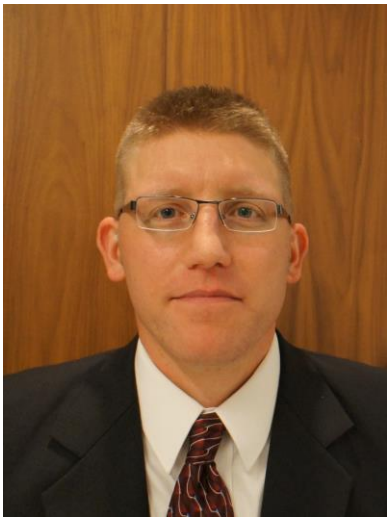
RECONSTRUCTING CHICAGO'S INTERCHANGE BY THE LAKE



CHRISTOPHER L. STINE

BIOGRAPHY

Christopher L. Stine is a Senior Structural Engineer at AECOM in Chicago, IL and holds both a B.S. and M.S. from Southern Illinois University Carbondale. Chris has 14 years of experience in bridge design, construction, & management including work with several complex structures. Previous experience includes the E-W Wacker Drive Project (Chicago IL), George Washington Carver Tied-Arch Bridge (Des Moines, IA), I-355 Des Plaines River Brg. (Lemont, IL), Illinois-170 Bridge (Seneca, IL), Tri-Level Interchange (East St. Louis, IL), and 41st/43rd Street Pedestrian Bridge (Chicago, IL). Chris is a licensed SE in Illinois as well as a licensed PE in Iowa, Kansas, Texas, and Wisconsin.

SUMMARY

The I-55 and Lake Shore Drive Interchange is two miles south of downtown Chicago, directly south of McCormick Place, and connects the north end of I-55 to US Rte. 41 (Lake Shore Drive). The interchange is comprised of six bridges and six approaches. The bridges utilize steel plate girders metalized or galvanized for long-term durability, while the approaches use light-weight fill to mitigate settlement issues. The main challenge in redesigning the interchange was staging. Using several offset alignments, an existing bridge widening, and a temp bridge allowed two lanes to be maintained on Ramps EN and SW for most of construction and avoided planned detours for single-lane Ramps ES and NW.

RECONSTRUCTING CHICAGO'S INTERCHANGE BY THE LAKE

Introduction

The existing I-55 and Lake Shore Drive Interchange was built in 1965 above the Illinois Central Railroad (ICRR) connecting the northern limit of Interstate 55 to U.S. Route 41. I-55 traditionally runs north-south, although the portion in Cook County (known locally as the Adlai Stevenson Expressway) runs east-west. U.S. Route 41 (known locally as Lake Shore Drive) runs north-south through Burnham Park on the west shore of Lake Michigan. The interchange is located two miles south of downtown Chicago, south of McCormick Place (MP), which is the largest convention center in the United States at 2.6 million square feet.

While the size and shape of the new interchange was significantly influenced by MP, the size and shape of the existing interchange was governed by the ICRR. The State of Illinois chartered the ICRR in 1851 who built the Chicago Branch down to Centralia in 1856. While the tracks were initially along Lake Michigan, its shoreline moved about 1,000 feet east after rubble from the Great Fire (1871) was pushed into the lake. The original shoreline lay within MP Parking Lot B, between the current tracks and the future Moe Drive. In addition to the more than a dozen mainline tracks, there was a rail yard south of the future interchange.

When the existing interchange was first constructed, there were as many as 16 tracks below Ramp ES, 14 tracks below Ramp EN, and 12 tracks beneath Ramp SW near their current location and three tracks under all four ramps at the existing location of Moe Drive. Because of the substantial number of railroad tracks, most of the existing interchange consists of elevated bridge structure with all piers parallel to these tracks. Four of the west tracks were ICRR's commuter lines that were electrified in 1926 by addition of overhead catenary lines as mandated by the City of Chicago in 1919 to improve the air quality near Lake Michigan.

Over the past half century, the railroad has decreased to only six tracks. The west most track was removed and is currently occupied by the private MP Busway. The next four tracks, which were ICRR's commuter line, were sold to the Metropolitan Rail Corporation (Metra) in 1987 and are now the Metra Electric Line. Remaining freight tracks were sold to the New York based Prospect Group in 1989, which later sold them to the Canadian National Railroad (CNRR) in 1998. Today, CNRR operates the two tracks east of Metra. Remaining tracks have been eliminated including the three tracks where Moe Drive is now (see Figure 1).

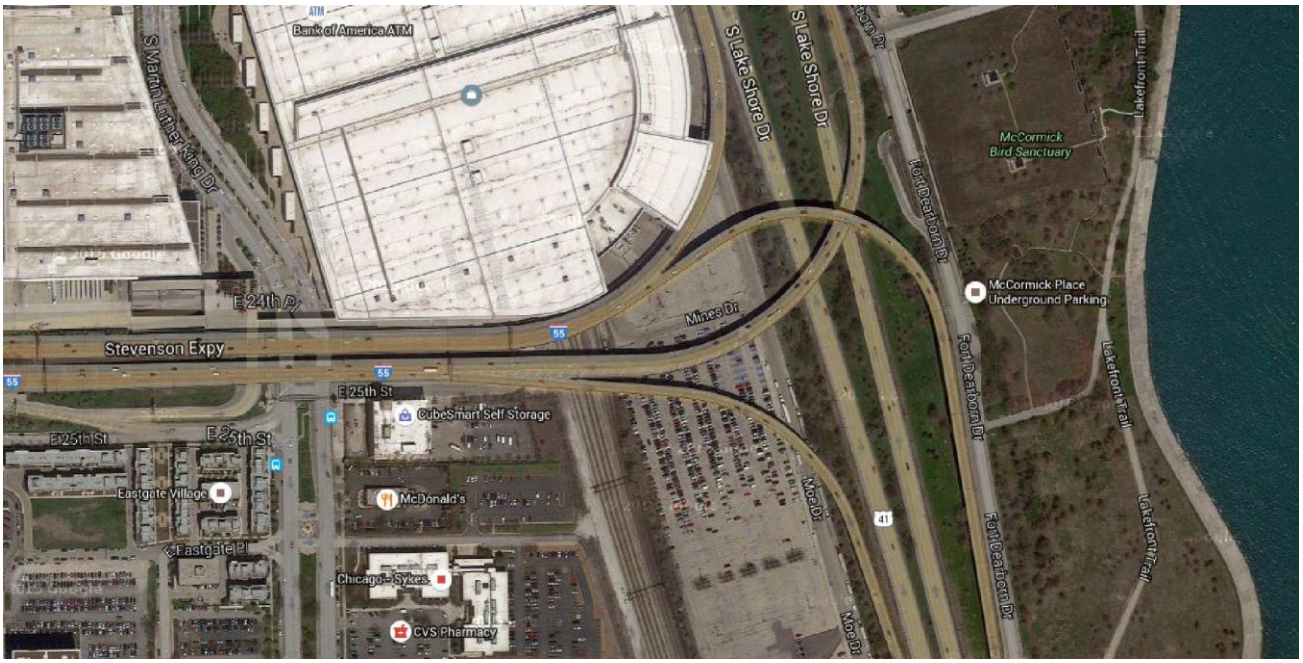


Figure 1: Existing I-55 & Lake Shore Drive Interchange

Existing Structures

The present-day interchange contains six structures, which each include a bridge and approach structure. The majority of the bridges utilize steel plate girders, although some shorter spans use wide flange beams. All girders and beams use A36 steel composite with a 7.5" thick concrete deck. All substructures employ multi-column concrete piers, except for two piers on Ramps ES and SW which use integral steel portal or straddle piers classified as fracture-critical members. All abutments, piers, and vaulted approach structures are supported on drilled shafts that extend to and are socketed at least one foot in bedrock (see Figure 2).

Between the western project limits and the railroads, there are two parallel structures which run east-west. The southern structure is NB I-55 that supports three lanes of eastbound traffic, while the one north of NB I-55 and south of the MP West and South Buildings is SB I-55 carrying three lanes of westbound traffic. The structures consist of a 299'-9" vaulted approach and four steel units with an 88'-110'-88' 3-span unit, a 102'-102' 2-span unit, an 83'-104'-83' 3-span unit, and then either an 85'-85' 2-span unit for NB I-55 or a 78'-78' 2-span unit for SB I-55 with 10 total spans. All spans in both structures utilize 50" plate girders.

