HILL-TO-HILL BRIDGE
PA Route 378 spanning the Lehigh River,
Lehigh Canal, Conrail, Monacacy Creek
and City Streets
City of Bethlehem
Northhampton and Lehigh Counties
Pennsylvania

HAER ~~HABS~~ NO. PA-131

HAER
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17-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Mid-Atlantic Region
National Park Service
Department of the Interior
Philadelphia, Pennsylvania 19106

HISTORIC AMERICAN ENGINEERING RECORD

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HAER NO. PA-131

Photographer: (Views 1-36) A. Pierce Bounds June 1988

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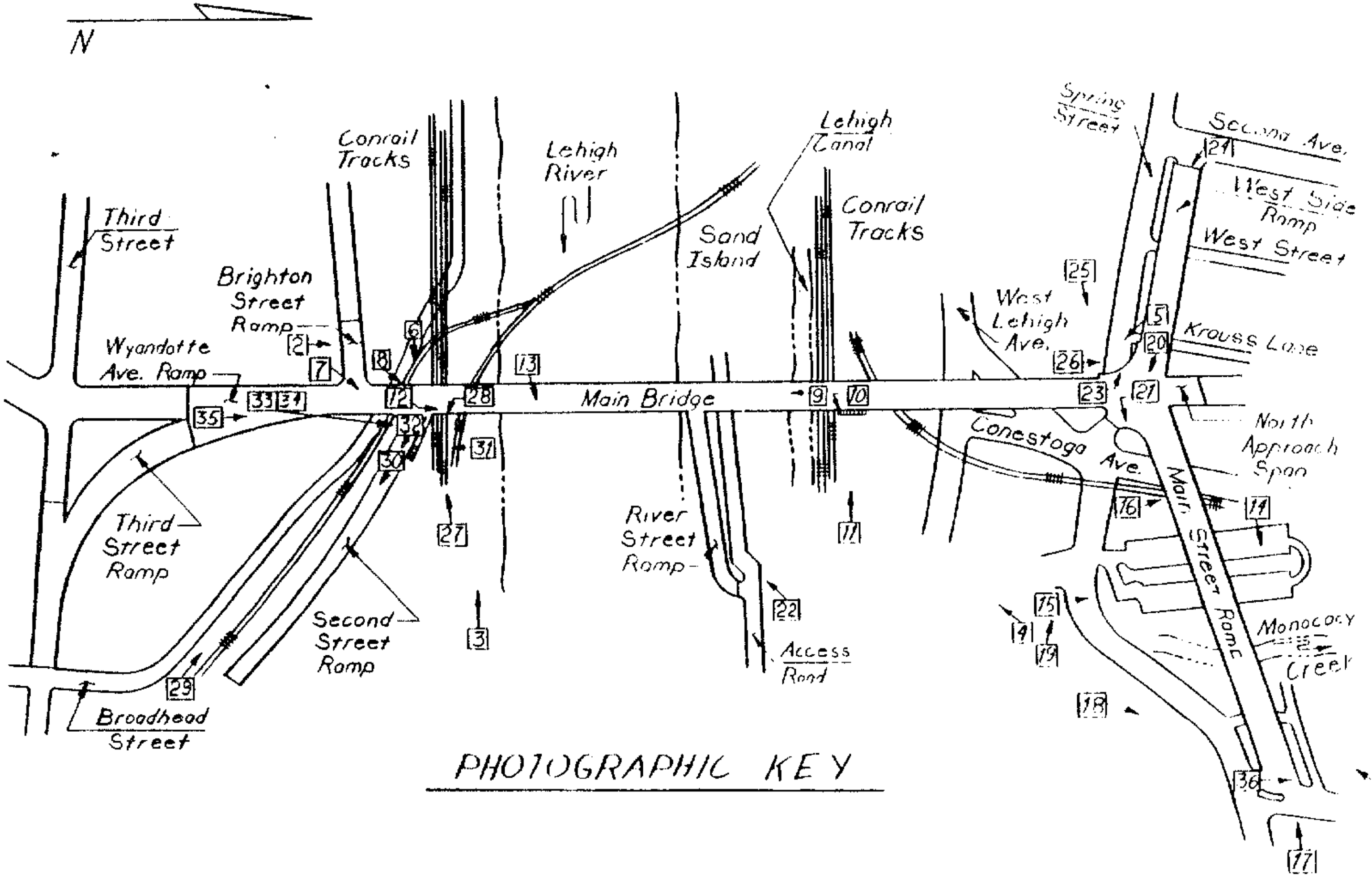

PHOTOGRAPHIC KEY

HISTORIC AMERICAN ENGINEERING RECORD

HILL-TO-HILL BRIDGE

HAER No. PA-131

Location: Pennsylvania Route 378 spanning the Lehigh River, Lehigh Canal, Conrail tracks, Monocacy Creek and city streets in the City of Bethlehem, Northampton and Lehigh Counties, Pennsylvania.

UTM: 18.467440.4495820
Quad: Allentown East, Pennsylvania

Engineer: Clarence W. Hudson

General Contractor: Rodgers and Haggerty, Inc., New York City

Steel Subcontractor: Bethlehem Steel & Bridge Corporation, Bethlehem, PA

Date of Construction: 1921 - 1924

Present Owner: Pennsylvania Department of Transportation Harrisburg, PA 17120 and the City of Bethlehem.

Present Use: Vehicular bridge with pedestrian sidewalks. South Main Street ramp demolished in 1965. North Approach Span added in 1967.

Significance: The Hill-to-Hill Bridge was the first bridge to join the boroughs of the City of Bethlehem with a high-level structure eliminating all railroad grade crossings. The structure, constructed almost entirely of reinforced concrete, owed its unusual shape to the eight access ramp structures that fed traffic to the Main Bridge avoiding numerous railroad tracks. The bridge was determined eligible for listing in the National Register of Historic Places as part of the expanded Central Bethlehem Historic District in 1988. The southern part of the bridge is included in the Fountain Hill Historic District. The structure crosses over the Delaware and Lehigh Canal National Heritage Corridor.

Project Information: This documentation was undertaken in October, 1988 in accordance with the Memorandum of Agreement the Advisory Council on Historic Preservation ratified March 22, 1985 as a mitigative measure prior to the demolition of the Second Street Ramp and the rehabilitation of the remainder of the structure.

Michael J. Cuddy
A. G. LICHTENSTEIN & ASSOCS., INC.
Langhorne, Pennsylvania
for Penna. Dept. of Transportation

The Hill-to-Hill Bridge spans the Lehigh River, Lehigh Canal, Conrail Tracks, Monocacy Creek and city streets in the City of Bethlehem. In addition, the structure connects the Fountain Hill and Central Bethlehem areas of the city. Both Fountain Hill and Central Bethlehem are listed on the National Register of Historic Places as historic districts containing eighteenth and nineteenth century buildings associated with the founding and development of the City of Bethlehem as well as the subsequent expansion of its industrial and transportation facilities. The structure also crosses over the Delaware and Lehigh Canal National Heritage Corridor which includes the Lehigh Canal and adjacent towpath. The bridge carries Pennsylvania Route 378, a highway that merges with U.S. Route 22, a major east-west artery through Pennsylvania, approximately 4 miles north of the structure. The Hill-to-Hill Bridge accommodates an average daily traffic volume of 38,388 vehicles. This structure has long been considered a vital transportation link for the area.

A ferry, located at approximately the same site as the present day structure, was the first means of crossing the Lehigh River in the City of Bethlehem. This method of transportation was begun in 1741, with the founding of Bethlehem, and served satisfactorily until the late 18th century. Increased travel between Bethlehem and Philadelphia and rumors of the old Philadelphia Road becoming a turnpike, caused the public spirited citizens of Bethlehem to investigate the building of a bridge across the Lehigh River.

On April 3, 1792, Governor Thomas Mifflin, signed an Act of Assembly authorizing the establishment and construction of a bridge crossing the Lehigh River.

The structure was built of hemlock timber, floated down the Lehigh River from forests along Panther Creek, by the Lehigh Bridge Company of Bethlehem at a cost of $7,800.00. The money for this structure was raised by selling stock, valued at $100 per share, to the citizens of Bethlehem. The structure was completed on September 27, 1794 and opened as a toll bridge, following a day of free passage. The bridge was an uncovered structure comprised of four timber truss spans supported by piers comprised of timber cribbing, filled with stones. The roadway width allowed for the passage of a single wagon with a "retreat", a triangular projection at the center of the bridge, built for pedestrians to wait for the passing of a carriage.

In 1816, after determining that the first bridge was unsafe, a new structure was built. This bridge was similar in form and construction to the original bridge, except it was supported by stone piers, protected by ice-breaks. On January 8, 1841, "gray with age and worn with travel", this bridge, as well as all of the bridges over the Lehigh River, was washed away by a severe flood.

