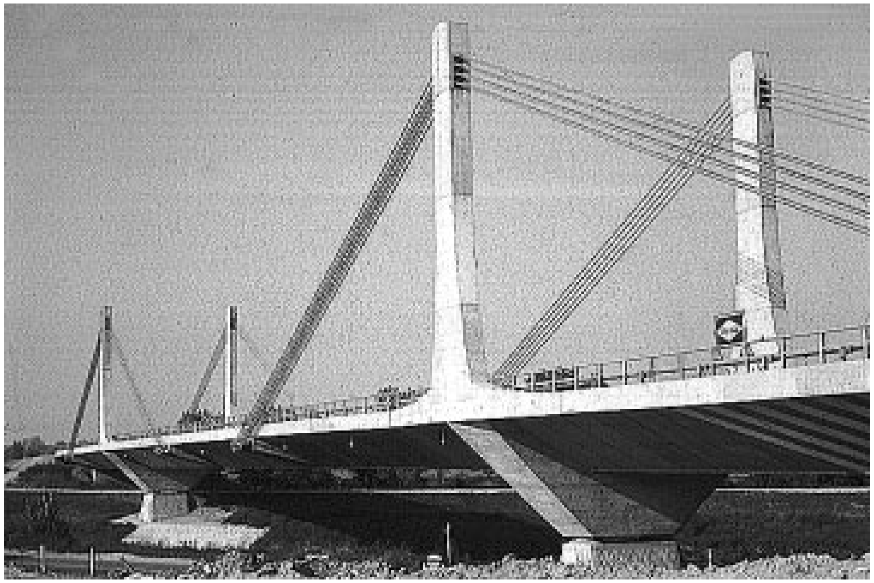
A cross section of the final design having the bridge building suspended by an arch. This design requires elevators which disrupt the smooth crossing of the river. Therefore I moved to a cable stayed system to facilitate and express flow, unification and bridging.



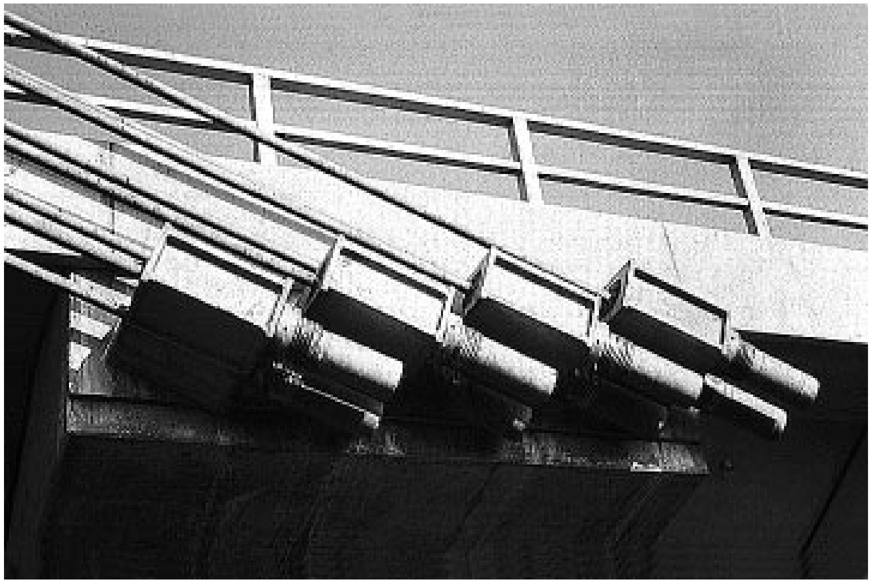
The Albert Bridge, which spans across the River Thames in London, England, opened in 1873 making it one of the earliest examples of cable-stayed bridges. It was strengthened in 1884 by replacing the wire ropes with the steel link chains of the present bridge, and a mid-span support was added to withstand modern traffic loads. The structure uses both curved chains hung from each tower, and straight chains acting as the "cable stays", to support the three spans of 147 feet, 384 feet, and 147 feet.

This is Santiago Calatrava's proposal for the Sevilla Bridge, an extra-urban viaduct linking the Spanish cities of Sevilla and Camas. The two twin towers at the one end of the bridge soar to a height of 531.5 feet and secure the cable stays along most of their length. This "harp" cable arrangement supports the 820 foot long bridge deck, which has a road and a raised walkway nearly 15 feet wide. The two towers are inclined to more efficiently resist the lateral force due to the cables.

This cable-stayed concrete bridge near Vienna, Austria, elegantly crosses the Danube Canal. Like the Albert Bridge, all the cable stays originate from the top of the supports, however, these cables do not "fan outward", but are aligned in parallel. This bridge was constructed in two self-supporting pieces, each parallel to the banks and balanced on one pier. The halves were then rotated on the piers and connected at mid-span. The outer spans are 180 feet, while the center span measures 390 feet.

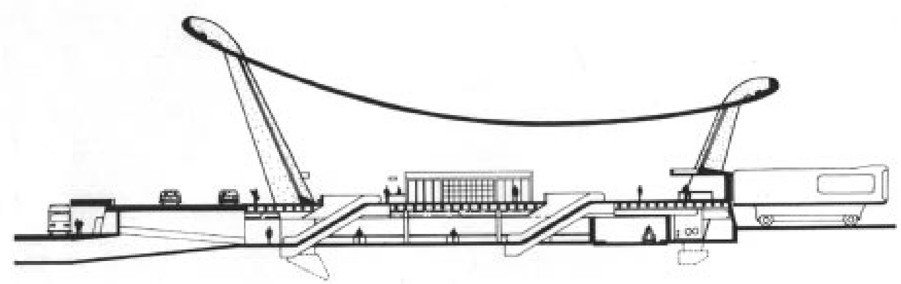


This is a close-up of how the cable stays of the bridge above are anchored to the bridge deck. The cable stays for my bridge building are anchored in a very similar manner; the major difference being my design calls for them to fan outward, therefore causing each stay to be secured to the building at intervals. Like this bridge, the stays in my project are initially secured to the supports, then tensioned from below. They are also attached to the base of the building where small adjustments can be made.



The roof of the airport terminal building at Dulles International Airport is supported in tension by cables. This building, which is located near Washington, D.C., was designed by Eero Saarinen in the late 50's and early 60's with a span of 141 feet. There are two rows of columns forty feet apart on each side of the concourse, sixty-five feet high on the approach side, and forty feet on the field side. Saarinen likened his design to a "huge continuous hammock suspended between concrete tress."

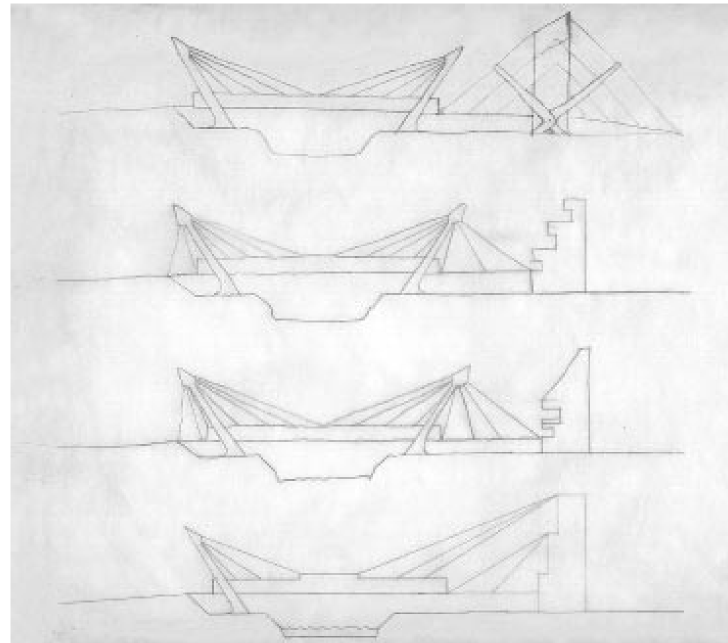
This cross section of the Dulles concourse reveals how the roof is suspended. The point of connection of the roof cable to the piers on the approach side is nearly 50 feet above the ground, while the connection for the field side occurs at approximately 34 feet. Similar to my project, these piers increase their width towards the ground and are inclined to efficiently counteract the resultant cable force located near the top of the supports.