The tangent structures cross the I-55 NB/SB U-Turn, Martin Luther King Jr. Drive, MP Bus Staging Area, and Donnelly Drive. The U-Turn permits eastbound traffic to exit to MP West Building or turn back west before the interchange. MLK Drive is a minor urban arterial composed of five NB lanes and five SB lanes (including left-turn lanes for East 24th or 25th Street) which carry 15,700 vehicles per day adjacent to MP. MP Bus Staging Area is an IDOT-owned parking lot that MP uses to stage buses shuttling visitors to MP. Donnelly Drive is a small, local road that runs under the MP South Building with access restricted by MP.

The east side of the current interchange includes four directional structures (Ramps ES, EN, SW, and NW) which touch down in Burnham Park next to the lake. The two letters designate a ramp's direction of travel (i.e. Ramp ES indicates an East to South movement). Existing Ramp ES carries one lane of NB I-55 traffic to SB Lake Shore Drive, whereas existing Ramp EN carries the remaining two lanes of NB I-55 traffic to NB Lake Shore Drive. Likewise, the existing Ramp SW carries two lanes of SB Lake Shore Drive traffic to SB I-55, while the existing Ramp NW carries just one lane of NB Lake Shore Drive traffic to SB I-55.

Existing Ramp ES contains 13 spans of 126', 94'-7", 110'-1", 80'-1", 90'-8", 107'-4", 64'-10", 106', 78', 76', and 3x65'. All spans use simple-span, chorded girders with a curved deck, except a continuous unit at Spans 2-3 and the continuous unit at Spans 11-13. Spans 1-8 utilize 54" plate girders, while Spans 9-13 use W36 and W33 wide flange beams. The structure ends using a 140' vaulted approach at the south end. Ramp ES crosses Metra, CNRR, MP Parking Lot B, and a 40'-0" wide freight road known as Moe Drive. In order to span Moe Drive at a skew of around 55°, existing Pier ES7 uses an integral steel straddle pier.

Existing Ramp EN has 13 spans of 81'-1", 123'-10", 86', 105'-6", 74'-3", 74'-2", 75'-4", 81'-10", 84'-9", 95'-10", 88', 164'-9", and 62'-8". All existing spans use simple-span, chorded girders with a curved deck. Spans 1-4 utilize 54" plate girders, while Spans 5-13 use 48" plate girders, except for Span 12 which uses 66" plate girders. The structure ends with a 127'-10" vaulted approach at the north end. Ramp EN crosses MP Busway, Metra, CNRR, MP Parking Lot B, Moe Drive, as well as both SB and NB Lake Shore Drive. Span 12 is the interchange's longest span at 164'-9" and one of the only spans which uses lateral bracing.

Existing Structure		Total Number of				Span Length		Structure Length		
Name	Str. No.	Lanes	Units	Joints	Spans	Min.	Max.	Appr.	Bridge	Total
NB I-55	016-0036	3	4	5	10	83'-0"	110'-0"	299'-9"	930'-0"	1229'-9"
SB I-55	016-1055	3	4	5	10	78'-0"	110'-0"	299'-9"	916'-0"	1215'-9"
Ramp ES	016-1045	1	10	10	13	64'-10"	126'-0"	140'-0"	1128'-7"	1268'-7"
Ramp EN	016-1075	3 to 2	13	13	13	62'-8"	164'-9"	127'-10"	1198'-0"	1325'-10"
Ramp SW	016-1052	2 to 3	11	11	11	65'-11"	121'-9"	253'-0"	974'-0"	1227'-0"
Ramp NW	016-1048	1	17	17	28	34'-5"	97'-6"	149'-6"	1952'-11"	2102'-5"
Total		---	59	61	85	---	---	1269'-10"	7099'-6"	8369'-4"

Figure 2: Existing Structures Information

Existing Ramp SW has 11 spans of 66'-2", 121'-9", 121', 76'-9", 85'-5", 95'-1", 72'-8", 92'-2", 65'-11", 95', and 82'. All spans utilize simple-span, chorded girders with a curved deck. Spans 1-9 use 54" plate girders, while Spans 10-11 employ 48" plate girders. The structure ends via a 253' vaulted approach at the north end atop a 12' tall crib wall east of Moe Drive, which retains embankment for SB Lake Shore Drive. Ramp SW traverses the MP Busway, Metra, CNRR, Mines Drive, Moe Drive, and the MP Parking Lot B. In order to span Moe Drive at a skew of around 59°, existing Pier W21 uses an integral steel straddle pier.

Existing Ramp NW has 13 curved spans of 2x77'-8", 77'-5", 79'-3", 73', 79'-11", 70', 97'-6", 34'-5",75', 2x79', and 78' followed by 15 tangent spans of 65'. Curved spans use simple-span, chorded girders with a curved deck, except a continuous unit at Spans 2-3. Tangent spans employ five continuous 3-span units. Curved Spans 1-4 use 54" plate girders while curved Spans 5-13 use 48" plate girders. Tangent Spans 14-28 employ W33 wide flange beams and the structure ends via a 149'-6" vaulted approach at the south end. Ramp NW spans the MP Parking Lot B, Moe Drive, SB and NB Lake Shore Drive, as well as Ramp EN.

As mentioned earlier, all six existing structures have vaulted approaches. These utilize 12" thick concrete walls on each side supporting a 12.5" concrete deck. In addition to these walls, there are also intermediate longitudinal concrete beams for wider structures that support more than one traffic lane such that the deck does not have to span more than 19'-0" transversely. Both walls and beams are supported upon 24" or 30" diameter drilled shafts that extend down to bedrock. The reason this was used rather than spread footings is that the interchange is constructed on lakefront fill that is compressible and subject to large settlements.

Over the last half century, the current structures have deteriorated to the point of needing full replacement. In 1975, the steel was repainted, all expansion joints replaced, and decks repaired with an overlay added. In 1990, expansion bearings were replaced. In 1994, all piers were repaired, all expansion joints replaced, and the overlay with upper portion of deck replaced. In 1996, the piers on Ramps EN, SW, and NW were repaired again. In 2002, the steel was painted again. In 2005, piers on all bridges were repaired yet again along with more deck repairs on all bridges in 2008. Additional repairs have continued up to the present.

The most deteriorated element was the concrete deck which at 50 years old was well beyond its useful life. After just 10 years, the original 7" deck was repaired and a 1.75" asphalt overlay installed. After 25 years, the overlay and upper 1.5" of the deck were removed and replaced with a 2" microsilica concrete overlay. This resulted in the current 7.5" thick deck, although it could be argued that only 5.5" of this is structural. This along with spalling of the deck's bottom cover resulted in a thin deck which has had several failures though they have been hard to detect since protective shielding is utilized below most spans (see Figure 3).

Another element with deterioration was the concrete piers especially those located under expansion joints. While it is typical of heavily-salted bridge structures, what is unusual is that most piers are beneath joints. This is a direct consequence of utilizing simple-span, chorded girders for the curved bridges as continuous, curved girders were rarely utilized during the 1960s. This results in considerable corrosion of the girders, bearings, and piers below these joints (see Figure 4). These simple spans often have a different number of girders in adjacent spans as well as variable spacing, which also makes stage removal problematic as well.

Figure 3: Deterioration of Existing Deck

Figure 4: Deterioration of Existing Piers

Project Constraints

Besides needing to be more durable than the old one, the new interchange was subject to many constraints. The largest project constraint was McCormick Place whose buildings and parking lots limited changes to alignments, span arrangements, widths, and staging. The original MP was built in 1960 in Burnham Park between Lake Shore Drive and the lake, north of the future interchange. Though it burned down in 1967, it was rebuilt in 1971 and became the East Building. Over the last 30 years, MP has expanded north of the existing interchange with the additions of the North, South, and West Buildings in 1986, 1996, and 2007.