A new toll bridge was built in 1841 by the Bethlehem Bridge Company at a cost of $7,258.00. The three-span timber Burr arch truss was covered but open on the sides and had a roadway width of 18 feet to accommodate the increased traffic demands brought on by the industrialization of Bethlehem. On

June 5, 1862, a flood washed away the northern two spans and the supporting pier. The south span, although slightly damaged, was basically sound and capable of reuse. The damaged portions of the structure were quickly rebuilt and the bridge again opened to traffic.

The structure consisted of three simple spans of timber Burr Arch Trusses, a construction technique common to many early timber bridges where a wooden arch is combined with a multiple king post truss. The spans were made semi-continuous by bolting two pieces of timber planking from end post to end post of adjacent trusses. The continuity of the roof and sidewalks also aided in the distribution of moments from one span to the next. The span lengths were 146'-9", 120'-0" and 109'-2" from south to north respectively. The trusses were spaced at 20'-0" on center with a height of 14'-0", from center-to-center of chord members. Each side of the structure exhibited 7'-0" wide sidewalks, constructed of 2" timber flooring and supported by timber brackets extended from the floorbeams. The roof consisted of a slate covering to protect the timber elements below. The bridge was constructed approximately 23 feet above the mean low water mark of the Lehigh River.

The south span was comprised of twelve panels, the center two were 11'-11" wide and the remainder were 12'-3 ½" wide. Four timber arches, two on each side, were connected to each truss of this span. One set of arches was from the original construction of 1841, while the other set was added to strengthen the span in 1862. The middle and north spans contained ten panels each with a width of 12 feet and 10'-11" respectively. Two timber arches, one on each side, were connected to each truss of these spans.

Even though this bridge was quickly rebuilt, the directors of the Bethlehem Bridge Company failed to provide the best possible service to the citizens and industries of Bethlehem. The construction of the Lehigh Canal in 1827, in conjunction with development of the Lehigh Valley Railroad and the Bethlehem Iron (later Steel) Company (both of which were headquarted in Bethlehem) as important industries, caused many businesses and people to move into the Bethlehem area. As commerce and industry grew, more residences were constructed in downtown Bethlehem and the Fountain Hill section (South Bethlehem) quickly became home for the middle to upper level managers of these booming industries. The directors of the Bethlehem Bridge Company lacked the foresight to provide a structure capable of handling the increased traffic demand present in 1862. The private enterprises that owned many of the major bridges throughout the country at this time were similarly concerned only with maximizing profits. This stood in stark contrast with the philosophy of the railroad companies who built many bridges and maintained and improved them for the overall efficiency of the system.

The increase in industry and commerce in the Bethlehem area led to the rapid growth of train traffic through the city. It was not uncommon for pedestrians and motorists using the bridge to experience considerable delays due to the passing of a long train. These delays served to effectively restrict the movement of important traffic throughout the area. It was these delays, the inherent danger of railroad grade crossings and the desire to have a bridge that was safe from the floodwaters of the Lehigh River, that the idea of a bridge from "Hill-to-Hill" was formulated.

In 1887 the Nisky Hill Bridge Company was incorporated for the purpose of constructing a new "free" bridge across the Lehigh River and Canal east of Nisky Hill Cemetery. Much debate occurred over the site of the new bridge and whether instead of constructing a new bridge, the existing structure should be "freed". This idea was strongly opposed by the directors of the Bethlehem Bridge Company who profited from the tolls collected on the present bridge. The Nisky Hill Bridge Company was dissolved in 1892 when no decisions could be reached. On November 8, 1892, the Bethlehem Bridge Company allowed for the free passage of horses and wagons over the old covered bridge. However, tolls were still collected for powered vehicles. These events marked the beginning of the long, hard fought struggle to construct the Hill-to-Hill Bridge.

Efforts continued in the years to follow to build a new modern structure capable of carrying the heavier vehicles of the day and eliminating dangerous railroad grade crossings. Even though these efforts had strong public support, the proposals presented were not satisfactory to all parties involved. The lack of a neutral coordinating authority to bring all of the varied interests together was seen as the largest obstacle in the building of a new bridge.

In 1892, the county commissioners from Northampton and Lehigh Counties paid the Bethlehem Bridge Company $26,000 for the old covered bridge and "freed" the structure. In the September 6th, 1892 issue of the Daily Times, the following quote appeared and represented the general public sentiment regarding this bridge, "The Bethlehems will have a free bridge, though it will be a very old one, well worn, and an unsightly object to look upon."

The efforts to build a new bridge continued and in 1894, the Joint Bridge Commission was organized and asked the railroads and all parties involved to cooperate in the design and construction of a new bridge across the Lehigh River and Canal. Engineers Mansfield Merriman and Clarence W. Hudson examined the feasibility and costs of the proposed plans for the new bridge. The only bid received for the construction of this bridge was from McClintic-Marshall Co. of Pittsburgh on January 31, 1907. The bid price received for the steel structure was slightly under $500,000. This price was viewed as excessive by the parties involved and when the Commission could not solve the many problems that arose from this proposal, the idea was shelved again.

In 1911, the Bethlehem's Joint Bridge Commission was formulated from committees from Bethlehem and South Bethlehem. In meetings held with the Northampton County Commissioners, the following resolutions were unanimously passed:

1. The old covered bridge was not adequate to accommodate present traffic for it was too narrow and in need of rehabilitation.

2. The new structure would eliminate all railroad grade crossings on both sides of the river and channel traffic over the same structure.

3. Recommended submission of petition for favorable action by the Grand Juries of both counties.

R. E. Neumeyer was retained to submit plans for the new bridge to the Joint Bridge Commission. Neumeyer's Plan No. 1 was submitted on July 26, 1911 with an engineer's estimate of $482,000. The Grand Juries of Northampton and Lehigh Counties approved these plans. However, the Lehigh County Court refused to approve or confirm the findings of the Grand Jury. Even though no agreement could be reached, the following pledges were received for the construction of the bridge:

Northampton County	$100,000
Lehigh County	$ 95,000
Lehigh Coal & Navigation Co. & Railroad	$275,000
Mr. Schwab & Mr. Wilber	$ 50,000

From December of 1912 to November of 1914, no meetings were held due to problems with the railroads. By June 18, 1915, the entire plan had come undone and was on the verge of abandonment. The Industrial Committee (from North Bethlehem) was opposed to building a bridge from shore-to-shore of the Lehigh River, the railroad companies demanded that certain railroad grade crossings be eliminated and all parties were questioning the effect of the bridge location on the financial growth of the town. To make matters worse, the old covered bridge was closed to heavy trucks and horse teams.

In July of 1915, a petition was filed with the Public Service Commission (PSC)[1] for the construction of the Hill-to-Hill Bridge. The petition was signed by hundreds of citizens who pledged $5.00 each to help defray the cost of data collection, surveys and preliminary plans. R. E. Neumeyer was chosen to draw up plans for approval by the PSC. A petition was also filed before the PSC on August 3, 1915 to abolish certain dangerous railroad grade crossings.

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[1] The Public Service Commission was formed in 1906 by the State of Pennsylvania to regulate the public utilities. This regulation included the setting of rates and settling disputes that arose between the utilities or between the utilities and the public. In 1937 the PSC was replaced by the more powerful Public Utility Commission.

Neumeyer presented Plan No. 1 and 2 (a bridge from "hill-to-hill" eliminating certain grade crossings) to the PSC on August 5, 1915. The PSC, in the months that followed, debated the following issues:

1) The feasibility of repairing the old covered bridge.
2) Which railroad grade crossings should be eliminated.
3) The construction of a temporary bridge.

It was decided that as a temporary measure, the old covered bridge should be repaired. Upon completion of the repair program, which cost $8,000, the bridge was reopened to all traffic with a warning sign which cautioned that using the structure was at one's own risk.

On September 8, 1916, a meeting was held with the citizens of Bethlehem so that they could voice their opinion regarding the recently PSC approved Neumeyer Plan No. 1 for the new bridge. The public was in strong favor of an alternate scheme, Neumeyer-McKibben Plan No. 3, which extended Neumeyer Plan No. 1 to the intersection of Church and Main Streets at its northern terminus with a width of 60 feet and a ramp to West Bethlehem. The PSC, in a meeting on September 12, 1916, held that it did not have the authority to authorize this plan due to the substantial increase in cost over the approved plan. PSC Chairman W.D.B. Ainey stated that if the citizens of Bethlehem could raise $200,000 within thirty (30) days to defray a portion of the additional cost involved, the Commission would be apt to approve the preferred plan.