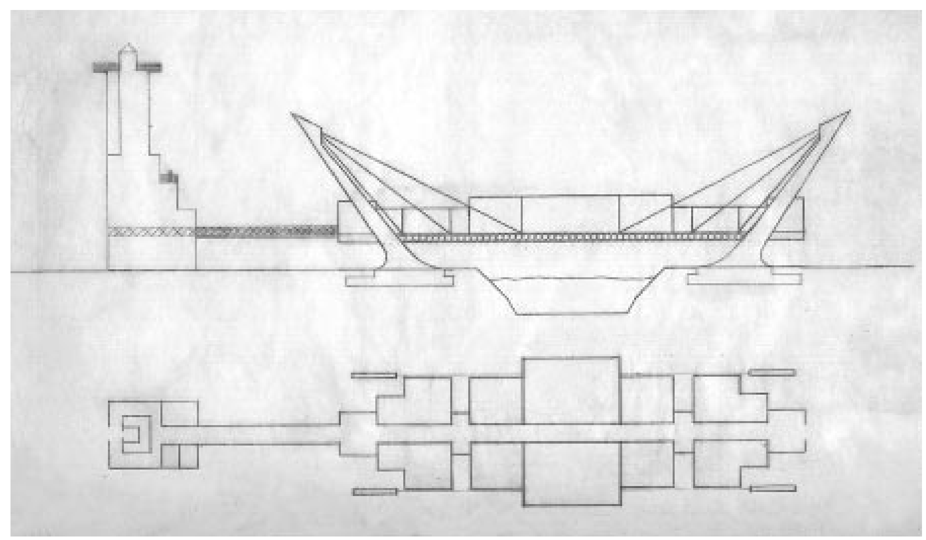
This building in Squaw Valley, California shows how a roof can be suspended by cable stays in a striking style. Built for the Winter Olympic Games, this building encloses an ice rink with a 300 foot roof span designed to withstand a snow load of 50 psf. The specified 100 psf snow load for this area was reduced by pumping warm air through the cells of the roof deck. The towers are restrained from buckling inward by cables, and they were prestressed backwards, so they are straight under live load.

The Westcoast Office Building in Vancouver, Canada shows that entire buildings can be suspended by cable stays. In this twelve story building, the floors are hung from the top of the central 270 foot high concrete core by sets of continuous steel bridge cables. The floors were erected from the top down, and the cables are largest at the top and reduce in size toward the ground as the loads lessen. The core is 36 feet by 36 feet in section, and can be seen at both the top and bottom of the building.

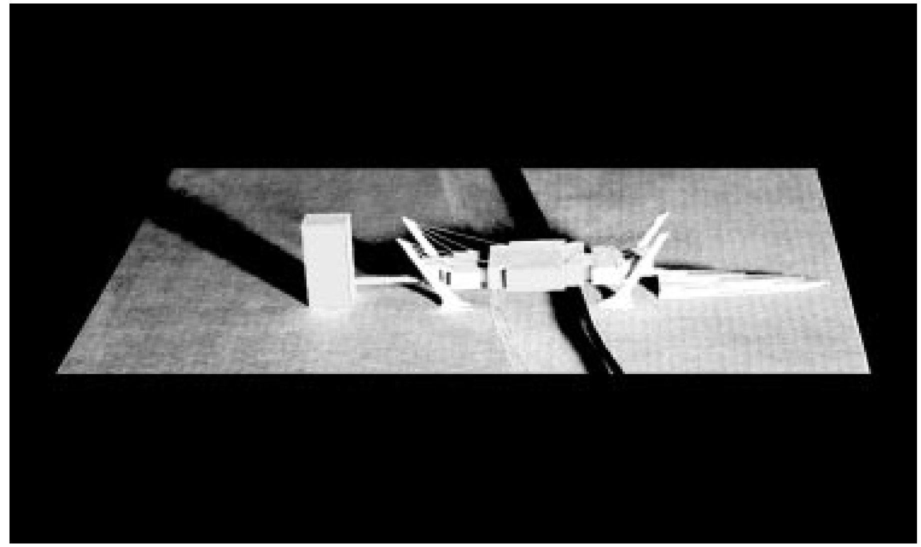
My exploration of the cable stayed bridge building considered the form of the observation tower and the arrangement of the cables. In the early stages of design I experimented with supporting the pedestrian bridge from the observation tower as well as from the bridge building's structural towers. Both entrance ramps are also supported by cable stays in many of the early sketches, an idea changed at a later stage. My early designs also have the cables attached to the top of the bridge building; further in the design process the connections are located at the building's base.



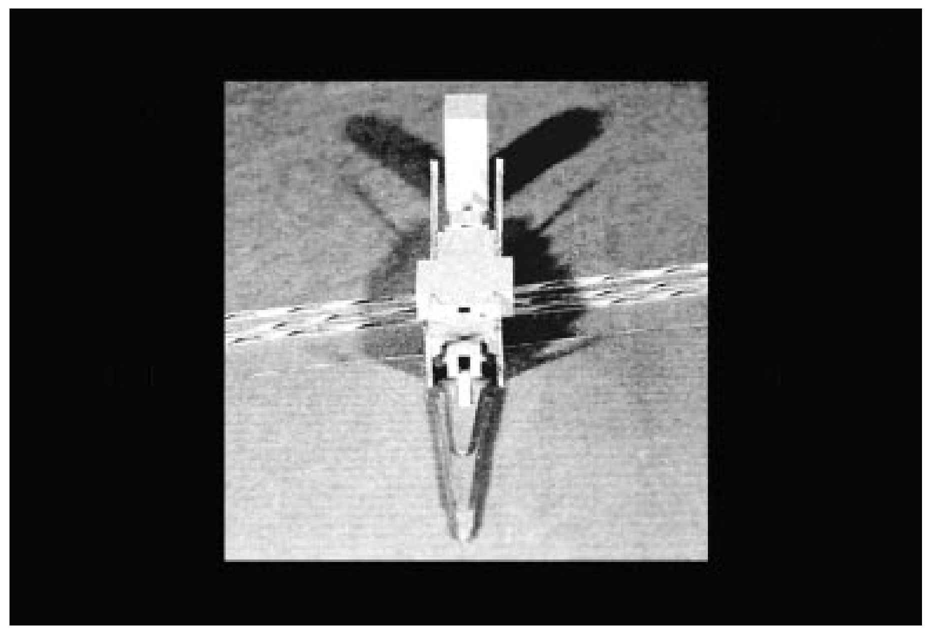
This is one of the last drawings of the bridge building before I started completing the design using CADD. The cable stays now support it from below, plus its elevation and plan are well developed. The inclined supports have foundations which extend outward, nearly to the ends of the building, to counteract the large overturning moment. The elevation clearly shows my intention to have this building "hover" by only being vertically suppprted by the cables.



The east elevation of the first developed study model using the cable stayed support system. The shape of the bridge building and its four supports are close to their final version. A left entrance, or southern ramp, is in the final design, but I was thinking visitors would just use an elevator or stairs in the tower to reach the ground during this time. The pedestrian bridge is not supported by cables, but it is only in the very early stages of design.

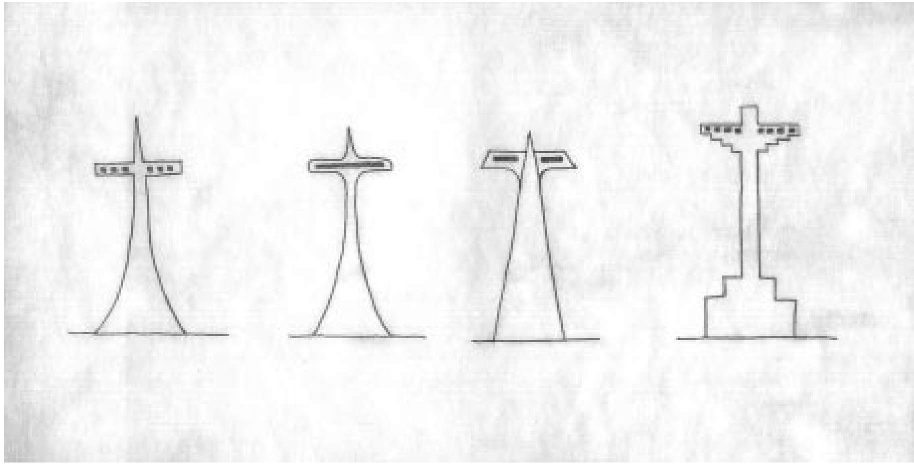


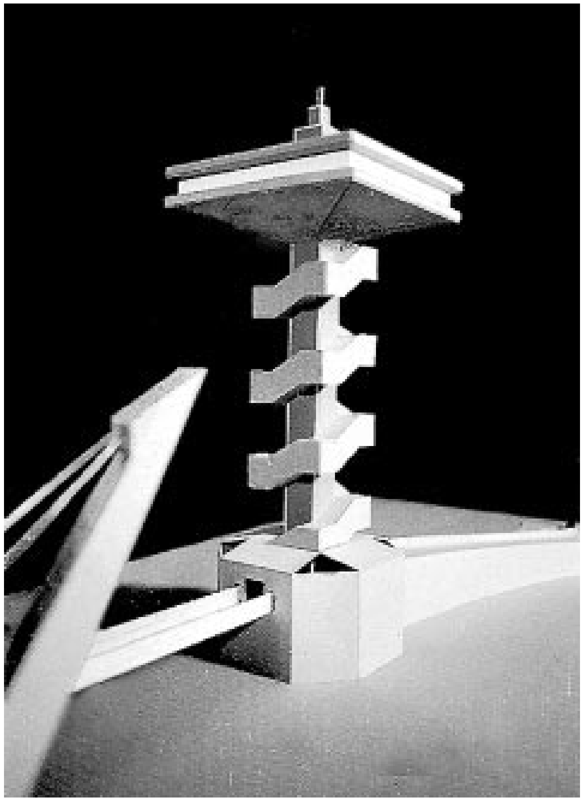
The northern elevation of the facilities comprising the "path across the river" from an elevated perspective to clearly show the cable stays are connected to the roof of the bridge building. The location of the observation tower between the supports of the bridge building has been determined, and its exterior walls are aligned with the rest of the "path", but it is still just an unarticulated volume. Obviously the northern entrance is not very developed, but it is straight like the final version and approximately the same length.