On the west side, the MP West and South Buildings prevent widening SB I-55 to the north (see Figure 5) which dictates the widening of SB I-55 and NB I-55. The MP Bus Staging Area also presented challenges as buses pass between columns and under pier caps. Existing piers have lateral clearances from 15'-2" to 19'-9" with a minimum vertical clearance of 12'-10" (see Figure 6). While four columns at 18' generates 14' wide openings for a 69' long proposed pier cap, this was deemed inadequate for bus turning such that three columns had to be used. It was also necessary to increase vertical cap clearances to at least 14'-9".

On the east side, the curved southeast face of the MP South Building follows Ramp SW precluding it from being shifted inward to obtain a larger radius, design speed, and/or stopping sight distance (see Figure 7). Additionally, MP Parking Lot B also determined the proposed pier placements and the span arrangements of all four ramps between the CNRR and Moe Drive. The total number of parking spaces to be eliminated by the proposed piers was required to be less than or equal to those previously occupied by existing piers. Proposed piers were also not allowed to be placed in parking aisles like existing structures (see Figure 8).

Besides site limitations, MP issued other constraints. Preliminary studies recommended reducing two-lane Ramps EN and SW to one lane in construction while detouring traffic for single-lane Ramps ES and NW. The detours require routing traffic north through the 18th Street underpass 0.75 miles north of the project to gain access to SB Lake Shore Drive and SB I-55. Both MP and the nearby NFL stadium Soldier Field opposed these as they would disrupt traffic to events at these entertainment venues and impact attendance. Soldier Field was especially concerned as it reduced traffic in and out of their lot to a lane each direction.

Figure 5: Existing SB I-55 next to MP West Bldg.

Figure 6: Existing Piers in MP Bus Staging Area

Figure 7: Existing Ramp SW by MP South Bldg.

Figure 8: Existing Piers in MP Parking Lot Aisles

Other agencies with site restrictions were Metra and CNRR who require clearances of 25' horizontal and 23' vertical. The first was reduced as MP had many nearby crashwalls with clearances as small as 9'-6". Another hurdle was Metra's overhead catenary lines affixed to the existing girders of Ramps EN and SW. Not only did they need to be detached and affixed to new portal frames but service could not be disrupted. The number of RR tracks to be closed was inversely proportional to the time allowed. While either Track 1 or 4 could be closed for a weekend, closing all four tracks was only allowed from 2-4 am (see Figure 9).

Another local agency with many constraints was the Chicago Park District (CPD) who oversees Burnham Park from Moe Drive to Lake Michigan's shoreline. CPD owns an 80 year old retaining wall east of Moe Drive which uses stacked precast concrete segments. This crib wall holds embankment on the west side of SB Lake Shore Drive, and is in need of replacement. The MP South Building was built alongside the wall with dozens of exposed columns only a foot from it. The unknown width of the existing crib wall as well as the proximity and overhang of the nearby building make replacing the wall problematic (see Figure 10).

Figure 9: Metra Catenary Lines below Ramp SW

Figure 10: Existing Crib Wall east of Moe Drive

CPD also owns MP Parking Garage C to the east of Fort Dearborn Drive and south of MP East Building. While the underground parking lot is not a problem, the garage's exit ramp built just west of it in 2000 is. Not only is the ramp 30' from the existing Ramp EN but it is also supported on a 14' wide spread footing, which decreases the horizontal clearance to only 21' and hinders the ability to offset Ramp EN to the east. Above the underground lot is the MP Bird Sanctuary which is a 6-acre wildlife refuge constructed in 2003 to attract migratory birds. Noise concerns adjacent to the sanctuary eliminated driven piles (see Figure 11).

Another project constraint of the CPD is the Chicago Lakefront Protection Ordinance, which they uphold. One rule of this ordinance is that structures shall not obstruct the view of Lake Michigan from the public. This counters our plan to fill as many of the existing 65' spans on Ramp NW as possible (see Figure 12). Other project constraints include constructing the six approach structures on highly compressible lake fill, increasing numerous substandard vertical clearances, eliminating fracture-critical members, locating piers near Lake Shore Drive to allow for additional lanes, and improving overall aesthetics for the interchange.

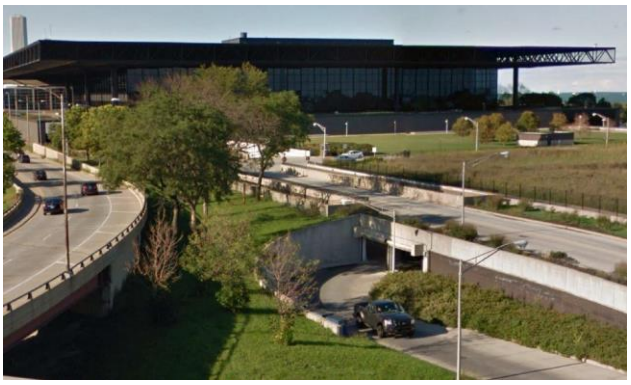


Figure 11: MP Exit Ramp & MP Bird Sanctuary

Figure 12: Existing Tangent Spans of Ramp NW

Proposed Structures

The numerous project constraints as well as the need to provide more durable and cost-efficient structures resulted in the proposed structures described herein. The first upgrade that addressed many of these items was replacing as many current spans as possible with retained fill. While this seems like a simple solution, it was complicated by the geotechnical requirements. As discussed, the structures are built on lakefront fill that is compressible and subject to large settlements. This typically leads to the use of deep foundations to support the approaches beneath compressible layers, but this was expensive so other options were sought.

Ground improvement methods such as rock columns were considered, but ultimately dismissed, since the compressible clay layer was 40’ to 60’ below grade. While these options are economical near the surface, they become cost prohibitive at depths such as these. The final solution was lightweight cellular concrete, which allowed MSE-type retaining walls to be used, except the fill was concrete with a density of 30 pcf. A 3’-6” embedment resulted in a maximum retaining wall height of 20’ to limit settlements to less than 1”. Deeper embedments were necessary in some areas to offset more of the 120 pcf in situ soil being replaced.

The second upgrade that tackled many of these items was reducing the number of spans and substructures. Longer spans solved numerous challenges including avoiding piers in the medians and RR right of ways, while fewer piers offered current and future savings. While preliminary studies proposed reusing existing drilled shaft foundations as one cost saving measure, this was rejected since it severely limited changes to alignments, span arrangements, widths, and staging. Utilizing longer retaining walls in combination with the longer span lengths resulted in a reduction in the total number of spans from 85 to 40 (see Figure 13).

A third upgrade which addressed the durability was decreasing the number of units and expansion joints. This was achieved by using continuous plate girders with a minimal number of modular expansion joints. This reduced the total number of units from 59 to 12 and total number of expansion joints from 61 to 16. The total number of units and joints could have been even less, although some were necessary for staging. After the18th Street detour was eliminated, the south 4-span unit of Ramp NW was split into 2-span units so the curved Unit 3 could be built within one stage, while the tangent Unit 4 could be stage constructed.

Another upgrade that explicitly addressed durability was the coating of the structural steel on this project. The current steel has been repainted twice and would require it again in 10 years, based on a 25 year cycle. IDOT District 1, who is responsible for maintaining the state bridges in Chicago, is aware of the problem and has recently required steel on many structures to be hot-dipped galvanized (HDG) rather than painted. While hot-dipped galvanizing is estimated to protect structural steel for the majority of the structure’s life, it is limited to steel that can fit in a galvanizing tank. Girders that are deep, long, or curved are a problem.

On this project, 60” and 72” plate girders were used, and girder segments ranged from 62’-6” to 112’-6”. While extra field splices can reduce segment lengths, it was not possible to HDG the many curved girders. The final solution was thermal-spraying (metalizing) that coats the steel with 8-12 mils of zinc like HDG, except it is sprayed so there are no geometric limits. Like HDG, metalizing provides cathodic protection so the zinc will sacrifice itself (corrode) for the steel. Its service life at 25-40 years is not as good as HDG, but it exceeds the service life of paint at 15-25 years. HDG was used on cross frames due to its lower cost.