The Joint Bridge Commission met on September 27, 1916 and organized a fund raising drive to collect the necessary money. The drive started on October 2, 1916 and by the time it closed on October 8, a total of $456,849.66 had been collected, of which $200,000 was from the Bethlehem Steel Company and $50,000 from Mr. C. M. Schwab. At the end of the fund-raising drive a total of $1,196,849.66 was available to build the bridge. A breakdown of the pledges received is as follows:

Individual Contributions	$ 206,849.66
Personal contribution of Mr. C. M. Schwab	50,000.00
Bethlehem Steel Company	200,000.00
Northampton County	150,000.00
Lehigh County	125,000.00
Lehigh Valley Transit Co. (for franchise)	100,000.00
South Bethlehem Borough	25,000.00
Bethlehem Borough	25,000.00
Lehigh & New England R.R. Co. and allied interests	15,000.00
Phila. & Reading, Lehigh Valley, and Central Railroad Companies	300,000.00

In January of 1917, sensing the great local interest in the bridge project and the difficulty in supervising a project of this magnitude from a great distance, the PSC appointed a local committee to act as agents and to handle all matters for the PSC. This committee, Bethlehem's Bridge Commission, hired Clarence W. Hudson[2] to prepare final plans and to supervise construction. The truss he designed for the Hill-to-Hill Bridge, named the Hudson Truss in his honor, is unique for it eliminates the diagonals commonly found on trusses of the era, and allows for the passage of vehicles between the truss verticals.

In 1918 Hudson completed the design of the Hill-to-Hill Bridge but World War I prevented any further work on the structure. In 1919 the PSC increased the engineer's estimate for the structure to $2,250,000. This increase was due to the increased costs associated with labor and materials at the completion of the war.

Throughout 1919, additional items arose that delayed the carrying through of these plans. On April 30, 1919, the Lehigh Valley Railroad requested that the steel spans over the railroad tracks be made longer. This change was made at the cost of the railroad. On July 2, 1919, the Lehigh Valley Transit Company declined the privilege of using the structure, thereby eliminating the $100,000 franchise fee. This money was made up when the railroads agreed to pay $500,000. At the close of 1919, Hudson estimated the cost of the bridge (including land acquisition) to be $2,278,412.

On December 29, 1919, the PSC advertised for bids for the construction of the Hill-to-Hill Bridge. T. L. Eyre submitted the only bid which came in at $4,871,437. This dramatic increase in price was attributed to the post-war economic conditions. When informed of this bid, the railroads again began to have doubts about the feasibility of this project.

Throughout 1920 and the early part of 1921 Hudson worked on revising the plans. His intent was to reduce the cost of the structure without eliminating the essential qualities of the design. Hudson modified ornamental features by substituting a less expensive but serviceable type of construction. New bids

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[2] Clarence W. Hudson was born in Manasquan, New Jersey in 1867. He graduated from Lehigh University in 1889 with a civil engineering degree. From 1892-1906 he served as a design engineer for the Phoenix Bridge Company. From 1906 he served as a consulting engineer in the city of New York. From 1909 he served as Department Head of the Civil Engineering Department at Polytechnic Institute of Brooklyn. He wrote several books: "Deflections and Statically Indeterminate Structures" and "Notes on Plate Girder Design".

The truss he designed for the Hill-to-Hill Bridge, named the Hudson Truss in his honor, is unique for it eliminates the diagonals commonly found on trusses of the era, and allows for the passage of vehicles between the truss verticals.

were advertised for and of the five bids received, Rodgers and Hagerty, Inc's.[3] of New York City was the lowest with a bid of $2,568,000. Even though this bid amount was higher than the PSC allocation of November 11, 1919, a contract between the PSC and Rodgers and Hagerty, Inc. was signed on July 25, 1921 in Harrisburg, PA.

Work was officially begun on the Hill-to-Hill Bridge on August 1, 1921, when Rodgers and Hagerty, Inc. opened an office in Bethlehem. Excavation was begun on September 27, 1921 at Piers 9 and 11 and concrete work was begun on December 14, 1921 at Pier 14. At the height of construction, in the summer of 1923, over 400 men were employed. A temporary wooden structure was built slightly downstream from the old covered bridge so that the old bridge could be demolished in order to clear the area for the new structure.

The construction of the Hill-to-Hill Bridge involved the use of many new and novel techniques to efficiently construct a structure of this magnitude.

The excavation for all piers, except Pier 2, was carried down to solid rock through the use of open shafts. The deepest excavation was at Pier 3 (52 feet deep) and the shallowest was at Pier 24 (10 feet deep). The excavated material, comprised of an average of 10 feet of loam, 10 to 15 feet of gravel, and a varying depth of fractured rock, was handled primarily by 13 stiffleg and 4 guy derricks with 45 to 80 foot booms and 1 cubic yard orange peel or clam shell buckets and a Brownhoist Locomotive Crane with a 52 foot boom. The excavated material was removed to a 5-acre spoil bank located on Sand Island. To ease the excavation of the fractured rock strata, considerable blasting was required at certain pier locations. Steam drills were utilized in preparing the blasting holes.

Wood sheeting was used to support shallow excavations and 14 inch arch web Lackawanna Steel sheet piles, ranging in length from 40 to 45 feet, were used in the deeper excavations. The sheet piles were assembled to form complete 35 x 75 foot cofferdams. The cofferdams were then driven by sheeting hammers, suspended, without leads, from the derrick booms. A minimum 24 inch clearance was provided for the pier formwork inside the cofferdam. Interior bracing, consisting of horizontal and vertical 10" x 10" and 12" x 12" timbers, were placed on four foot centers throughout the shaft to support the cofferdams.

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3 Rodgers and Hagerty, Inc. were prominent contractors of the era and during the construction of the Hill-to-Hill Bridge they were also constructing the Manhattan approach section of the New York to New Jersey vehicular tunnel.

All of the deep piers passed through or into a strata of water, therefore requiring a continual pumping system. Numerous electric driven single stage centrifugal pumps were used through-out the site with 8 or 10 inch discharge pipes. At the deepest excavations, where the head was too great for single pumps, a platform was constructed and a booster pump added. The cofferdams of the river piers were made practically watertight by placing the excavated material, which contained a large quantity of fine material, on the outside of the sheet piles, forming protective embankments.

The piers were concreted in stages with the concrete poured up to the level of the next layer of horizontal timber braces. The vertical braces were left in the concrete until that layer had set. The braces were then removed and the empty spaces filled with concrete. Once the pier was complete and the backfill placed, the sheet piles were pulled by driving the sheeting hammers upwards against a steel harness attached to the top of the piles. One hammer pulled an average of twenty sheet pile sections a day. These sections were then reused at adjacent excavations.

In order to avoid a deep open excavation between the two tracks of the Lehigh Valley Railroad, Pier 2 was founded on one hundred reinforced concrete piles with cast iron points. The piles were driven by steam hammers delivering approximately 60 blows per minute on a sacrificial "cushion" that lasted only two hours under continual load. The piles generally penetrated 15 feet in the first 15 minutes and approximately one foot in five minutes after that. The piles were driven to a refusal of 50 blows for the last one half inch penetration. When boulders or other obstacles were encountered, the refusal was 100 blows for the last one half inch penetration. After each pile was driven, the portion of the pile above the cut-off elevation was removed with pneumatic hammers and oxyacetylene torches.

The portion of the piers above the approximate finished ground line was "rubbed down" with carborundum blocks to give it a smooth white finish. Each pier had a series of drain outlets which connected into the superstructure drainage system. The river piers were constructed with rounded noses to facilitate the breaking up of ice.

The arches were constructed in sections with the section nearest a pier poured first. The section at the crown of the arch was poured next and the remaining sections were then poured symmetrically to balance the load on the formwork. The keys were the last sections poured and were done so after the voussoir concrete had set and the bulkheads (key formwork) removed. Canvas covers were placed over freshly poured concrete to retard it from setting until an entire section was in place and also to protect the fresh concrete from the sun. Wooden formwork, consisting of 10" x 10" vertical posts braced by 2" x 10" longitudinal and transverse diagonals with 4" x 10" scabs was used almost entirely throughout the construction of the arches. The lumber used for the falsework and forming was provided by the Construction Lumber Company of Pittsburgh, Pennsylvania and the Trexler Lumber Company of Allentown, Pennysivania. Wooden piles were driven into the bottom of the Lehigh River and capped to support the falsework for the construction of the arch spans over the river. Additional support was provided by the old bridge piers that had been partially removed.

After the arch ring concrete had set, the falsework was removed and construction began on the spandrel walls. These walls were formed with 1-7/8" tongue and groove boards with 2" x 6" verticals spaced at 16 inches on center and pairs of 3" x 6" wales spaced 3 feet apart vertically. The formwork was braced by inclined struts and permanent 5/8" diameter horizontal tie-rods coupled to short removable end sections. The lower tie-rods, at the base of the spandrel walls, were tied into anchor bolts set in the arch ring and were used to maintain the form alignment.