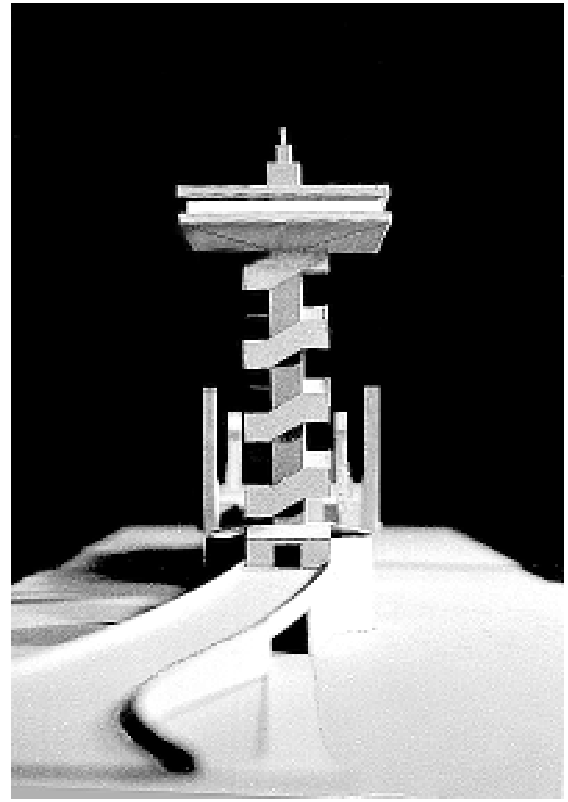


Three precedents considered in the development of my observation tower were left to right: the television tower in Stuttgart, Germany, the Seattle Space Needle, and the CN Tower in Toronto. The base diameter of the television tower is 35.4 feet with a concrete wall thickness of only 2.4 inches. The three curved legs of the Seattle Space Needle consist of three 36 inch wide flange steel beams welded flange-to-flange to form a 3-sided tube. The CN Tower is the tallest freestanding structure in the world and gracefully soars to a height of 1,815 feet.

While studying numerous existing towers like the three above, I realized I needed to begin my exploration of its form with a clear pure concept. Here I dismiss with the notion of having several levels of observation decks for one near the top of the tower. This idea leads to a much stronger form, and due to the height of the coliseum and natatorium, is a more reasonable alternative.



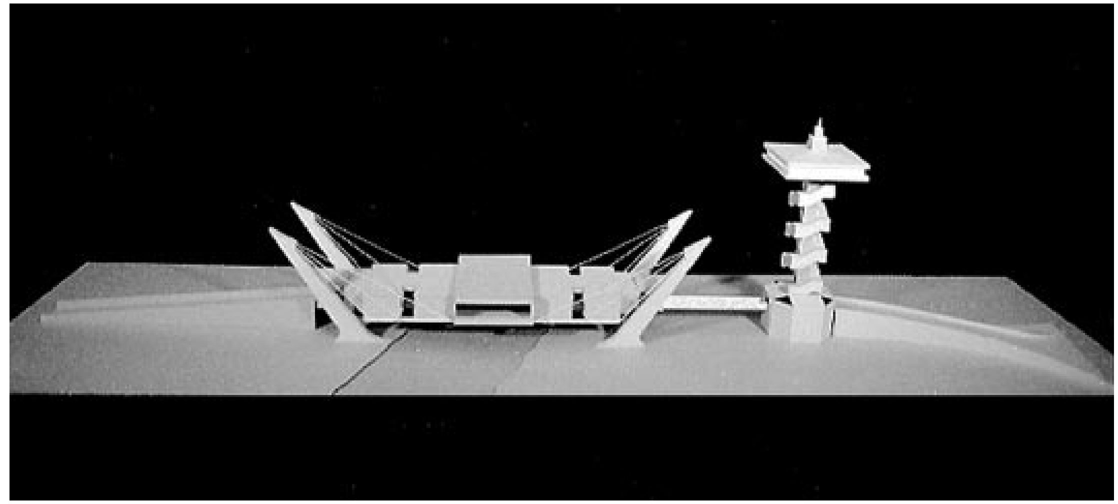




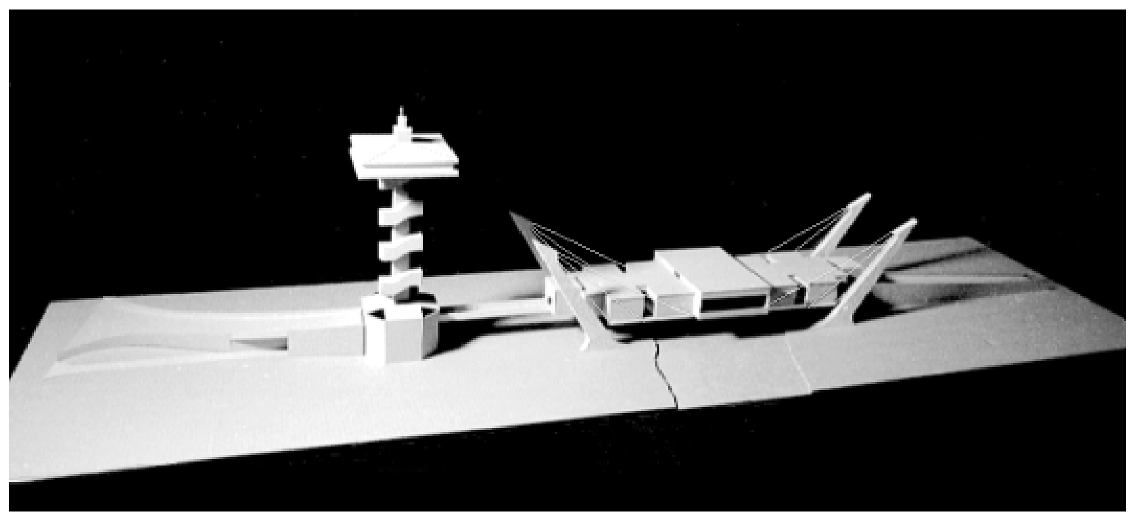
The observation tower for the second study model is taller than the first for a better view over the natatorium and coliseum. The hexagonal base allows for a smooth circulation pattern around the core of the tower. An elevator is located inside the core and can be accessed from the ground level, the pedestrian bridge level, or the observation deck. An enclosed exterior staircase winds its way around the stem to the observation deck revealing the slenderness of the tower's core.

The southern entrance to the new facilities affords visitors two paths. The lower one allows them to check into the complex on the ground level of the tower, and then to either proceed to the natatorium on the right, or left toward the exercise rooms and coliseum. The curved ramp, which is not monolithic in the final design, is used to gain access to the bridge building or to cross the Roanoke River. Along with the change to the ramp, the observation deck is reduced in the final design.