Proposed Structure		Total Number of				Span Length		Structure Length		
Name	Str. No.	Lanes	Units	Joints	Spans	Min.	Max.	Appr.	Bridge	Total
NB I-55	016-1500	4	1	2	5	115'-0"	180'-0"	490'-0"	740'-0"	1230'-0"
SB I-55	016-1501	4	1	2	5	115'-0"	180'-0"	490'-0"	740'-0"	1230'-0"
Ramp ES	016-1502	2	1	2	4	135'-0"	165'-0"	264'-5"	605'-0"	869'-5"
Ramp EN	016-1503	4 to 2	3	3	9	120'-0"	165'-0"	173'-11"	1251'-0"	1424'-11"
Ramp SW	016-1504	2 to 4	2	2	7	100'-0"	180'-0"	388'-5"	1018'-0"	1406'-5"
Ramp NW	016-1505	2	4	5	10	125'-0"	180'-0"	307'-3"	1444'-0"	1751'-3"
Total		---	12	16	40	---	---	2114'-0"	5798'-0"	7912'-0"

Figure 13: Proposed Structures Information

The proposed superstructures consisted of 60” to 72” steel plate girders of AASHTO M270 Grade 50 steel composite their full length with an 8” concrete deck. While steel box girders were another feasible option especially for the curved bridges and their tight radii, they were not considered as requested by the owner. Design, construction, inspection, and maintenance of box girders are more complex than that for I-girders. This along with IDOT’s familiarity and success with curved I-girders ultimately led to that structure type. I-girders also provided more flexibility with staging that was problematic due to the minimal clearances.

All steel plate girders were designed according to the 2012 AASHTO LRFD Bridge Design Specifications and 2013 interim revisions (1) using MDX software. MDX is a commercial software used to analyze and design straight and curved I-girders and box girders. While MDX models typically use a 2D grid/grillage, a plate and eccentric beam (PEB) alternate was used. PEB models use two planes of coordinates to offset the deck and girders from each other to better model stiffness of the deck and distribute composite loads. While girder forces are virtually the same with PEB, cross frame forces are about 50 percent less using it.

Plate thicknesses were limited to four sizes to reduce the number that had to be obtained by the fabricator. Typically, 1” plate was used for flanges at midspans and 2” plate was used for flanges over interior piers with flange transitions limited to bolted field splices. A 1.5” plate was utilized for bottom flanges in a few spans to limit fatigue stress and live load deflections. A 5/8” web slightly thicker than the D/150 minimum (AASHTO 6.10.2.1.1) (1) was used for all girders to limit transverse stiffeners to just a few pier locations. Cross frame angles, gusset plates, connection plates, and most flange splice plates also utilized 5/8” plate.

The typical bracing consisted of X-type cross frames with both top and bottom chords at a 15-25’ spacing as well as K-type cross frames at the end of all units. Cross frames utilized L4x4x5/8 angles with only six 7/8”φ bolts in each corner thanks to the PEB models. Cross frame spacing near the upper end of this range resulted in large lateral flange bending stresses in the curved girders for new Ramps ES, EN, SW, and NW which have radii of only 578’, 544’, 580’, and 490’. Thus, a tight 15’-0” spacing along with wide flanges were used to limit the lateral flange bending stresses without any temporary or permanent lateral bracing.

The proposed substructures consisted of both multi-column concrete piers for the tangent structures and hammerhead concrete piers for the curved structures, with concrete stub abutments for the six approaches. Hammerheads minimize foundation footprints in the parking lots, maximize Lake Shore Drive clearances, and improve the aesthetics for the project’s east side. Space savings could have been even more using the single-column/single-shaft hammerheads originally proposed, although these were rejected by the owner as they are flexible, nonredundant, and require both lengthy cap overhangs and drilled shaft foundations.

Abutments and piers were designed according to the same AASHTO specifications as the superstructure. The multi-column piers were analyzed and designed using RCPIER, and the hammerheads were analyzed and designed using custom-built Excel spreadsheets. Lateral effects were determined via LPILE software. LPILE is a commercial software that utilizes the p-y method to analyze piles and shafts for lateral loading to determine reactions, shears, moments, deflections, and rotations over the length of these piles or shafts. LPILE allows the user to input the soil properties for various soil layers based on info from the boring log.

While it is the preference of the IDOT Bridge Office to use multi-column piers on footings and steel piles, wide-wall hammerheads using 4’x14’ columns atop two 5’-6” diameter shafts were chosen for the ramps. This provided most of the benefits of single-column/ single-shaft hammerheads but with more redundancy and smaller overhangs (17’-6” decreased to 13’-6”). While the redundancy of dual shafts can be debated, they are certainly more redundant than a single shaft. The decision to utilize shafts over piles was based on the number of major utility conflicts that diminished from 17 to 1 though minor utility conflicts remained.

Foundations for all piers use concrete drilled shafts. Due to very poor soil conditions, belled shafts were not considered and all shafts were taken to bedrock. Abutment shafts that only require a 200 ksf nominal bearing capacity (100 ksf factored bearing capacity) were taken to bedrock, but did not use rock sockets. Pier shafts that require a nominal bearing capacity of 300-500 ksf (150-250 ksf factored bearing capacity) were taken into bedrock with 4-6’ deep rock sockets. Capacities are based on the rock quality designation (RQD) values. If a rock had an RQD of 75 or more, then 500 ksf was used, otherwise 300 ksf was used.

On the west side of the project, the tangent structures were upgraded from 3 to 4 lanes. With the MP West and South Buildings blocking widening to the north, SB I-55 had to be widened to the south reducing the gap between tangent bridges from 16'-5" to 4'-10". This small gap forced NB I-55 to also be widened to the south which caused many issues with that bridge. Currently the I-55 bridges use a pier in the median of MLK Drive, between the 102' spans, which hampers turning left from SB MLK Drive to East 25th Street. Bus movements simulated via AutoTURN show that buses must overlap adjacent lanes to make that turn.

Widening NB I-55 moves this median pier 12' south making a turn within the left-turn lane unachievable. The solution suggested in preliminary studies was to use a post-tensioned (P-T) concrete cap integral with the girders for the NB I-55 pier in the MLK median. While a pier cap with P-T is complex and expensive, a P-T pier cap integral with the steel is even more so. This also requires a 12' overhang if the south face of the new column is aligned with the south face of the existing cap, just to maintain the present bus turning. This is unrealistic such that even an integral P-T cap would further reduce the current left-turn movement.

The final solution was to eliminate the median piers and span NB and SB MLK Drive with a single span. This was done with a 180' span though Piers 1E/1W were located in the 17' wide sidewalk west of MLK and Piers 2E/2W were placed within East 25th Street. This required sliding the East 25th Street's north curb 2' south along with eliminating a taper and reducing a radius of the curb at its intersection with NB MLK. The span layout was 120'-180'-160'-160'-115' with nine 60" plate girders spaced at 8'-0" and 3'-7" deck overhangs. Decks have a 71'-2" out-to-out width for four 12' lanes and two 10' shoulders (see Figure 14).

Proposed piers utilized 5'-6" wide x 4'-6" deep caps atop 5' diameter columns and 5'-6" diameter shafts. The 69' long caps used three columns at 24' spacing to accommodate the MP Bus Staging Area beneath it and 10'-6" overhangs (8' clear) over East 25th Street. This provided 19' laterally between columns, 14'-9" vertical cap clearance for the MP Bus Staging Area, and 15'-8" vertical cap clearance for East 25th Street. Crashwalls were employed for Piers 1E/1W, 2E/2W, and 5E/5W although not at Piers 3E/3W and 4E/4W. Design of a 600-kip collision (AASHTO 3.6.5.1) (1) at the single columns dictated the large column size.