The only locations where wooden formwork was not utilized was for the curved sections at the base of the coping for the balustrade and at the base of the hub area columns. Since the coping was duplicated throughout the entire structure, steel forms were used to reduce some of the carpentry requirements. The bases of the hub area columns, in the area adjacent to Pier 14, were required to be identical in form and dimensions, therefore, to reduce the cost of the complicated formwork involved in the construction of these columns, a concrete mold was made for each column and used as a form for the base.

Prior to backfilling the arch structure, upon completion of the spandrel walls, the arch extrados and inside faces of the spandrel walls were waterproofed. The waterproofing system was applied by the Minwax Company and consisted of a coat of tar on the concrete surface, followed by a 2-ply membrane fabric and a second coat of tar. The waterproofing system was also applied to the inside faces of the retaining wall structures of the approach ramps. A total of 230,000 square yards of waterproofing was placed by the Minwax Waterproofing Company of New York City.

Travelling derricks, mounted on top of the finished spandrel walls, were used in removing the excavated material from the spoil bank on Sand Island and backfilling the closed spandrel arches at a rate of approximately 250 cubic yards per day. The backfill was wet down with a hose and tamped in 12 inch thick layers by hand. On the approaches, a 12-Ton Gasoline Road Roller compacted the fill behind the retaining walls.

The most unique feature in the construction of the Hill-to-Hill Bridge was the system of distribution towers used for transporting concrete from mixing plant to placement. The concrete work was divided into two sections with Lehigh Avenue as the boundary. Each section was a separate entity with their own equipment and foreman. An Insley steel distribution tower and two, one cubic yard concrete mixers were the principal equipment of each section.

The northern section was serviced by a distribution tower, 200 feet high, located at Pier 14. A 37 cubic foot hoisting bucket raised concrete from the mixing plant to the top of the tower where it was placed in a 3-way hopper. The hopper served three lines of Insley steel chutes, suspended by cables, one each for the Main Bridge, Main Street Ramp and West Side Ramp. The chutes terminated at derrick mast hoppers located at the top of 80 foot high derrick masts. From here, chutes were suspended from the derrick boom to distribute the concrete from the derrick mast hoppers to where it was needed on the structure.

The southern section of the bridge was serviced by a 240 feet high distribution tower located at Pier 7. Two chute lines extended from this tower, the north one crossed the Lehigh Canal for placements at Pier 9 and the south one extended to an auxiliary steel tower, 160 feet high, located in the middle of the Lehigh River. The use of this auxiliary tower enabled concrete placements at Pier 1.

For portions of the structure outside the area within reach of these distribution towers, trucks with one cubic yard hoppers with undercut gates were utilized. These trucks were operated at ground level and discharged their concrete into buggies for placement. All of the concrete for the Second Street Ramp was transported by trucks with drop bottom buckets to a 15 ton locomotive crane which hoisted the buckets to the forms. Once the trolley tracks were laid in the roadway, the contractor fitted one of his trucks with flanged steel wheels and used it to transport concrete. The normal output for each tower for a 10 hour shift was 300-350 cubic yards, with a maximum quantity placed in a 24 hour period of 1,050 cubic yards.

The aggregate used in the concrete was primarily obtained from a limestone quarry, Groman's Quarry, located along the Monocacy Creek about a mile and a half from the bridge site. Rodgers and Hagerty also operated a crushing plant at this location, ensuring a continuous supply of crushed stone. Sand used in the concrete was shipped from Kenvil, New Jersey, near Lake Hopatcong. Cement was furnished by the Pennsylvania Cement Company and the Lehigh-Portland Cement Company. An average of 2,000 bags of cement were delivered to the site each day.

A total of approximately 107,000 cubic yards of concrete was required to construct the Hill-to-Hill Bridge. Concrete of the following proportions were required: 1:2:4 for arch rings, beams, girders, slabs and columns; 1:2-1/2:5 from main piers, abutments, and spandrel walls; 1:3:5 for foundations below ground. The maximum aggregate size was 1 inch for the arch rings, 2 inches for plain concrete and 3/4 of an inch for floor slabs, railings and lamp posts. The proportions were easily mixed with the use of one cubic yard measuring boxes with horizontal marks inside to indicate the amount of aggregate, sand and cement required for a 1:3:5 mix. To measure the components of a different concrete mix, wooden boxes having a volume of one cubic foot, were nailed inside the measuring box at the corresponding location. This system allowed for a quick and easy method of concrete component measurement. Every batch of concrete was mixed in a mixer drum, set for 20 revolutions per minute, for a minimum of two minutes.

Rodgers and Hagerty subcontracted out the fabrication and erection of the steel spans, Spans 1 and 8 of the Main Bridge and the South Main Street Ramp, to Bethlehem Steel Corporation of Bethlehem, Pennsylvania. Trusses were utilized for Spans 1 and 8 of the Main Bridge in order to provide the clearance under the structure required by the railroads. If reinforced concrete arches had been used, to be consistent with the remainder of the Main Bridge, a higher crown elevation would have been required resulting in a higher structure cost due to the additional reinforcement and concrete required and the larger foundations. The total quantity of steel erected by Bethlehem Steel was approximately 1,118 tons for Spans 1 and 8 and 573 tons for the South Main Street Ramp. The truss spans were erected with the aid of timber falsework bents and a traveler, with a 76 foot boom, whose rails were supported by the truss stringers.

The most complicated construction occurred at Pier 14, at the intersection of the Main Bridge, South Main Street Ramp, Main Street Ramp and West Side Ramp. A large rectangular manhole and several reinforced concrete columns were constructed within this earth filled pier. The manhole served as the central point for all wiring on the structure. The bridge wiring was installed by Tucker Electric Construction Company of New York City.

The bridge lighting was comprised primarily of bronze lamps mounted on reinforced concrete poles. The steel spans exhibited cast iron lamp fixtures and poles. General Electric 1000 watt lamps were installed using a three phase, 60 cycle alternating current at 220 volts and 6.6 amps. Each lamp was wired to an individual, independent transformer which transferred the current to 50 volts and 20 amps.

A total of 23,500 square yards of roadway surface required granite block paving. The four inch paving blocks were furnished and installed by J. Meehan and Son of Philadelphia, Pennsylvania. The blocks were obtained from granite quarries in Georgia and Maine.

On November 1, 1924, the Hill-to-Hill Bridge was officially opened. Pedestrians had been using the structure for several months and even though the bridge was completed several weeks before the official opening, no vehicles were permitted to cross. This delay was caused by difficulties determining who was to assume responsibility for the maintenance costs of the bridge. It was eventually decided at a PSC meeting on October 28, 1924, that the City of Bethlehem should pay 50 percent of the maintenance costs while Lehigh and Northampton Counties divided the remaining 50 percent. Shortly after this accord was reached, the bridge opened for all traffic.

At the time of its construction, the Hill-to-Hill Bridge measured approximately 6,055 feet in length, with nine distinct sections (the Main Bridge and eight access structures). The general shape of the Hill-to-Hill Bridge was that of a "Y" with the West Side and Main Street Ramps forming the upper portion. The remaining access structures were offshoots from the Main Bridge, placed so as to avoid railroad grade crossings. The tracks of four railroad companies, the Lehigh River, and the Lehigh Canal cut this heavily developed industrial area of Bethlehem into narrow strips of land. In order to provide access to every strip, it was necessary for the Hill-to-Hill Bridge to take the form that it did. A detailed description of the various sections forming the Hill-to-Hill Bridge, as constructed, follows.

The Main Bridge is comprised of 13 spans consisting of one doubly reinforced concrete beam span, two truss spans and ten reinforced concrete arch spans, with a total length of approximately 1,627 feet, along the bridge centerline, from the centerline of Pier 1 to the intersections of the Main Bridge, Main Street Ramp and West Side Ramp centerlines at Pier 14. The Main Bridge carries two traffic lanes northbound and two southbound with a minimum roadway width of 40'-0" at the truss spans and a 44'-0" roadway width throughout the remainder of the structure. The structure is on a tangent horizontal alignment with no vertical grade.

The truss spans (Spans 1 and 8) are comprised of riveted steel, built-up, 8-panel, Hudson Trusses. The trusses are spaced at 44'-0" on center with a panel width of 21'-4 ½" and a span length, from centerline-to-centerline of bearings, of 171'-0". The maximum height of the trusses, from centerline-to-centerline of chord members, is 40'-0". The roadway width is 40'-0" from curb-to-curb.