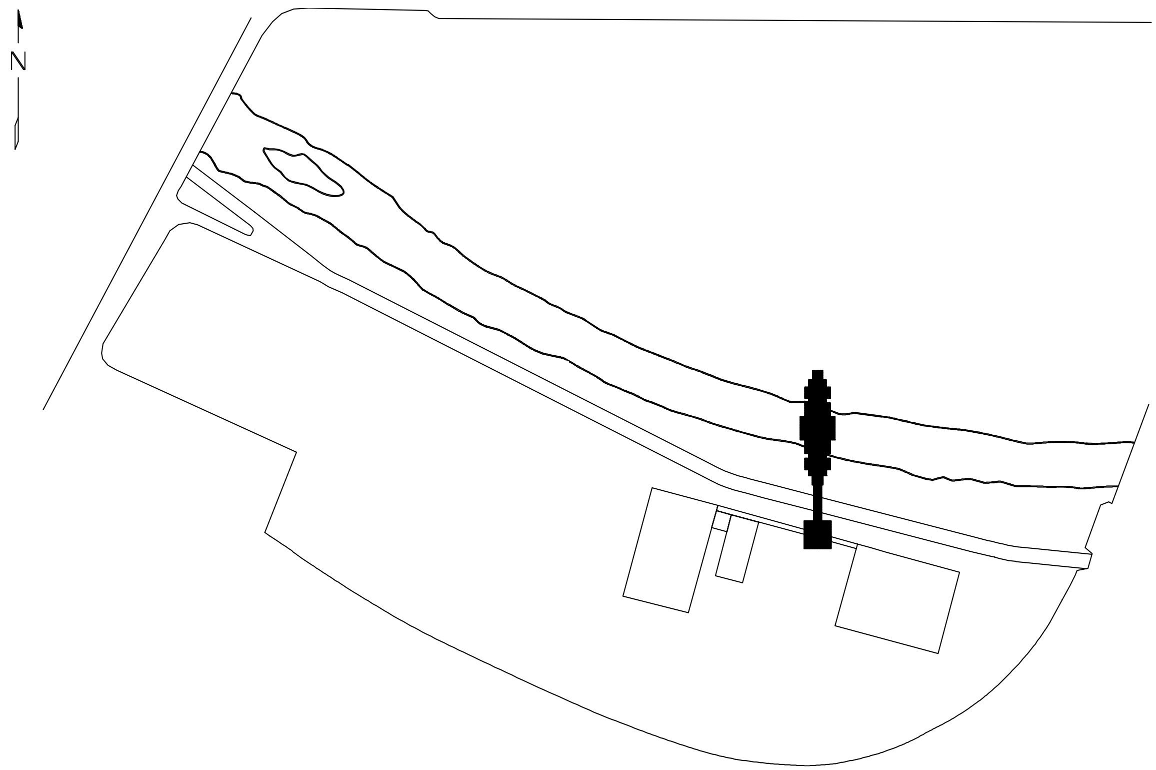
The west elevation of the second study model shows the curved ramp for the southern exit leading people to the fields on that side. Both ramps are monolithic on this model; however, the final design calls for ramps to be supported on unobstructed columns. This change allows pedestrians to walk underneath the northern ramp on the jog path, and it enables the lower entrance to the observation tower to be widened. This is needed because many of the visitors will also be using this path.



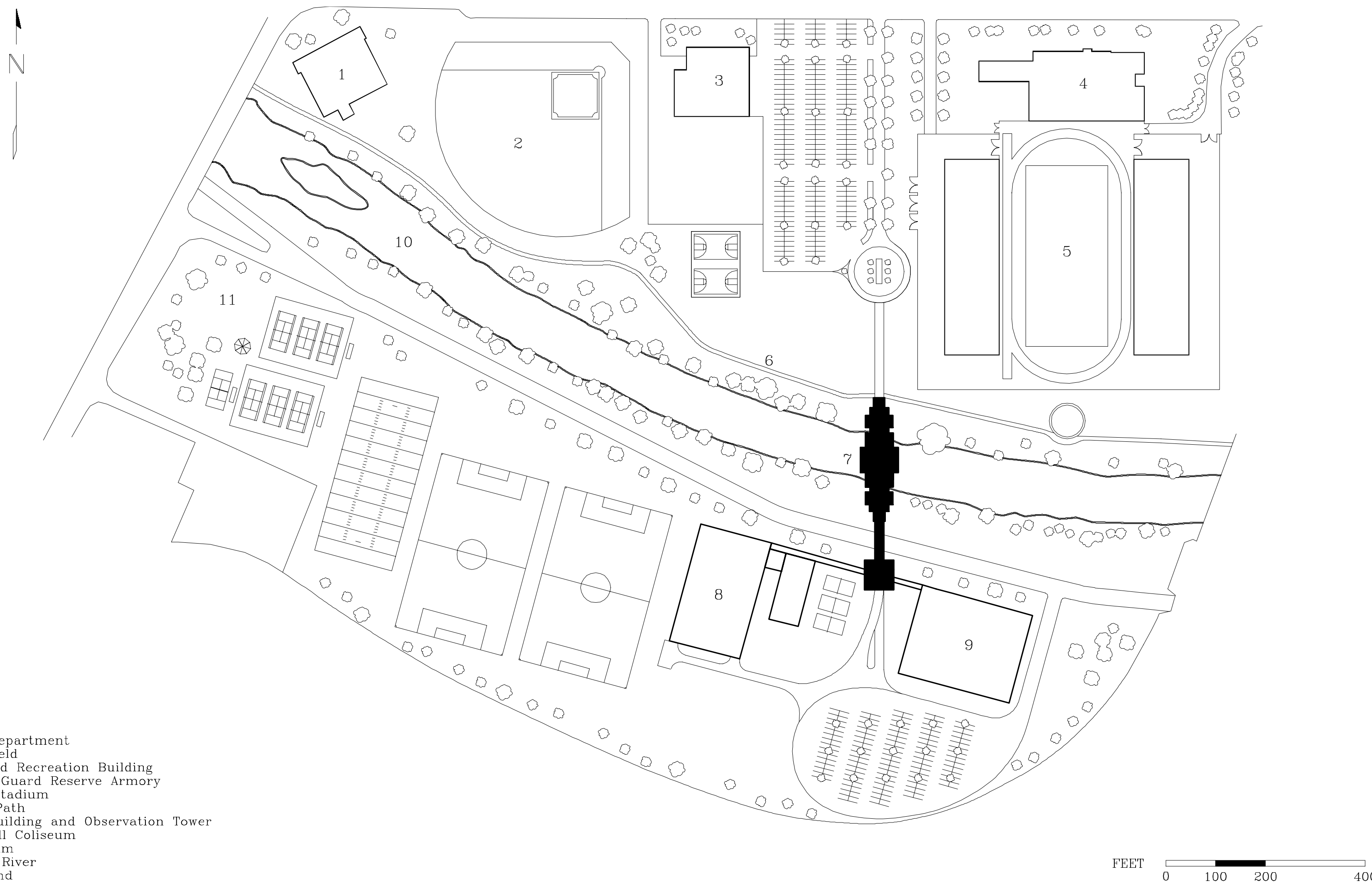
This east elevation shows the lower path to the observation tower tunneling through the curved southern ramp. As mentioned above, this lower path needs to be widened and a nonmonolithic design makes this possible. The pedestrian bridge still needs to be developed. Here it would be supported by the tower and bridge building, but the end of the bridge building is already cantilevered making this design very inefficient. The final version has the pedestrian bridge supported by two columns.



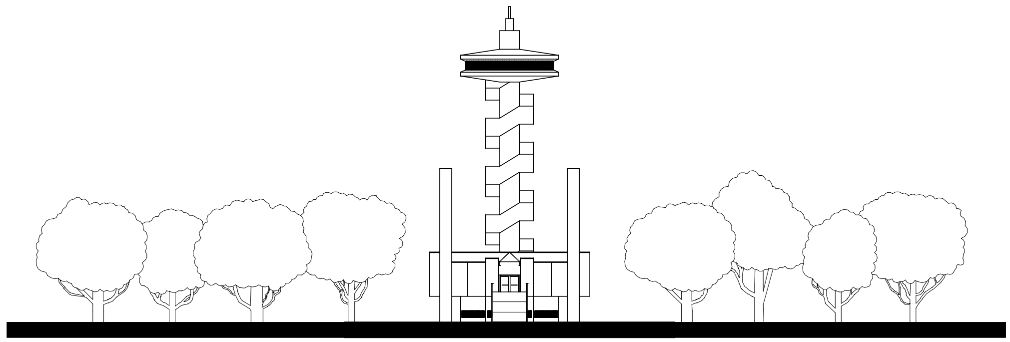
The Bridge Building and Facilities



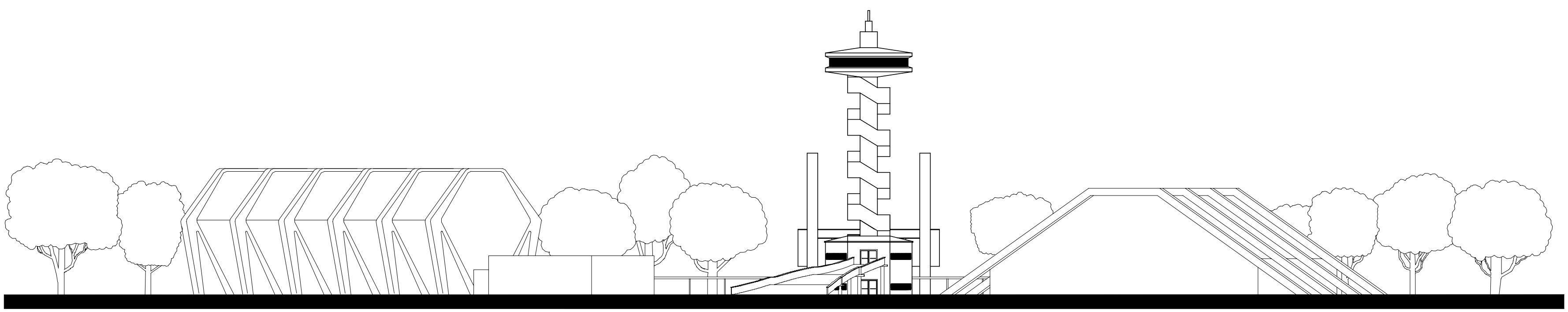
The proposed buildings for the River's Edge Sports Complex