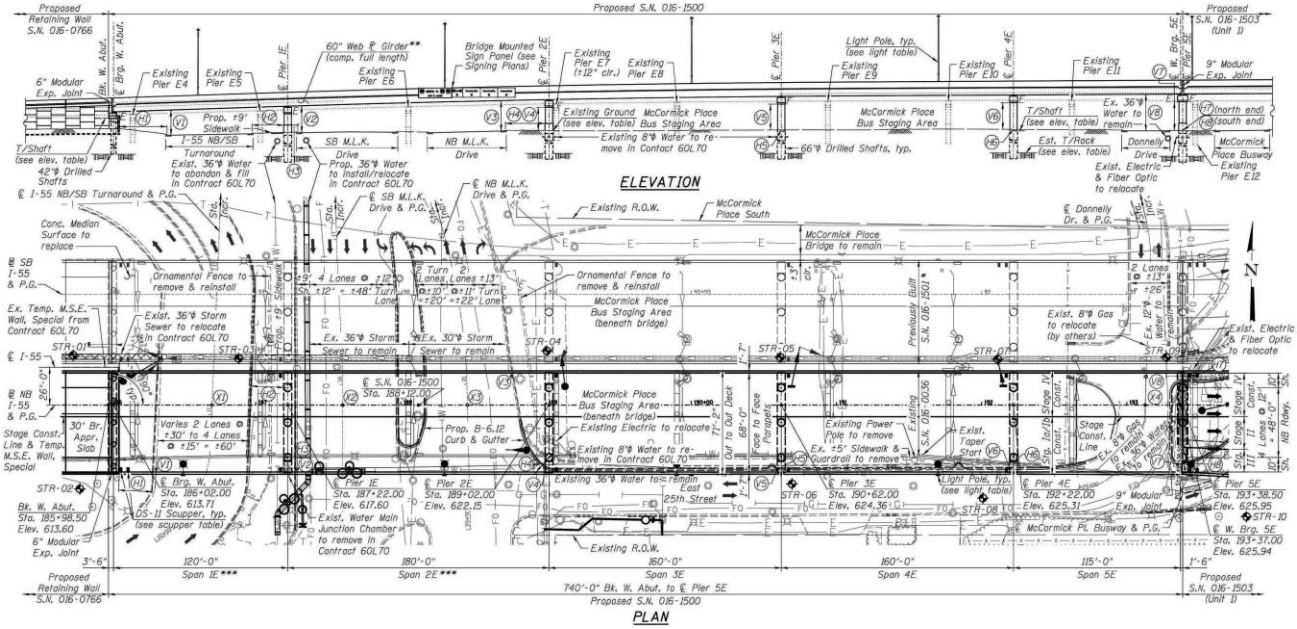


Figure 14: Proposed NB & SB I-55 Bridges

On the east side, Ramp ES was upgraded from 1 to 2 lanes since traffic always backs up on NB I-55 and is forecast to grow to 23,000 vehicles per day by 2040. The bridge was shortened on the west by moving the divergent point east (bridge no longer over railroad) and on the east by using a steeper 4.62% downgrade east of Moe Drive and filling in the south four spans. The existing bridge utilizes an integral steel straddle pier to cross over Moe Drive at a skew of about 55°. In order to avoid similar fracture-critical conditions, preliminary studies proposed a P-T concrete straddle pier integral with steel plate girders over Moe Drive.

As an alternative to one of the integral straddle piers, the new bridge spans Moe Drive using a single span. This requires Pier 15E to overhang a 17’ sidewalk to the west and a barrier to protect Pier 16E on the east. The proposed structure utilizes a single, symmetrical 135’-165’-165’-135’ 4-span unit with six 72” curved plate girders spaced at 7’-4” (3’-3” deck overhangs). The deck has a 43’-2” out-to-out width with two 12’ lanes, a 10’ inside shoulder, and 6’ outside shoulder. Hammerhead Piers 14E, 15E, and 16E are located to miss parking aisles and minimize the parking spaces they eliminate in MP Parking Lot B (see Figure 15).

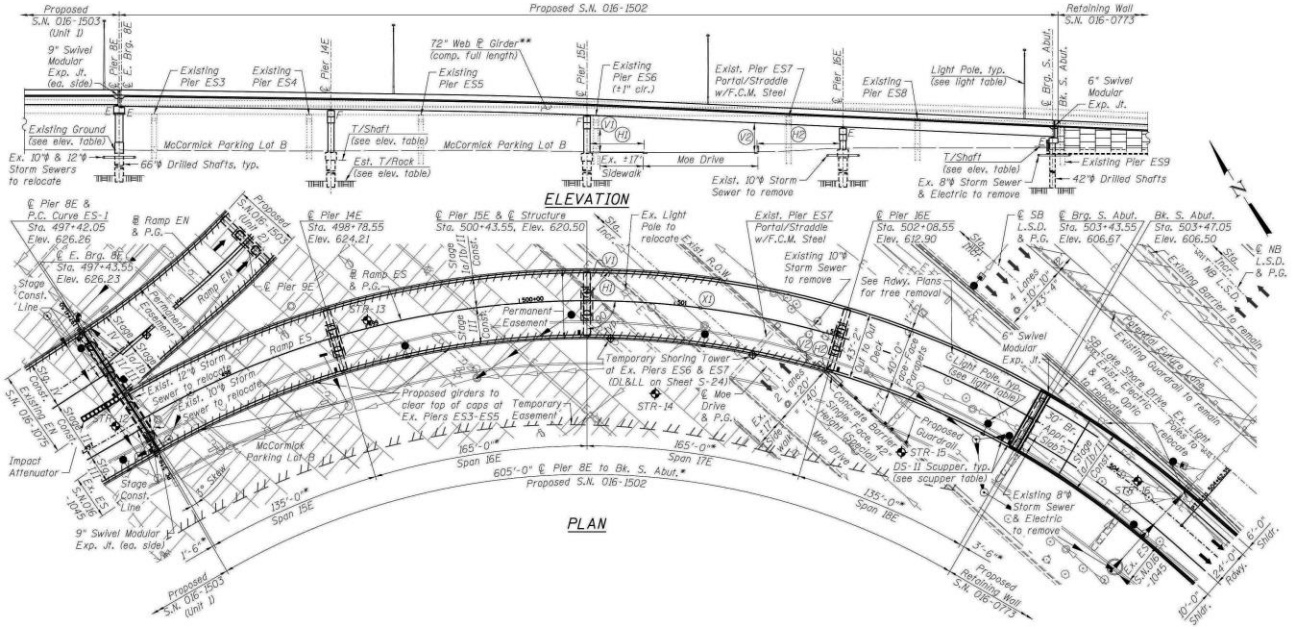


Figure 15: Proposed Ramp ES

Ramp EN maintains 2 lanes of traffic forecast to just slightly increase to 47,000 vehicles per day by 2040. The proposed structure uses three symmetrical units. Unit 1 is a 120’-160’-120’ flared 3-span over the MP Busway, Metra, and CNRR that varies in width from 71’-2” at Pier 5E to 92’-4” at Pier 8E, and Unit 2 is a 120’-120’ curved flared 2-span in MP Parking Lot B that varies in width from 48’-2” at Pier 8E to 43’-2” at Pier 10E with flaring near Pier 8E (see Figure 16). Unit 3 is a 135’-165’-165’-135’ curved 4-span under Ramp EN and over both Moe Drive and Lake Shore Drive with a 43’-2” out-to-out width (see Figure 17).

Unit 1 uses eleven 60” plate girders spaced at 8’ and is laid out so the flaring is contained within the unit. The north 10’ shoulder, north two 12’ lanes, and six girders under them run east-west parallel to NB I-55. The south 10’ shoulder, south two 12’ lanes, and the south three girders follow the standard 3° exit taper. Girders 4 and 5 run at 2° and 1° south with Girder 4 framing into a header beam at the west contraflexure point (east of splice) in the mainspan over the tracks. Unit 2 employs six 72” curved plate girders typically spaced at 7’-4” and was widened 5’ south at Pier 8E to offer an additional lane during stage construction.

The alignment and span arrangement of Unit 3 were changed many times. The initial proposed alignment, slightly west of its current location, was shifted east to offer an additional lane during stage construction. To avoid a retaining wall and its 14’ wide footing for the exit ramp to underground MP Parking Garage C, the span arrangement of Unit 3 was lengthened from 135’-165’-165’-135’ to 135’-180’-180’-150’, so the north endspan could bridge over the existing footing. The original spans were later restored to save around $500,000. This savings is from both a shorter bridge and smaller flanges (less steel) along Unit 3’s length.

The final Unit 3 span arrangement required the north approach to bear on the exit ramp’s existing footing, which had to be analyzed for this additional loading. Though the proposed north approach is much higher, this was offset with the lightweight cellular concrete which is 4x lighter than the current backfill material. The final span arrangement of Unit 3 also allows for a potential future widening of NB Lake Shore Drive to the west in addition to a previously planned future widening of NB or SB Lake Shore Drive to the east. The proposed Ramp NW can likewise accommodate the widening to either side of NB Lake Shore Drive.