The Second Street Ramp connects with the Main Bridge at the middle of Span 1. In order to allow vehicles to pass through the truss verticals, the usual diagonal configuration could not be used. A diagonal chord, passing from L1 and L7 to U4, was designed to carry a large percentage of the load. The design live load for the truss spans was taken as 100 pounds per square foot of sidewalk and 150 pounds per square foot of roadway. In order to determine the maximum stress in a member, truck and trolley loads were also considered. The truck load examined consisted of two axles, spaced 12 feet apart, with concentrated loads of 16 tons on one axle and 8 tons on the other. The wheels of each axle were spaced at six feet on center and the truck was assumed to cover a floor area of 10 feet by 32 feet. The trolley loading considered consisted of two coupled cars, each 45 feet long, with two trucks per car and a total load of 60 tons per car. The trucks were 26 feet on center for each car and 19 feet from center-to-center between adjacent cars. The wheels of each truck were 6 feet apart from center-to-center. Impact was considered for all stresses due to concentrated loads and taken as the following percentage of the live load stress:

$$I = [150 - (L + 300)] \times LL$$

Where L equals the loaded length producing the maximum stress.

The truss is comprised of various size, built-up riveted steel members, connected by large gusset plates. Lateral and sway X-bracing is found at each upper chord panel point and is comprised of rolled steel angles connected with gusset plates. The portal bracing is comprised of rolled steel angles and gusset plates. Built-up steel floorbeams, spaced at 21'-4 ½" from center-to-center, frame into the truss bottom chord. The stringers, 24 x 84 Bethlehem I-beams, are framed into the floorbeams and have a spacing of 5'-1" except the first stringer on either fascia which is located at 4'-2 ½" from the center-line of the truss. Built-up riveted steel overhang brackets are found at each interior bottom chord panel point. The brackets are connected to the bottom chord by web connection angles and to the floorbeam by tie plates. The tie plates at Panel Points L2, L3, L4, L5 and L6 are comprised of one plate with a hole provided in the middle for the truss hanger to pass through. At Panel Points L1 and L7 slots are provided in the bottom chord gusset plates to allow the tie plates to pass through. The overhang brackets support two sidewalk stringers, a rolled steel I-beam (18 x 48.5 Bethlehem shape) and a riveted built-up channel.

A seven inch thick reinforced concrete deck is supported by the stringers. Armored steel expansion dams are present at each end of the concrete deck. A 10'-3" wide sidewalk, from centerline of railing to curb, is present on each truss span. A 3'-8" high cast iron ornamental railing is also present. The built-up channel fascia stringer is encased by a minimum two inch thick layer of concrete reinforced with a 2 inch mesh of 12 gauge expanded metal. A coating of mesh reinforced concrete, with a minimum thickness of 1½" was placed on the bottom chord members at locations over railroad tracks.

The truss expansion bearings are comprised of nested 12 inch high rockers with keeper plates arranged to keep the rockers in their proper relative positions. The center rocker of each bearing shoe is geared to the upper and lower plates of the bearing assembly. The fixed truss bearings are pinned to allow for rotation. The pins of both the fixed and expansion bearings are 12 inches in diameter. The sidewalk stringer bearings, at the piers, are comprised of sliding steel plates.

Span 2 is comprised of 14 doubly reinforced concrete beams with a span length of 51'-0" from centerline-to-centerline of bearings. The beams are haunched, to give an arch-like appearance, with a minimum depth of 6'-2" at the centerline of the span and a depth of 10'- 3-9/16" over the centerline of bearings. The beams are 2'-0" wide with a spacing of 4'-0" for the first five beams in from either fascia and a spacing of 5'-0" for the remaining interior beams. The beams are reinforced with 12 1-3/8" diameter rods, top and bottom. A 10 inch thick reinforced concrete slab is present between each beam with the top of the slab elevation even with the top of the beam elevation. One foot thick, full-height, reinforced concrete diaphragms, located over the bearings and at the third points, are present between each beam. The beams bear on one inch thick cast iron plates at the expansion end and bear directly on the pier concrete at the fixed end.

The closed spandrel arch spans are comprised of reinforced concrete arch barrels and spandrel walls. The clear span lengths, from face-to-face of piers of the arches vary as shown below:

Spans 3 through 7, 9 and 10	Length = 107'-0"
Span 11	Length = 146'-0"
Span 12 and 13	Length = 65'-5"

The arch barrel of Span 11 is 2'-6" thick at the crown, and reinforced longitudinally with 1-1/4" diameter rods placed with a center-to-center spacing of four inches, top and bottom. The remaining arch spans have a 2'-0" barrel thickness at the crown and are reinforced longitudinally with one inch diameter rods placed with a center-to-center spacing six inches, top and bottom. Transverse reinforcement, 5/8" diameter bars placed at a center-to-center spacing of twelve inches, are also found top and bottom.

The reinforced concrete spandrel walls have minimal reinforcement consisting of 1/2" diameter dowels on the front and back faces and 1/2" diameter tension rods on the back face. A deviation between the design drawings and field observations was identified at the construction joint located at the top of the spandrel wall. The design plans call for a construction joint at Elevation 267.61 (at the top of the first curved section of balustrade coping) while field observations located a construction joint approximately six inches below this elevation at the base of the balustrade coping. This field change, seemingly minor at the time, has caused numerous structural problems over the years.

The Main Street Ramp provides access for the Main Bridge to the central business district of Bethlehem. The ramp carried two eastbound and two westbound traffic lanes on a 44'-0" roadway from the northern terminus of the Main Bridge at Pier 14 to Main Street. The ramp is comprised of five closed spandrel reinforced concrete arch spans with clear span lengths, from face-to-face of piers, as follows:

Span 14	Length = 88'-0"
Spans 15 through 18	Length = 129'-0"

The total length of the structure, from the intersection of the Main Bridge and Main Street Ramp centerlines at Pier 14 to the centerline of the pylons at the end of the retaining walls, is 854'-0". The ramp is on a tangent horizontal alignment, at a bearing North 71° - 52' East of the Main Bridge centerline bearing, with an essentially flat vertical alignment. A vertical grade begins at Pier 19 and carries the retained earth approach to the elevation of Main Street.

The arch barrel of Span 14 is 2'-0" thick at the crown, while the arch barrels of Spans 15 through 18 are 2'-3" thick. All of the spans are reinforced longitudinally with one inch diameter rods placed with a center-to-center spacing of six-inches, top and bottom, and transverse reinforcement consisting of 5/8" diameter bars placed with a center-to-center spacing of 12 inches top and bottom. The remaining construction details of these arch spans are similar to the arches of the Main Bridge.

A large amount of pedestrian traffic was present on the west side of Main Street at the time the bridge was constructed. Therefore, a pedestrian tunnel with a clear width of 10'-0" and a maximum height of 12'-0" was constructed through the retaining walls behind Pier 19. This eliminated the need for pedestrians to cross the roadway at the entrance to the ramp.

The West Side Ramp provides access for the Main Bridge to the residential district of West Bethlehem. The ramp carried a 36'-0" wide roadway, for eastbound and westbound motorists, from the northern terminus of the Main Bridge at Pier 14 to Albert Street (now Second Avenue) immediately north of its intersection with Spring Street. The ramp is comprised of five closed spandrel reinforced concrete arches (Spans 19-23) with a clear span length, from face-to-face of piers, of 56'-0". The total length of the structure, from the intersection of the Main Bridge and West Side Ramp centerlines at Pier 14 to the centerline of the pylons at the end of the retaining walls, is 488'-3-3/4". The ramp is on a tangent horizontal alignment, at a bearing North 79^0 - 29' West of the Main Bridge centerline bearing with a crest vertical curve with 4% grades on either side of the P.V.I.. The P.V.I. of the ramp structure occurs over West Street, where a minimum 13'-0" clearance beneath the bridge was provided.

The arch barrel of Spans 19 - 23 is 1'-3" thick at the crown and reinforced longitudinally with one inch diameter rods placed at six inches center-to-center, top and bottom. The transverse reinforcement is comprised of 5/8" diameter rods placed on twelve inch centers top and bottom. The remaining construction details of these arch spans are similar to the arches of the Main Bridge.

The West Side Ramp hub area consists of a curved balustrade, a 7'-6" wide sidewalk and a portion of the roadway that provides a smooth transition from the West Side Ramp to the Main Bridge. The hub area is comprised of reinforced concrete girders supported by reinforced concrete circular columns and rectangular reinforced columns at Piers 13, 14 and 19. The girders vary in size and amount of reinforcement and are laid out with a generally triangular framing plan with the curved fascia girder forming the hypotenuse. The girders support an approximately 20 inch thick reinforced concrete structural slab.

The South Main Street Ramp (removed in 1965) carried traffic from the northern terminus of the Main Bridge (Pier 14) to the intersection of Lehigh Avenue and South Main Street. The ramp structure carried a 27'-11" wide roadway for a total length of 507'-6" from centerline of bearings to the end of the retaining walls. The structure was on a tangent horizontal alignment, at a bearing South 39^0 - 45' East of the Main Bridge centerline bearing, with a vertical grade of 6.75%.