1. School Department
2. Maher Field
3. Parks and Recreation Building
4. National Guard Reserve Armory
5. Victory Stadium
6. Jogging Path
7. "Core" Building and Observation Tower
8. Basketball Coliseum
9. Natatorium
10. Roanoke River
11. Playground

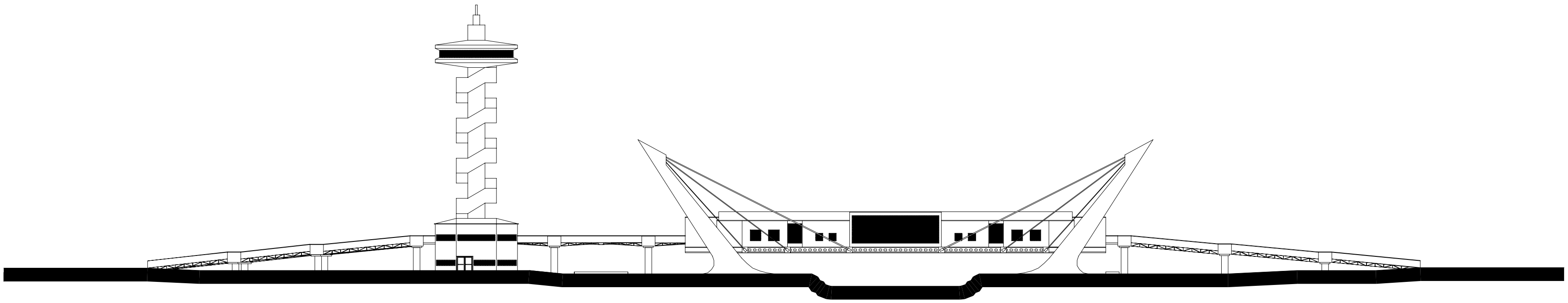


NORTH ELEVATION

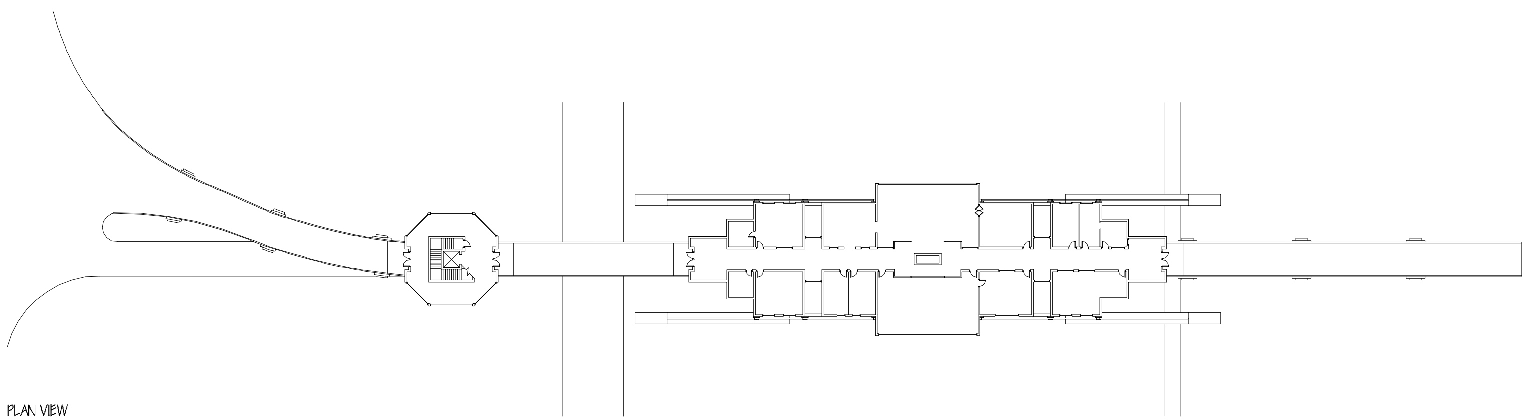


SOUTH ELEVATION

FEET 0 25 50 100



EAST ELEVATION



PLAN VIEW

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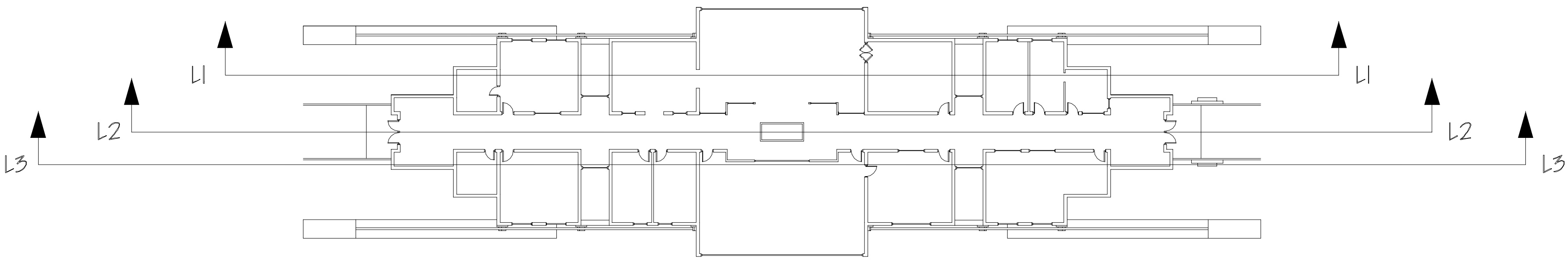

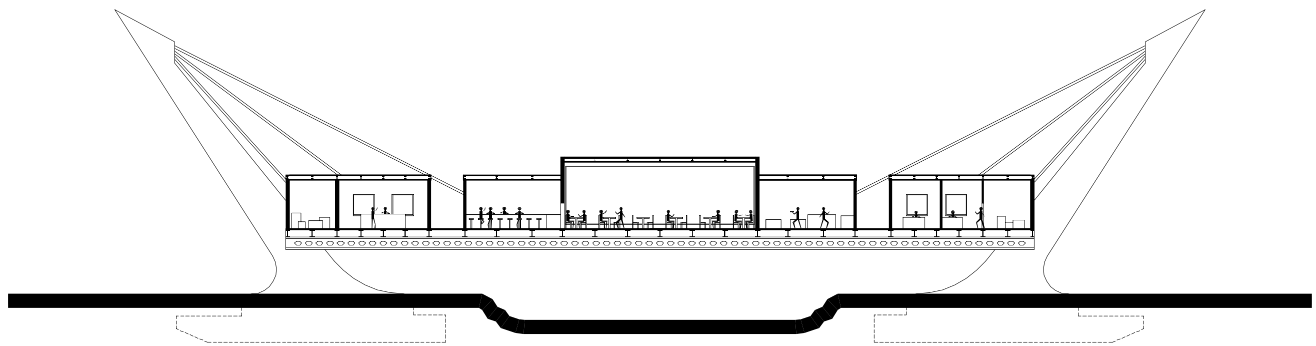

SECTION L1

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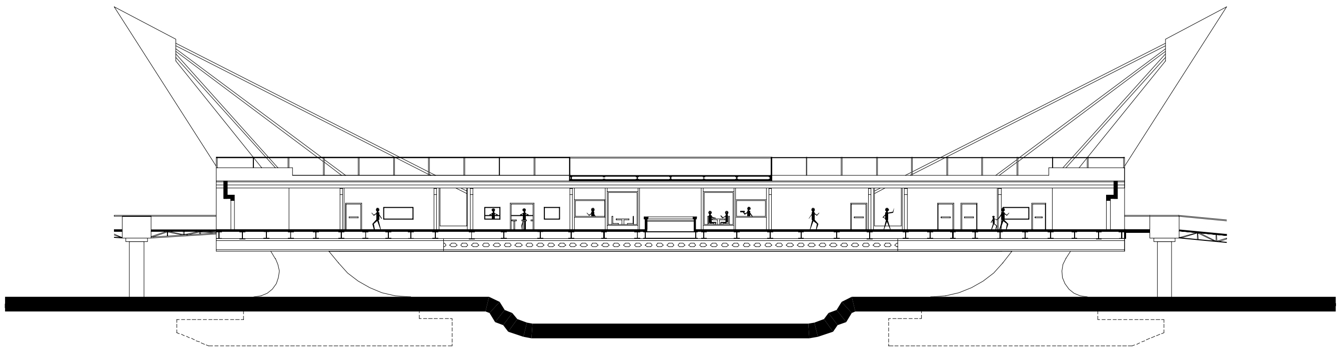