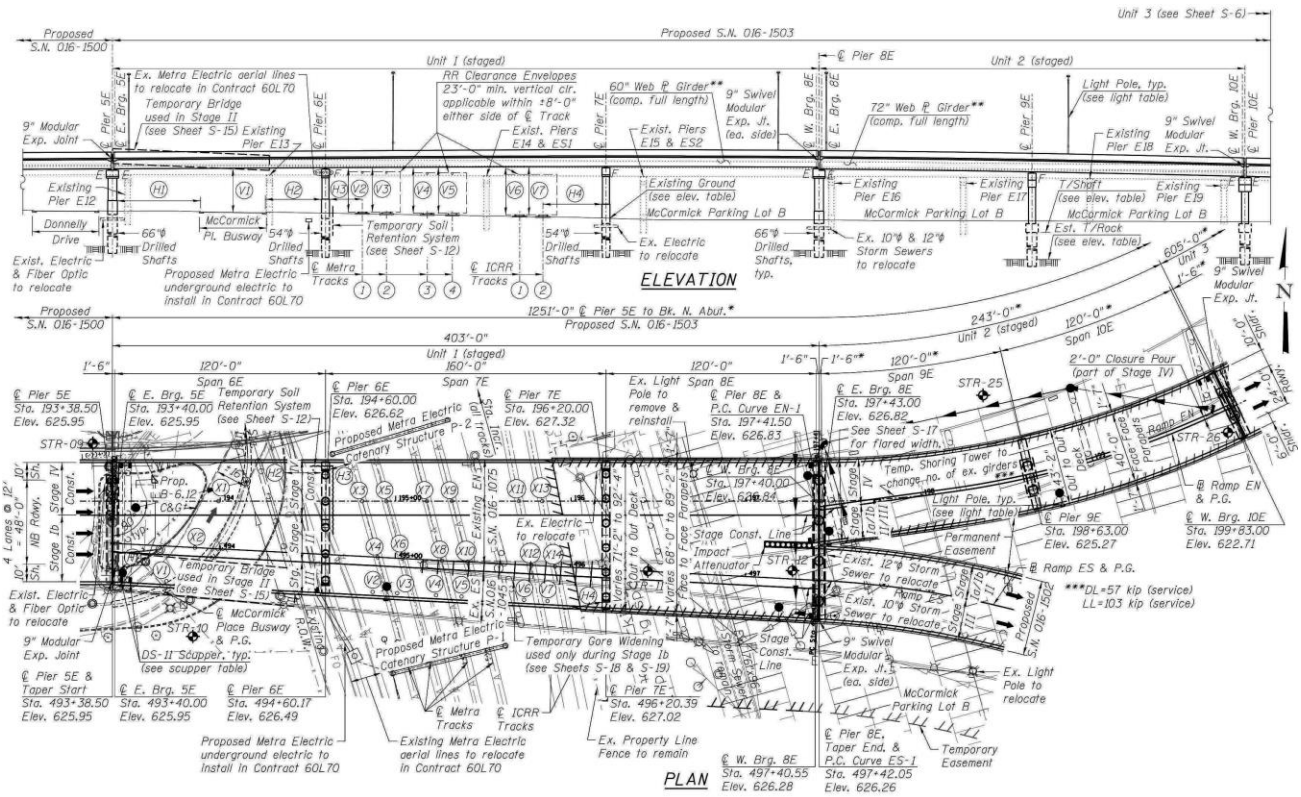


Figure 16: Proposed Ramp EN (Units 1 & 2)

Figure 17: Proposed Ramp EN (Unit 3)

Ramp SW maintains 2 lanes of traffic forecast to just slightly increase to 41,000 vehicles per day by 2040. The new bridge has two symmetrical units. Unit 1 is a 100'-150'-100' curved flared 3-span above the MP Busway, Metra, CNRR, and Mines Drive that varies in width from 71'-2"at Pier 5W to 87'-6" at Pier 8W (see Figure 18), and Unit 2 is a 150'-180'-180'-150' curved 4-span above the MP Parking Lot B and Moe Drive with a 43'-2" out-to-out width (see Figure 19). An 8" gas main below the north endspan dictated the large spans and forced the hammerhead at Pier 11W to be changed to a multi-column to avoid this utility.

Unit 1 uses 60" plate girders and is laid out such that nine girders along Pier 5W are at 8' spacing, eleven girders along Pier 8W are at 8' spacing, and Girder 6 aligns with 13°24'17" kink at the center of Pier 8W. Girders 3 and 5 frame into header beams just east of the contraflexure point in endspan over Mines Drive. Unit 2 utilizes six 72" curved plate girders spaced at 7'-4" and crosses Moe Drive at a skew of about 59° via a single span to avoid fracture-critical conditions or a P-T concrete straddle pier (preliminary studies). Hammerheads are used for Piers 9W and 10W with multi-column Pier 8W kinked to eliminate any skew.

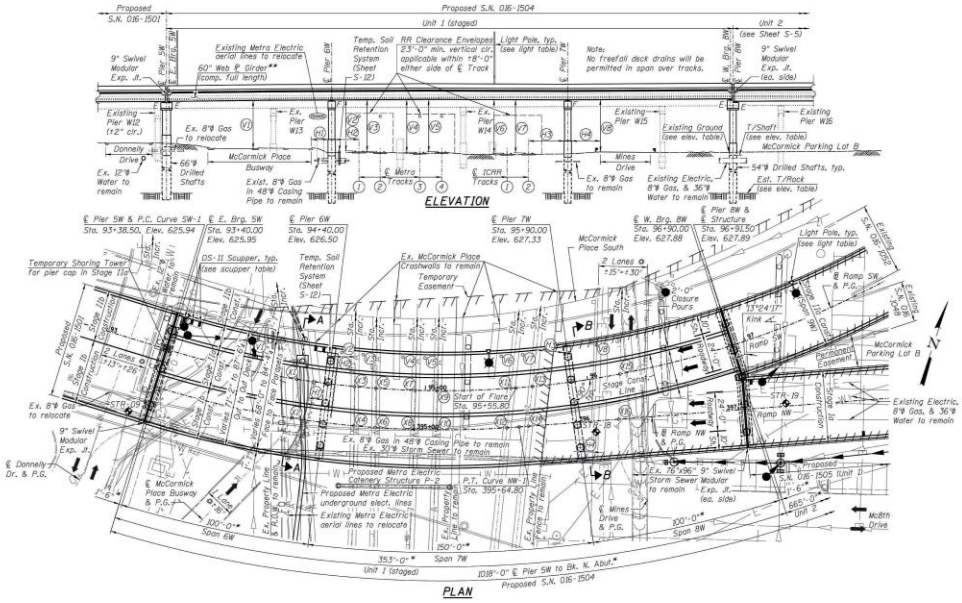


Figure 18: Proposed Ramp SW (Unit 1)