The structure consisted of riveted, built-up through girders and rolled steel floorbeams with a total length of 388'- 4½" from centerline-to-centerline of bearings. The near half of the ramp structure exhibited very irregular span lengths, since the steel columns supporting the through-girders were placed to limit impact on the streets and businesses below the structure. The final four spans exhibit a more regular framing plan with span lengths of 51'-6", 52'-9", 50'-8-3/4" and 49'- 5-3/4" respectively.

The through-girders were comprised of 8'-6" deep girders, from back-to-back of angles, with a center-to-center girder spacing of 38'-3", consisting of riveted built-up sections. The top flange consisted of four angles and a minimum of one twenty-one inch wide coverplate. The thickness and number of coverplates and size of angles was dependent on the girder span length. Two of the angles and the coverplate formed a built-up channel, attached vertical leg down, to the remaining two flange angles.

The interior floorbeams were comprised of rolled steel sections (30 x 180 Bethlehem Girder Beams), framed into the through-girders. Knee-braces, from the floorbeam top flange to the top flange of the girder, were present at each floorbeam locations. The end floorbeams, on either side of expansion joints, were comprised of 28 x 180 Bethlehem Girder Beams with a 15" x 3/4" full-length coverplate, top and bottom.

The floorbeams supported a nine inch thick reinforced concrete slab. Reinforced concrete curb blocks flanked the roadway. The left curb width was 1'-11" from edge of curb to the centerline of girder. An 8'-5" wide reinforced concrete sidewalk, from edge of curb to the centerline of girder (7'-6" clear), was found along the right side of the structure.

The through-girder spans were supported on riveted built-up steel columns, a 15 inch deep Bethlehem I-beam with additional riveted plates and angles to increase the compressive strength. Riveted, built-up steel struts were found between the columns of a pier line with knee braces between the girders and columns. The grade of the structure was accommodated through the use of beveled masonry plates. Bents 30 and 31 were comprised of built-up riveted transverse girders supported on built-up steel columns.

The Main Street Ramp Hub Area is found at the top of the South Main Street Ramp at its intersection with the Main Bridge and the Main Street Ramp. The area is comprised of variable size reinforced concrete girders, with an irregular framing arrangement, supporting an 1'-7-3/4" reinforced concrete structural slab. The girders are supported by reinforced concrete circular columns and rectangular columns at Piers 13, 14 and 15. A reinforced concrete pier bent is present to support the end girders of the South Main Street Ramp. Curved fascia girders provide a smooth transition between adjacent ramps.

The River Street Ramp provides access for the Main Bridge to Sand Island, an area of land located between the Lehigh River and Canal. The ramp carries a 21'-0" wide roadway from Span 6 of the Main Bridge to an access road. The structure consists of 18 spans of reinforced concrete girders and floorbeams with the following span lengths, from centerline-to-centerline of the south columns, four spans at 30'-0", five spans at 30'-9", three spans at 15'-9" and six spans at 15'-0". The total length of the structure, from its intersection with the Main Bridge to the end of the retaining wall, is 403'-5¼". The ramp is primarily on a tangent horizontal alignment, at a bearing North 83^{0} - 36' East of the Main Bridge centerline bearing, with a vertical grade of 8.9%. The last 65 feet of the ramp curve sharply to the left with a centerline curve radius of 44.91 feet.

The first nine spans of reinforced concrete girders are haunched, to give an arch-like appearance, with a minimum depth of approximately 7'-0" at the centerline of the span and a depth of 10'- 8-7/8" at the centerline of piers. The girders are 2'-6" wide with a spacing of 18'-0" from center-to-center and have twelve 1-5/16" diameter rods as tension reinforcement. The girders rest on one inch thick cast iron bearing plates at the expansion end of the beams and are poured integrally with the columns at the fixed bearing locations. The reinforced concrete floorbeams have a center-to-center spacing of 7'-6" and are 1'-3" wide with a depth of 3'-7½". The floorbeams are integral with a 10½" reinforced concrete structural slab and are reinforced with four 1-1/8" diameter rods. The attachment of the River Street Ramp to the Main Bridge is accomplished by cantilevering the concrete girders, an end floorbeam and the roadway from Pier 34, for a maximum length of approximately 8 feet from the centerline of the pier.

The final nine spans are comprised of two reinforced concrete girders, one along the south fascia and one along the centerline of the ramp with a reinforced concrete wall along the north fascia. The south girder is 1'-3" wide and haunched, similar to the first nine spans, and was reinforced with four 1-1/16" diameter rods. The centerline girder is 4'- 1½" deep by 1'-6" wide and reinforced with four 1-5/16" diameter rods. The north wall is battered along its back face with a maximum width of 1'-3" at the base and 1'-0" at the top below the balustrade coping. The floorbeams, 2'-5½" deep by 1'-3" wide and reinforced with four 1-1/8" diameter rods, are located at the columns and at the centerline of each span.

The ramp superstructure supports a 10½" thick reinforced concrete deck. The roadway is flanked on the left by a 1'-0" wide armored reinforced concrete curb and on the right side by a 5'-0" wide sidewalk.

The Second Street Ramp provides access for the Main Bridge to Second Street. The ramp carries a 27'-7" wide roadway from the east fascia of Span 1 to the intersection of Second Street and Broadhead Avenue. The structure consists of two spans of rolled steel stringers, six spans of reinforced concrete girders and floorbeams and six spans of reinforced concrete multi-girders, with span lengths of 27'-0", one that varies, two at 30', four at 30'-9", two at 30' and four at 30'-9" respectively. The total length of structure, including retaining walls, is approximately 664 feet, from the intersection with Span 1 to the end of the north pylon, along the ramp centerline. The ramp is predominantly on a horizontal curve with a radius of 1620.65 feet. The final 188 feet of the retaining walls are on a tangent horizontal alignment. The vertical grade is 5.4% throughout the structure.

The steel spans, Spans 53 and 54, are comprised of rolled steel stringers that frame into rolled steel and riveted built-up steel transverse girders. The stringers of Span 53 (span length equals 27'-0") consists of 26 x 90 Bethlehem I-Beams, while the stringers of Span 54 (variable stringer span lengths) consist of 18 x 52 or 15 x 38 Bethlehem I-Beams. The fascia stringers, comprised of built-up riveted channel sections, are partially encased with a 2 inch thick layer of wire mesh reinforced concrete. The fascia stringers support a cast iron railing and the sidewalk and are in turn supported by cantilevered, built-up riveted variable depth overhang brackets. The connection of the Second Street Ramp to the Main Bridge is accomplished by cantilevering a 10'-5" length of a 26 x 90 Bethlehem I-Beam, supported by top flange tie plates, from Girder 53.

Transverse Girder 53 is comprised of a riveted built-up section, 6'-0½" deep from back-to-back of flange angles, with variable depth overhang brackets. Transverse Girder 54 and 55 are comprised of rolled steel Bethlehem I-Beams, either 26 or 30 inches deep. Girders 53 and 54 are supported by built-up riveted steel columns. A portion of Girder 55 is suppported by a steel column while the remainder is supported by a reinforced concrete pier bent.

The steel stringers support a minimum 7 inch thick reinforced concrete slab. A variable width sidewalk area is present on the north side of the steel spans that lead to steel stairway that provides access to Union Station.

The reinforced concrete girders and floorbeams support a 10½ inch thick reinforced concrete structural slab. The girders, haunched to give an arch-like appearance, have a center-to-center spacing of 22'-0" with a minimum depth of 6'-7½" at the centerline and a maximum depth of 9'-10½" over the bearings. The girders are 2'-6" wide and reinforced with twelve 1-3/8" diameter rods. The floorbeams are 1-'4" wide by 2'-10" deep and reinforced by four 1-3/8" diameter rods. the girders bear on one inch thick cast iron bearing plates at the expansion ends and are poured integrally with the columns at the fixed ends. Reinforced concrete overhang brackets, 5'-9" wide from the face of the girders at the end balustrade posts and 4'-3" wide at intermediate posts, support the balustrade and sidewalk.

The concrete multi-stringer spans represent a change from the design drawings dated September 15, 1920, that appears on the shop drawings of 1923. These spans are comprised of five reinforced concrete stringers that frame into end reinforced concrete floorbeams supported by reinforced concrete columns. A full-height reinforced concrete diaphragm, 1'-0" wide, is found between the stringers at the centerline of each span.

The retaining walls are comprised of unreinforced concrete sections, with the exception of 3/8" diameter dowels used in connecting the balustrade coping to the retaining wall and the retaining wall to the footing.

The 27'-7" wide roadway is flanked by a 1'-0" wide reinforced concrete curb on the north side and 4'-5" wide sidewalk on the south side.

The Lehigh Street (now Brighton Street) Ramp carries a 30'-0" wide roadway from the Main Bridge past the main office of the Lehigh Valley Railroad and to the Fountain Hill residential district. The roadway is supported by earth fill contained by a pair of reinforced concrete retaining walls, with a total length of approximately 78'-4" from the point of tangent of the curved balustrade sections to the centerline of the end pylons. The ramp is on a tangent horizontal alignment, at a bearing South 36°-09' West of the Main Bridge centerline bearing, with a variable vertical grade. The grade is 5.3% for the half of the structure adjacent to the Main Bridge and 5.0% for the remainder of the ramp.