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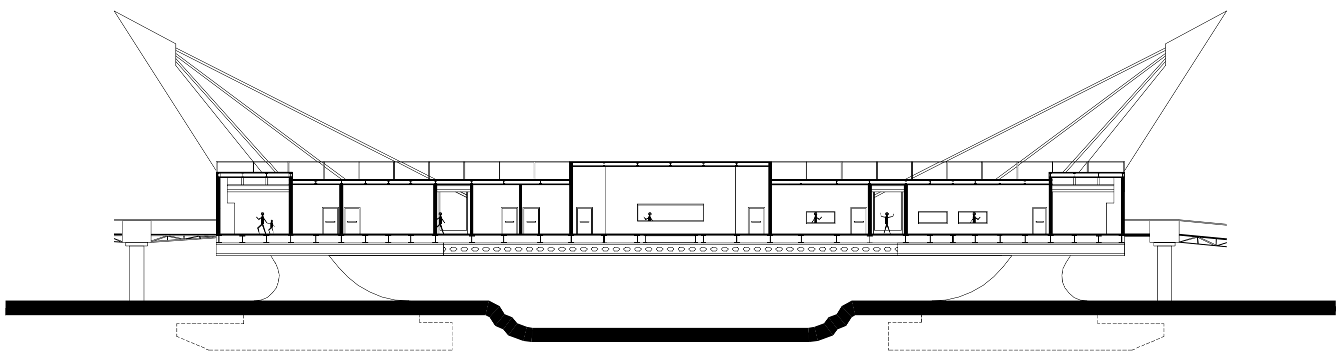

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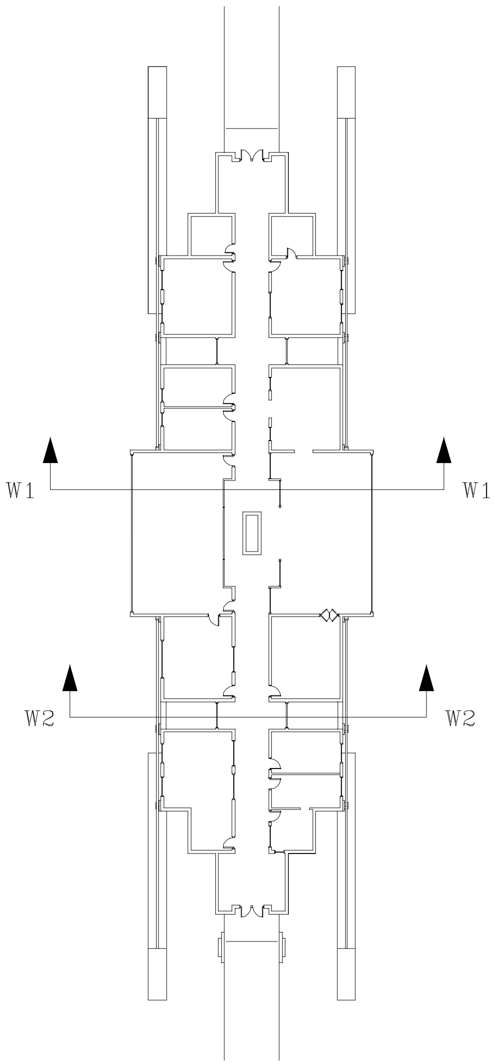

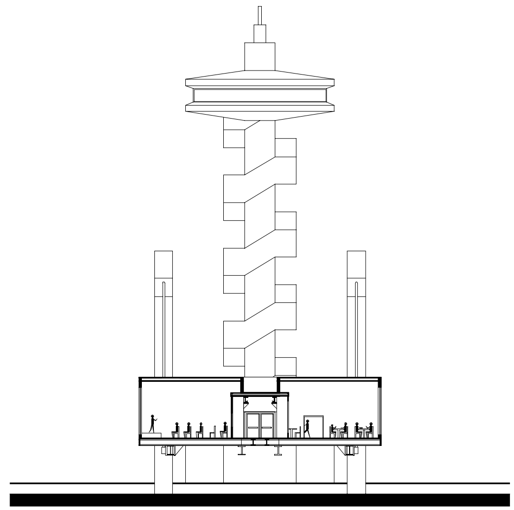

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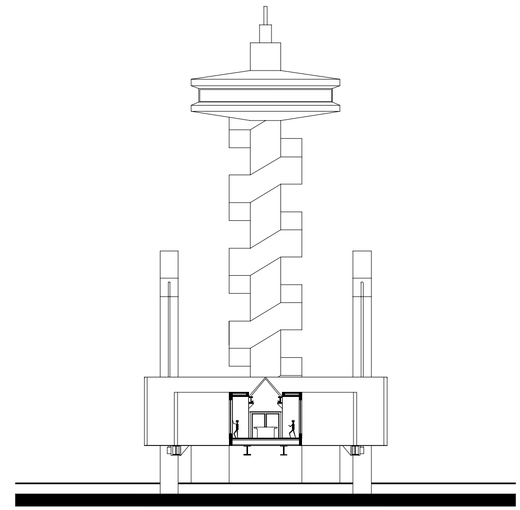

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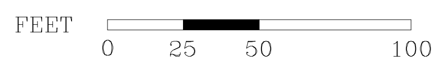