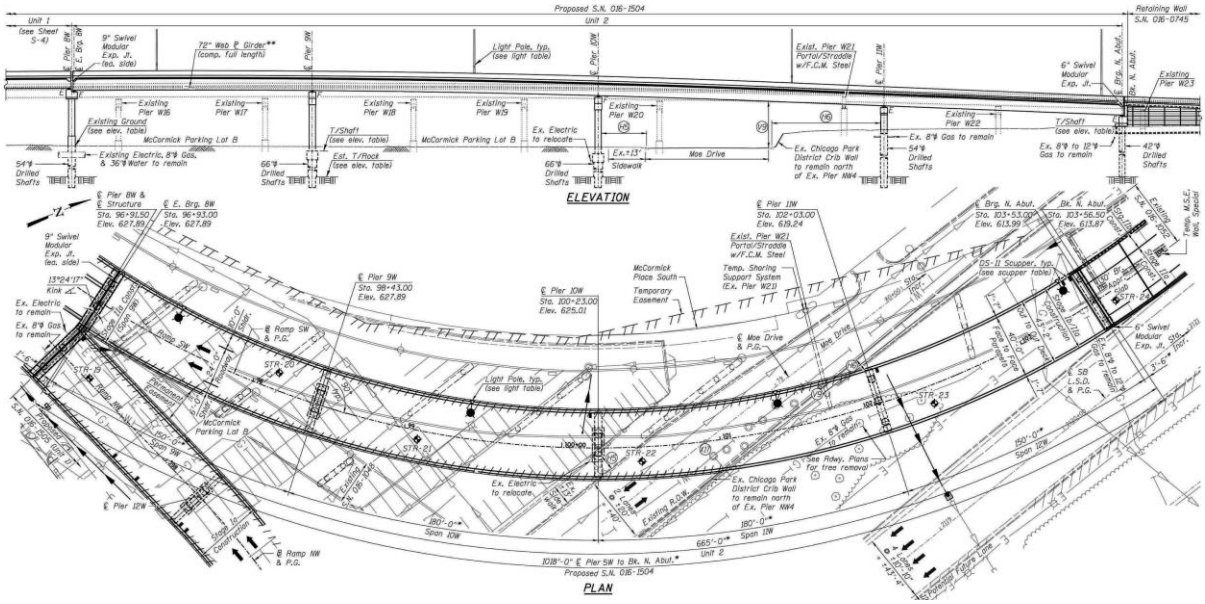


Figure 19: Proposed Ramp SW (Unit 2)

Ramp NW was upgraded from 1 to 2 lanes as traffic regularly backs up onto NB Lake Shore Drive and is forecast to grow to 22,000 vehicles per day by 2040. The bridge was shortened by offsetting its alignment 188’ south, using a steeper 4.00% downgrade east of Lake Shore Drive, and filling in the south five spans. The offsetting raised the interchange height by 4’-6”. Preliminary studies proposed replacing all 13 curved spans while rehabilitating the other 15 tangent spans. Since this required replacing every third pier beneath the joints and widening other piers along the tangent, it was decided to replace the tangent portion as well.

The proposed structure uses four symmetrical units. Unit 1 is a 125’-125’ 2-span over MP Parking Lot B with the west span tangent and the east span curved, while Unit 2 is a 125’-180’-180’-125’ curved 4-span above Moe Drive, Lake Shore Drive, and Ramp EN (see Figure 20). Unit 3 is the mirror image of Unit 1. Unit 4 is a 160’-160’ 2-span in the park which exists to meet the Chicago Lakefront Protection Ordinance (see Figure 21). All units utilize six 72” plate girders spaced at 7’-4”, 3’-3” deck overhangs, hammerhead piers, and a 43’-2” out-to-out width made of two 12’ lanes, a 10’ inside shoulder, and 6’ outside shoulder.

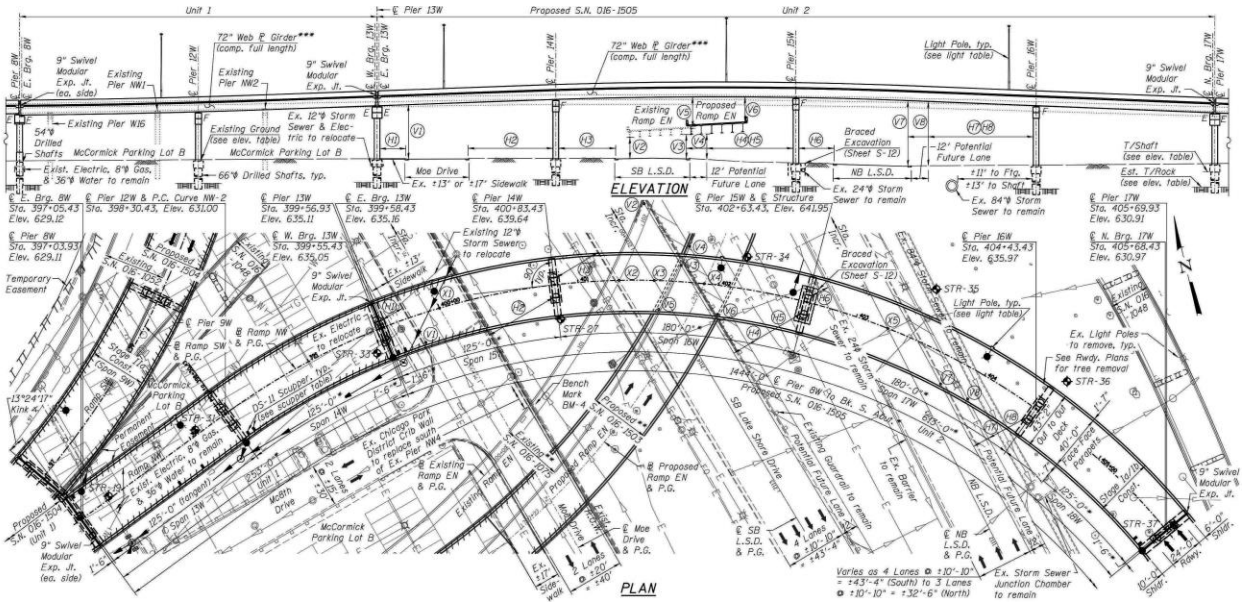


Figure 20: Proposed Ramp NW (Units 1 & 2)

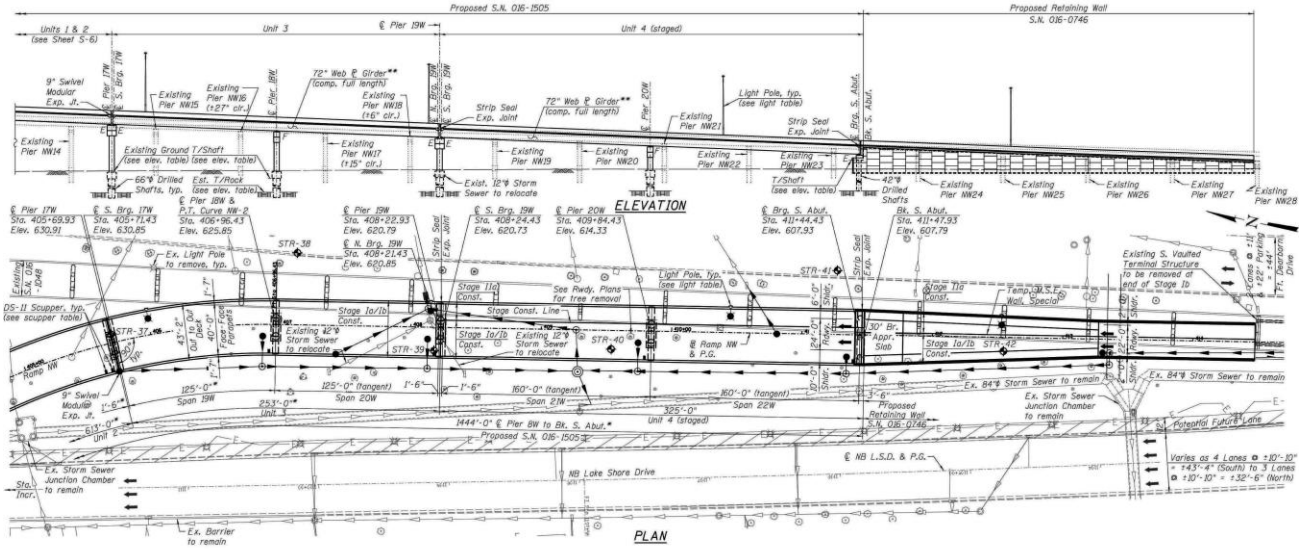


Figure 21: Proposed Ramp NW (Units 3 & 4)

Contract Packaging & Proposed Staging

IDOT District 1 split both design and construction of the proposed interchange into two separate contracts. This was ultimately chosen for a number of reasons. First, many large contractors in the Chicago area are currently working on the Illinois Tollway's 15-year, $12 billion capital improvement plan, *Move Illinois*. These large contractors which already have work are more apt to bid on more, if the contracts are smaller. Second, it allows smaller contractors to bid on work. Third, it was felt that splitting the construction of the proposed interchange in contracts of shorter duration would decrease the burden upon the traveling public.