The variable height retaining walls are unreinforced and battered 4-3/4" per foot on the inside faces. The walls are doweled to unreinforced concrete footings. Flanking the roadway are 7'-6" wide reinforced concrete sidewalks supported by a reinforced concrete curb block and railing cope block. The coping is doweled to the retaining wall with 3/8" diameter rods spaced at one foot centers.

The Wyandotte Avenue Ramp provides access for the Main Bridge to Wyandotte Avenue and Third Street. The south end of the ramp diverges forming an approach for Wyandotte Avenue and the Third Street Ramp. The total length of the structure, from the centerline of the pylon on Pier 1 to the end of the last pylon along Wyandotte Avenue, is approximately 339 feet. The structure is on a tangent horizontal alignment with the Third Street Ramp approach at a bearing of South 15° - 31' East of the Main Bridge centerline bearing. The vertical grade is 3.25%, with the exception of the north end of the structure which has no vertical grade.

The minimum 44'-0" wide roadway is supported by earth fill contained by unreinforced concrete retaining walls. The south end of the wall along the east fascia is comprised of reinforced concrete grade beams supported by reinforced concrete columns and spread footings. The columns are located under pylons and intermediate posts of the balustrade. Surmounted on these walls is a typical 3'-8" high reinforced concrete balustrade section. The balustrade flanks 7'-6" wide sidewalks.

The Third Street Ramp carries a 44'-0" wide roadway, on grade, from the Main Bridge to Third Street. The structure begins at the intersection with Wyandotte Avenue Ramp and continues to the intersection of Third Street and Broadhead Avenue with a length of approximately 628 feet as measured along the construction centerline. The ramp carries two traffic lanes northbound to the Main Bridge and two lanes east bound to Third Street. The first 442 feet of the structure centerline is on a horizontal curve with a radius of 450 feet with the remainder on a tangent alignment. The vertical grade varies from 5.5% to 6.4% along the length of the structure.

The roadway is supported on earth fill contained by variable height retaining walls. The walls are minimally reinforced and supported by unreinforced concrete footings. The walls are surmounted by 1'-2" high by 1'-0" wide reinforced concrete barriers. The barriers flank 7'-6" wide reinforced concrete sidewalks.

The roadway surface of the entire structure is comprised of a variable depth concrete foundation, a one inch mortar cushion and a four inch course of granite paving blocks. The concrete foundation is supported by a structural slab or the contained earth of the closed spandrel arches and the retaining walls. Tracks for trolley service were laid in the roadway of the Main Bridge, Main Street Ramp, West Side Ramp, Second Street Ramp, Wyandotte Avenue Ramp and Third Street Ramp. The tracks, which have a 4'-8½" gauge, are 7 inch deep girder rail sections supported by the concrete foundation and 4¼" deep girder rail sections supported by the concrete foundation and 4¼" deep Carnegie Steel Company steel I-tie section spaced at 4'-0" on center. Tie rods, 3/8" in diameter, with a center-to-center spacing of 6'-0", maintain the rail guage.

The original bridge sidewalks were comprised of 5 inch thick reinforced concrete slabs. The slabs were reinforced top and bottom with Clinton Wire Cloth with a 4" x 4" spacing of Number 6 galvanized wire. The sidewalks were supported by reinforced concrete curb blocks, balustrade cope and an intermediate support. The curb blocks, 20 inches wide and of variable depth, also formed the curbs for the roadway. The curbs were armored with Hauemeyer standard curb bars. The intermediate support is unreinforced and six inches wide. The sidewalks of the River Street and Second Street Ramps do not have an intermediate support. The balustrade copes are comprised of reinforced concrete and are dowelled into the spandrel walls or structural slab. Ornamental curved sections are found on the outside faces of these copes.

The curb blocks and interior supports for the sidewalks are supported by contained earth or reinforced concrete structural slabs, forming chambers below the sidewalk. These chambers are utilized for utility conduits and ducts. Bridge lighting ducts are found below the sidewalks of the Main Bridge and all approaches. Ducts are additionally found in the concrete curbs of the South

Main Street, Second Street and River Street Ramps. Utility ducts, for the power and telephone companies, are located under both sidewalks of the Main Bridge, Main Street Ramp, West Side Ramp, Third Street Ramp and Wyandotte Avenue Ramp.

The balustrades are massive, graceful reinforced concrete railings that are in line with the overall geometric proportions of the structure. The balustrades are supported by the balustrade cope section. The general dimensions of the railing are a top rail 1'-0" wide by 7-1/2" deep continually reinforced with 3/8" diameter rods and 7" by 7" posts spaced at 13 inches from center-to-center. The interior support posts are 1'-6" by 1'-6" and are typically spaced 15 to 18 feet from center-to-center. The railing sections have tongue and groove joints at the railing expansion joints.

The substructure of the bridge is comprised almost entirely of reinforced concrete. The arch span substructure is comprised of solid shaft unreinforced concrete piers founded on spread footings. Pier 2 is founded on one hundred reinforced concrete piles. The substructure of the remaining concrete spans is comprised of reinforced concrete columns supported by unreinforced concrete spread footings. The columns and footings of the River Street Ramp are additionally supported by timber piles.

In 1927, on June 14, the PSC shifted the maintenance responsibilities for the Hill-to-Hill Bridge. The order of 1924 was changed to give the responsibility to maintain the entire steel superstructure of the truss spans to the railroad company whose trains crossed under the span. The Lehigh Valley Railroad Company was ordered to maintain the superstructure of Span 1 as well as the steel viaduct connection with the Second Street Ramp. The Central Railroad Company of New Jersey was ordered to maintain the superstructure of Span 8. The City of Bethlehem was ordered to maintain the remainder of the Hill-to-Hill Bridge and to pay the above railroad companies a percentage of the cost of maintenance involved with their span. In addition, the remaining two railroads utilizing tracks under the bridge were ordered to make maintenance payments. The final distribution of responsibility was as follows:

- City of Bethlehem to pay the Lehigh Valley Railroad Company 25% of the maintenance costs of Span 1.
- Reading Company to pay the Lehigh Valley Railroad Company 37.5% of the maintenance costs of Span 1.
- City of Bethlehem to pay Central Railroad Company of New Jersey 50% of the maintenance costs of Span 8.
- Lehigh and New England Railroad Company to pay the City of Bethlehem 25% of the maintenance costs for the portion of the South Main Street Ramp over the railroad right-of-way.

On July 24, 1945, the City of Bethlehem was notified by the Pennsylvania Department of Highways that the Commonwealth was assuming the city's responsibility for the bridge. This change in responsibility was the result of the provisions of an Act of Assembly approved May 23, 1945 which stated that all bridges and viaducts on state highways in cities of the second and third class shall be taken over by the Department of Highways and maintained at their sole cost. The Commonwealth of Pennsylvania maintained this structure until 1950, when on February 15, the Department of Highways notified the City that the Commonwealth was disregarding any maintenance responsibilities on the structure.

In 1948, a major rehabilitation was performed on the Hill-to-Hill Bridge by the Kingston Contracting Co, Inc. of West Point, Montgomery County, Pennsylvania. The rehabilitation included structural bridge repairs and roadway reconstruction. Trench drains, continuous depressed concrete box gutters covered with open-grid steel bridge flooring, where added to facilitate the bridge drainage on the Main Bridge and the Main Street Ramp.

On November 12, 1957, the Pennsylvania Public Utility Commission (PUC), ordered the following division of maintenance responsibility:

- The City of Bethlehem is responsible for the operation and maintenance of the bridge lighting, removal of snow and ice, street cleaning and maintenance of the surface drainage system. The city is soley responsible for all maintenance on the Third Street Ramp, the Brighton Street Ramp, the Lehigh Avenue (South Main Street) Ramp and the Second Avenue (West Side) Ramp. The City also has the responsibility to maintain the sidewalks and railings on the main structure.

- The Department of Highways of the Commonwealth of Pennsylvania is responsible to maintain the remainder of the bridge structure.

The payments of the railroad companies were to remain the same except that they would now be paid by the Commonwealth of Pennsylvania.