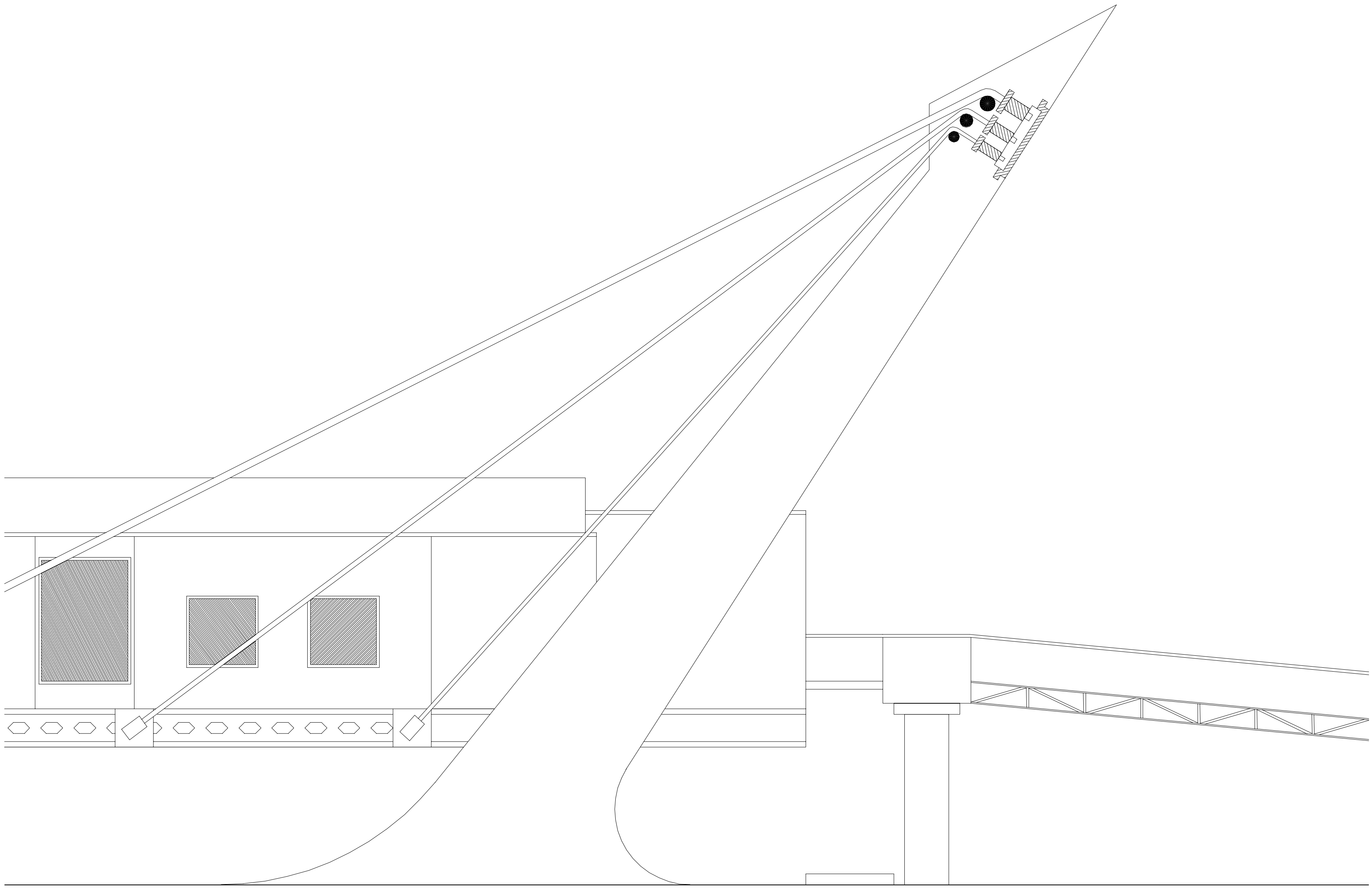

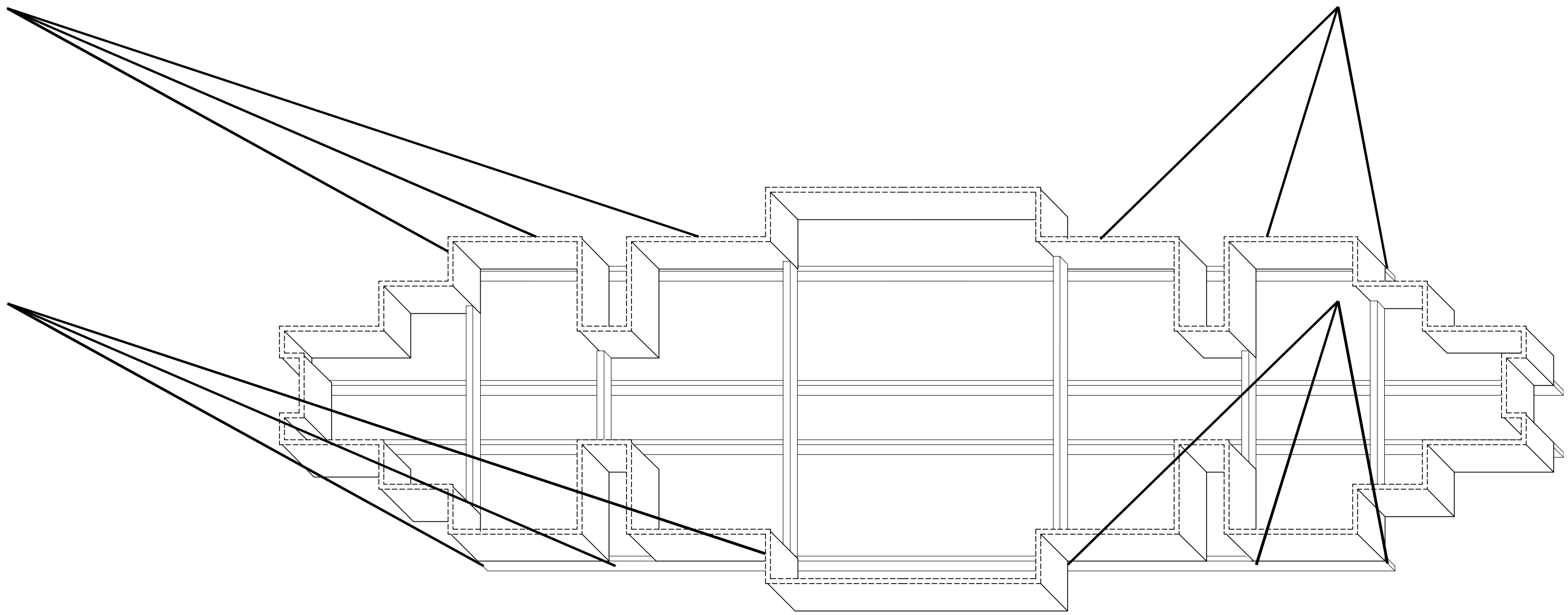

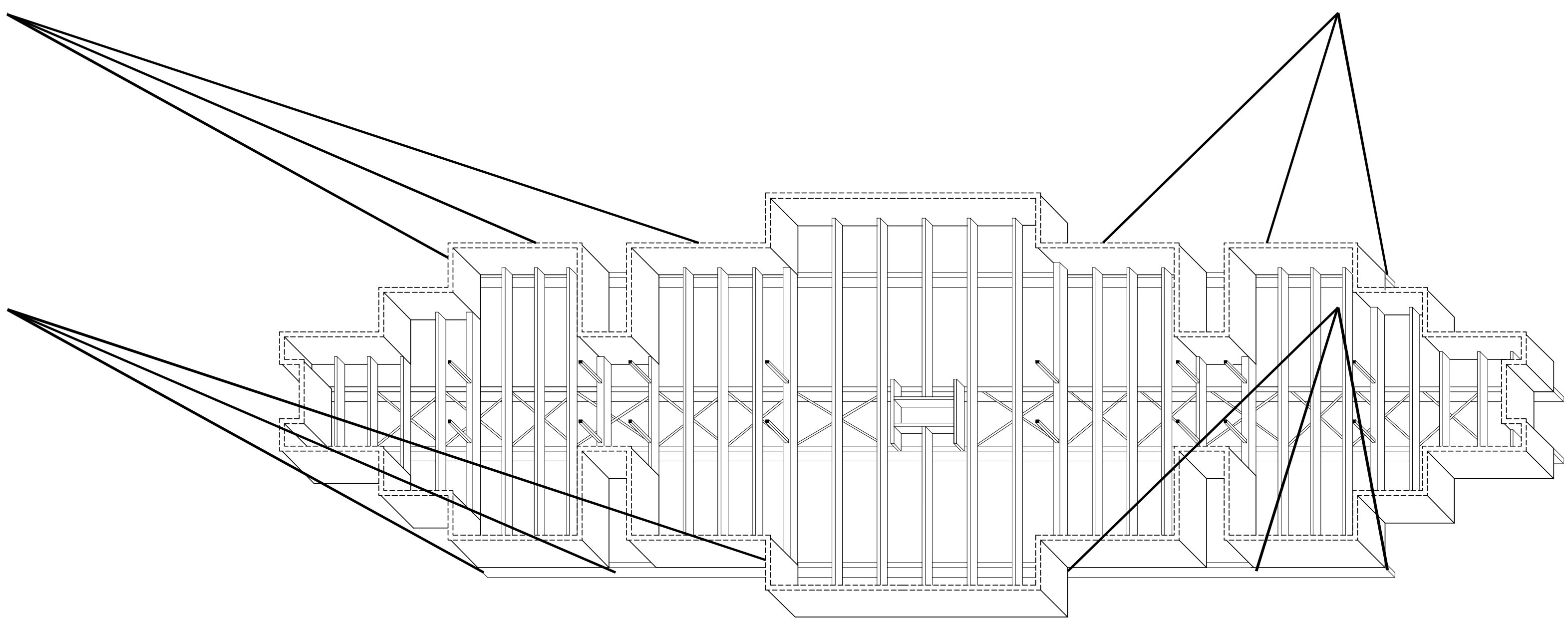

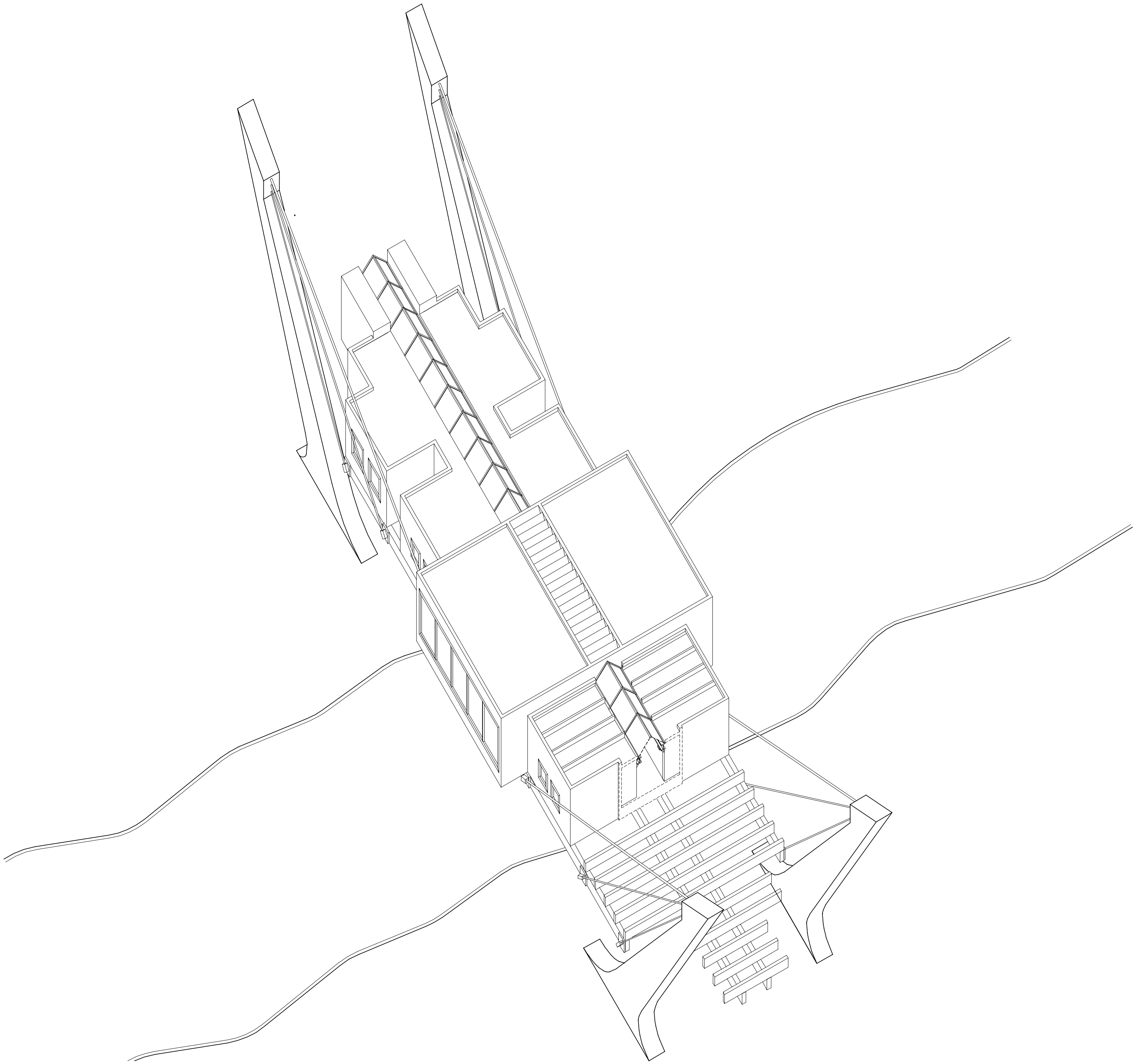

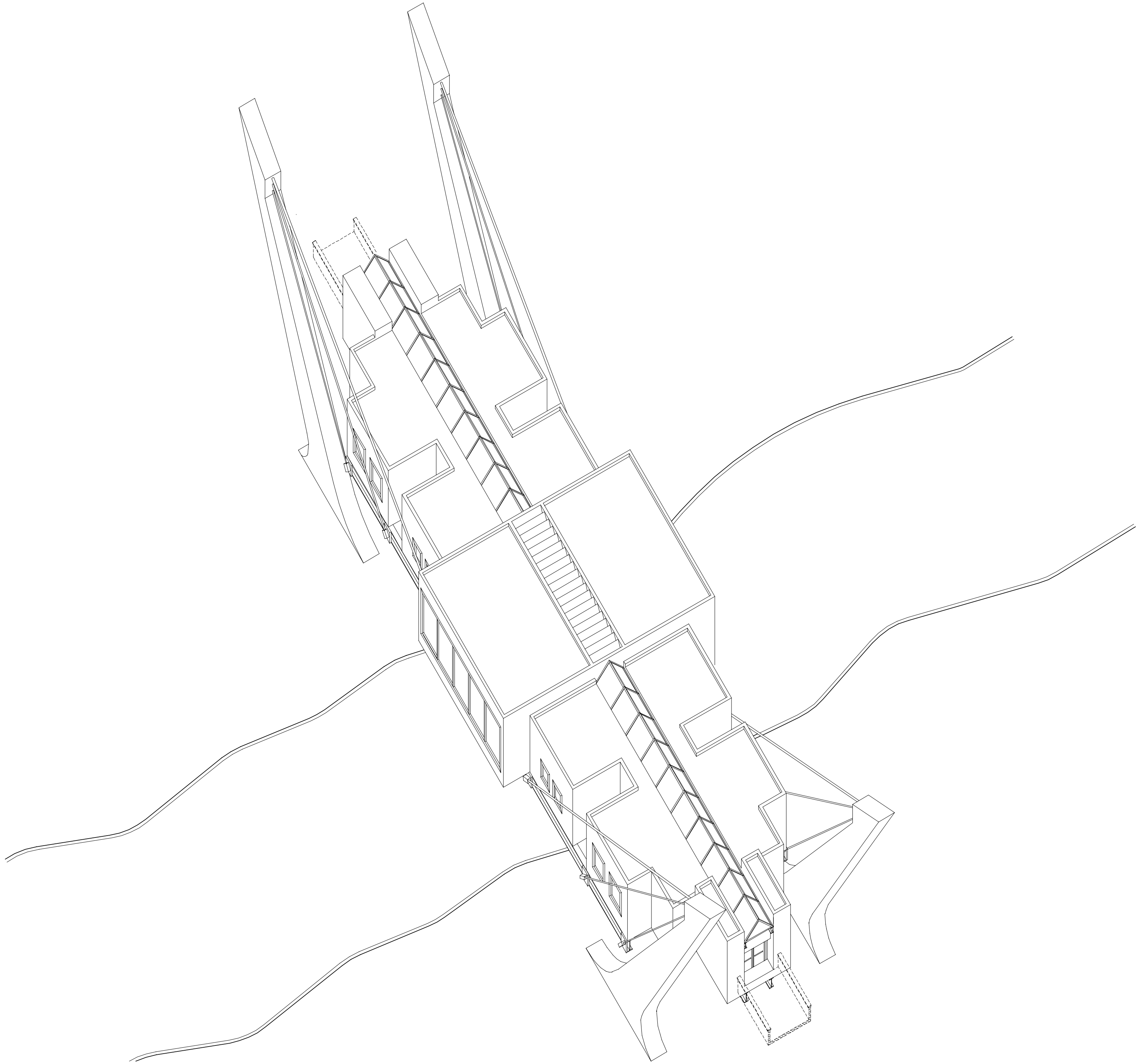

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Bibliography

Allen, Edward. Fundamentals of Building Construction: materials and methods. New York: John Wiley and Sons, 1990.

Blaser, Werner. Santiago Calatrava: engineering architecture. Basel: Birkhauser Verlag, 1990.

The Book Division. The Builders: marvels of engineering. Washington, D.C.: National Geographic Society, 1992.

Bonechi. All Florence. Florence: Arti Grafiche Parigi and Maggiorelli, 1974.

Godden, W.G. Structural Engineering Slide Library. 2 volumes. Berkeley: International Structural Slides, 1981.

Heinle, Erwin, and Fritz Leonhardt. Towers: a historical survey. New York: Rizzoli International Publications, Inc., 1989.

Hozumi, Nobuo. TWA Terminal Building and Dulles International Airport. Tokyo: A.D.A. EDITA Tokyo Co., Ltd., 1973.