In 1964, a second major repair program was undertaken on the Hill-to-Hill Bridge. This $50,000 program, funded by the City of Bethlehem, included realigning and anchoring balustrade sections and installing new sidewalks and curbs. Five balustrade sections, two each on the south side of Spans 19 and 20 of the West Side Ramp and one on the south side of Span 17 of the Main Street Ramp, were realigned and reanchored. The balustrade sections weigh approximately 20 tons and were anchored by 5/8" diameter by 3'-6" long tie rods grouted into the spandrel walls with a center-to-center spacing of 2'-0". The displacement, as much as 10 inches at one location, was thought to have been caused by frost action where water had seeped into the joint between the railing and sidewalk. This condition can also be attributed to the change in construction joint locations as seen from the original design drawings. With this change in location, the construction joint was lowered approximately six inches and the existing 3/8" diameter rod (3'-0" long) had inadequate embedment into the spandrel wall concrete. A detailed survey of the balustrade sections had revealed that numerous other sections exhibited some rotation. Anchors, identical to the ones described above, were installed at these locations with a spacing dependent on the amount of rotation present at the section. New sidewalks were provided for the Main Bridge, Main Street Ramp and West Side Ramp. The new sidewalk was anchored to the original one by driving studs (3/8" diameter by 3" long) in a 2' x 2' grid into the original sidewalk. The new sidewalk was a minimum 3-1/2" thick and reinforced by a six inch by six inch mesh of #4 wire. The reconstructed curb was significantly higher than the original curb to provide additional pedestrian safety in the event of an out-of-control vehicle.

In 1965, the South Main Street Ramp was demolished as part of Bethlehem's Monocacy Valley redevelopment program. Safety considerations, particularly at the ramp's intersection with the Main Bridge and Main Street Ramp at Pier 14, was also a major factor in the decision to demolish this ramp. Demolition was performed by the Industrial Wrecking Company of Easton, Pennsylvania. A plaza was constructed in the hub area between the Main Bridge and the Main Street Ramp with a reinforced concrete balustrade across the former entrance to the ramp.

In 1967, the pedestrian plaza on the north side of Pier 14 was demolished to allow for the construction of a 3.2 mile spur-route to connect the Hill-to-Hill Bridge and Bethlehem with the Lehigh Valley Thruway (U. S. Route 22). The connection was accomplished by constructing a single span, the North Approach Span, at the north face of Pier 14.

The North Approach Span consists of one span, 60'-4½" along the bridge centerline from the near face of the expansion joint at Pier 14 to the paving notch at the north abutment. The span is on a tangent horizontal alignment and a flat grade. The span carries two northbound and two southbound traffic lanes on a 56'-0" wide roadway. Three foot wide safety walks, with adjacent 1'-3" wide by 1'-8" high reinforced concrete parapets surmounted by standard two rail aluminum bridge railings, flank both sides of the roadway. A 4'-0" wide split, raised concrete median and an aluminum guiderail separate the northbound and southbound traffic. The deck joint at the north abutment consists of a steel sliding plate expansion dam and an unarmored expansion joint is present at the south end of the span.

The minimum 8 inch thick reinforced concrete deck is supported by and composite with ten rolled steel wide flange stringers. The stringers, W30 x 99 with a partial length welded bottom flange coverplate (9" x 3/4"), have a span length of 51'-0" from center-to-center of bearings with a variable length cantilevered section to make the connection at Pier 14. The maximum cantilevered length is approximately 6'-6". Diaphragms, comprised of rolled steel sections, are found at the centerline of bearings and the midpoint of the span. The expansion bearings, at the north abutment, consist of sliding plate bearings with a self lubricating bronze bearing plate. The fixed bearings are comprised of bearing and masonry plates.

The steel superstructure is supported by a reinforced concrete stub abutment with short wingwalls and chee kwalls and concrete pier bents comprised of circular columns. The north abutment is founded on steel bearing piles, while the south pier is founded on reinforced concrete spread footings and steel piles.

The construction of a spur-route at the north terminus of the Hill-to-Hill Bridge resulted in changes in the traffic patterns along the Main Street and West Side Ramps. The Main Street Ramp was made one-way, eastbound, as an off-ramp for the Main Bridge. The West Side Ramp was closed permanently to all vehicular traffic in August of 1973. The main reason for these changes were safety concerns. The spur-route was part of the interstate system and as such had to meet stringent criteria for entrances and exits.

In 1985 the Second Street Ramp was closed to all vehicular traffic. This closure was necessitated primarily by the advanced state of deterioration exhibited by the superstructure of this span. The low traffic volume, approximately 1,500 vehicles per day, and safety considerations also played a major role in closing this ramp. This ramp structure is scheduled for demolition in 1989.

In 1988 a low level bridge across the Lehigh Canal was constructed from Main Street to the access road on Sand Island. Once this structure was completed, the River Street Ramp was demolished. The major reasons for removing this structure were the condition of the concrete girders and the geometric constraints imposed on trucks passing onto or off of the Main Bridge from the Ramp.

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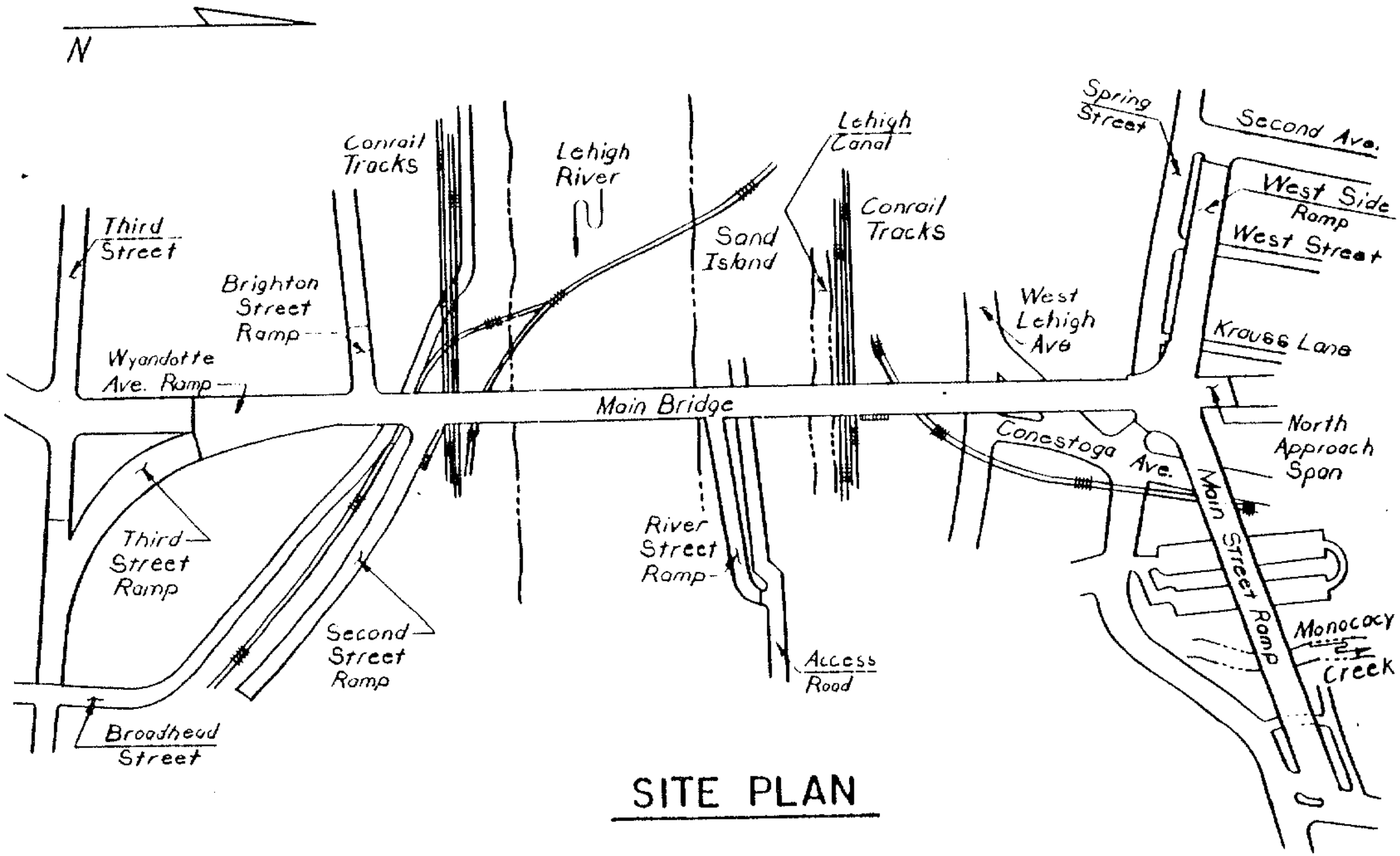
N
Third Street
Conrail Tracks
Lehigh River
Brighton Street Ramp
Wyandotte Ave. Ramp
Sand Island
Lehigh Canal
Conrail Tracks
Spring Street
Second Ave.
West Side Ramp
West Street
West Lehigh Ave
Krauss Lane
Main Bridge
Conestoga Ave.
North Approach Span
Main Street Ramp
Third Street Ramp
Second Street Ramp
River Street Ramp
Access Road
Monocacy Creek
Broadhead Street

SITE PLAN