Huxtable, Ada Louise. Pier Luigi Nervi. New York: George Braziller, Inc., 1960.

Kostof, Spiro. A History of Architecture: settings and rituals. New York and Oxford: Oxford University Press, 1995.

McCleary, Peter. "Structure and Intuition." AIA Journal. Oct. 1980: 56-58, 119.

Nervi, Pier Luigi. Buildings, Projects, Structures 1953-1963. New York: Frederick A. Praeger, 1963.

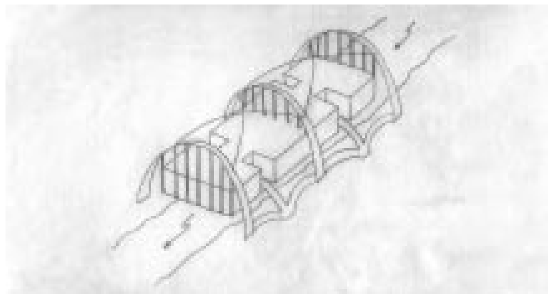
Saarinen, Eero. Eero Saarinen on His Work. New Haven and London: Yale University Press, 1968.

Siege social, services commerciaux. 4 Days in Paris. Paris: A. Leconte, 1994.

Turak, Theodore. William LeBaron Jenney: a pioneer of modern architecture. Ann Arbor: UMI Research Press, 1986.

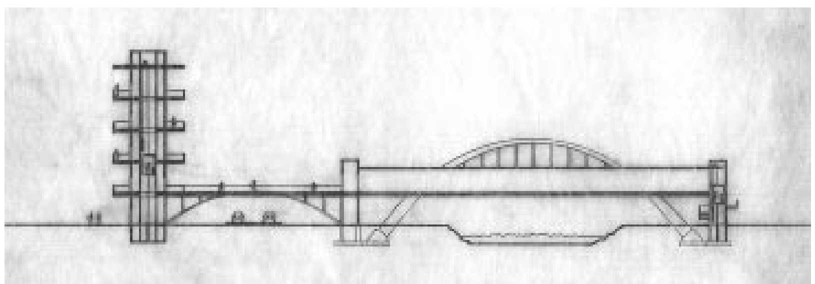
Wood, Richard A. The Weather Almanac. New York: Gale Research, an International Thomson Publishing Company, 1996.

VITA

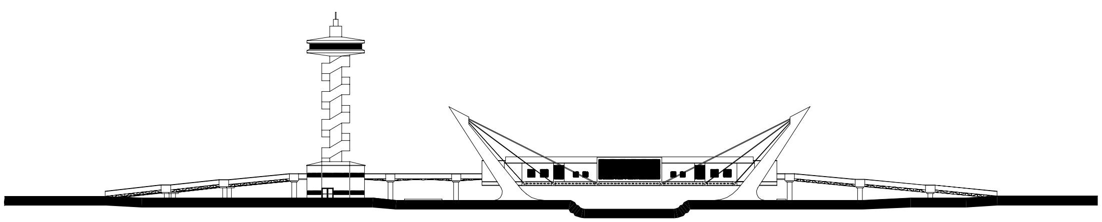


Robert L. Thomas

born: Richmond, Virginia, USA
raised: Winchester, Virginia, USA



Bachelor of Science
civil engineering
VPI&SU 1993



Master of Architecture
architecture
VPI&SU 1997