The first contract to be designed and constructed was the Outbound Structures made up of SB I-55, Ramp SW, and Ramp NW that carry traffic out of the city. Outbound was designed in the first half of 2014 for a September 2014 letting, although this was pushed to November 2014 when the Metra catenary relocation design work was added to AECOM's scope of work. This included designing new portal frames to receive the catenary lines relocated from the current bridges. The letting was again moved to January 2015 due to ongoing negation between IDOT and Metra, CNRR, and MP over permanent easements and right of way.

The second contract to be designed and constructed was the Inbound Structures made up of the NB I-55, Ramp ES, and Ramp EN that get traffic into the city. Inbound was designed in the first half of 2015 with a September 2017 letting, although this was moved to September 2015 due to multiple recent deck failures which required moving up the construction schedule. The letting was then moved up to July 2015 ahead of many Tollway contracts to be let in the fall of 2015. This required both contracts to be built concurrently, which was only possible because the detours that fed traffic from one contract to another were eliminated.

Contract 60L70(Outbound Structures) was awarded to IHC Construction Companies on March 13, 2015. The winning bid was $73.87 million, which included 4,125 tons of steel at $2.82/pound or $23.25 million. Contract 60X07(Inbound Structures) was awarded to Kenny Construction Company on August 19, 2015. The winning bid was $60.35 million, which included 3,475 tons of steel at $2.65/pound or $18.40 million. Although the unit prices for *Furnishing and Erecting Structural Steel* seem high, they include an estimated $0.50/pound for metalizing. This represents IDOT's largest use of metalizing on any state project to date.

As previously discussed with the project constraints, preliminary studies recommended reducing two-lane Ramps EN and SW to one lane in construction while detouring traffic for single-lane Ramps ES and NW. While it was not feasible to provide a second lane on Ramps EN and SW during all stages of construction, it was possible for all but one stage in each contract. This was attained by widening the tangent structures and offsetting the alignments of the proposed curved structures as much as possible from the current ones. The alignments for Ramps ES, EN, SW, and NW are offset a max of 18', 40', 26', and 188', respectively.

Ramp NW's enormous offset allowed the 18th Street detour to be eliminated for the Outbound Structures, although the solution was not so simple for avoiding that detour for Ramp ES with the Inbound Structures since the maximum offset for that ramp was just 18'. This required filling in the gap where existing Ramp ES diverges from existing Ramp EN (see Figure 22) and erecting a temporary bridge to connect proposed NB I-55 down to existing Ramp ES (see Figure 23). The gore widening connected existing fascia girders using 13 W21 beams at 8'-9", while a prefabricated through-truss was proposed as the temporary bridge.

Figure 22: Gore Widening at Existing Ramp EN

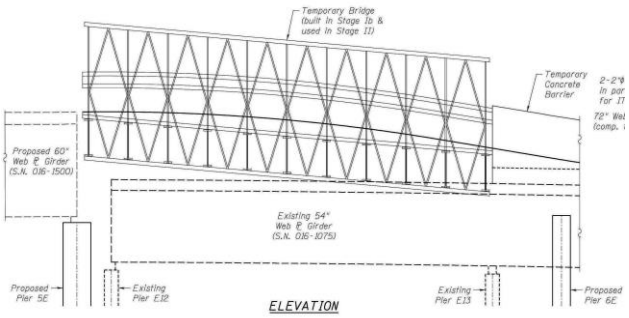


Figure 23: Proposed Temp Bridge for Ramp ES

Construction of the Outbound employed four stages. In Stage 1, the existing traffic is retained on all three existing structures including three lanes on SB I-55, two lanes on Ramp SW, and one lane on Ramp NW. This requires sliding NW traffic to the northeast half of existing Ramp NW for removal of the west girder on the 15 tangent spans. This allows construction of Spans 13W-20W of Ramp NW (Units 1-3) and the west half of Spans 21W-22W of Ramp NW (Unit 4). Catenary relocation work is to be done in this stage, which is even more critical now since both contracts require this work to be done up front (see Figure 24).

In Stage 2, WB traffic is reduced to two lanes on the north half of existing SB I-55, SW traffic is reduced to one lane on northwest half of existing Ramp SW, and NW traffic's lane is kept on existing Ramp NW. This permits construction of the south half of Spans 1W-5W of SB I-55, the south third of Spans 6W-8W of Ramp SW (Unit 1), and just the east half of Spans 10W-12W of Ramp SW (Unit 2). A second lane can be added on Ramp SW for special events at MP and Soldier Field but must merge with NW traffic's lane. Span 9W cannot be built in Stage 2 since it occupies the space where existing Ramps SW and NW merge.

In Stage 3, NW traffic is shifted from northeast half of existing Ramp NW to southwest half of proposed Ramp NW, while one of the two lanes of WB traffic is also shifted to the south half of proposed SB I-55. SW traffic is still maintained on existing Ramp SW, but demolition proceeds on southeast half such that a second lane is no longer available for special events. This allows construction of the center third of Spans 6W-8W of Ramp SW (Unit 1), all of Span 9W with west half of Spans 10W-12W of Ramp SW (Unit 2), and the east half of Spans 21W-22W of Ramp NW (Unit 4). Ramp SW (Unit 1) requires a closure pour.

In Stage 4, SW traffic is shifted from northwest half of existing Ramp SW to southeast half of proposed Ramp SW, and increased to two lanes. WB traffic is shifted from the north half of existing SB I-55 to the south half of proposed SB I-55, going to three lanes. NW traffic is preserved on the proposed Ramp NW. This permits construction of the north half of Spans 1W-5W of SB I-55 and north third of Spans 6W-8W of Ramp SW (Unit 1), which requires a closure pour. Besides the catenary relocation, it is also critical that Ramp NW be demolished so Ramp EN can be built now that these contracts are being built concurrently.

Construction of the Inbound made use of five stages. In Stage 1, EB traffic is decreased from three to two lanes and relocated to north half of existing NB I-55, while ES traffic's one lane is slid onto the southwest half of existing Ramp ES and EN traffic's two lanes are slid on the northwest half of existing Ramp EN. This permits construction of the south half of Spans 1E-3E of NB I-55, the south half of Spans 9E-10E of Ramp EN (Unit 2), most of Spans 11E-14E of Ramp EN (Unit 3), the northeast half of Spans 15E-18E of Ramp ES, and a 15' wide x 105' long gore widening between existing Ramps ES and EN (see Figure 24).

In Stage 2, traffic movements are maintained except the exit for Ramp ES is shifted about 100' to the east onto the gore widening constructed in the first stage. This permits construction of the south half of Spans 4E-5E of NB I-55 and erection of a temp bridge that extends from proposed Pier 5E to existing Pier E13. In Stage 3, ES traffic is shifted onto the south half of proposed NB I-55 and uses the temp bridge to carry ES traffic from NB I-55 down to existing Ramp ES. This allows construction of the center third of Spans 6E-8E of Ramp EN (Unit 1). Two lanes for EB and EN traffic are maintained on the existing structures.

In Stage 4, ES traffic is maintained on the south half of proposed NB I-55, but is relocated from the temp bridge onto the center third of Spans 6E-8E of Ramp EN (Unit 1) and from the southwest half of existing Ramp ES to the northeast half of the new Ramp ES. EB and EN traffic are kept on the existing structures. This permits construction of the south third of Spans 6E-8E of Ramp EN (Unit 1) and the southwest half of Spans 15E-18E of Ramp ES. A closure pour was avoided on Ramp ES by limiting the first deck pour to northeast half, despite most girders being erected, to limit differential deflections below the stage joint.

In Stage 5, EB traffic is relocated from the north half of existing NB I-55 to the south half of proposed NB I-55 (three lanes) while EN traffic is shifted from the northwest half of existing Ramp EN to the southeast half of proposed Ramp EN, and reduced to one lane. ES traffic is increased to two lanes on new Ramp ES that EN traffic can also use to access NB Lake Shore Drive via 31st Street to avoid the one-lane Ramp EN. This permits construction of the north half of Spans 1E-5E of NB I-55, the north third of Spans 6E-8E of Ramp EN (Unit 1), and north half of Spans 9E -10E of Ramp EN (Unit 2), which requires a closure pour.

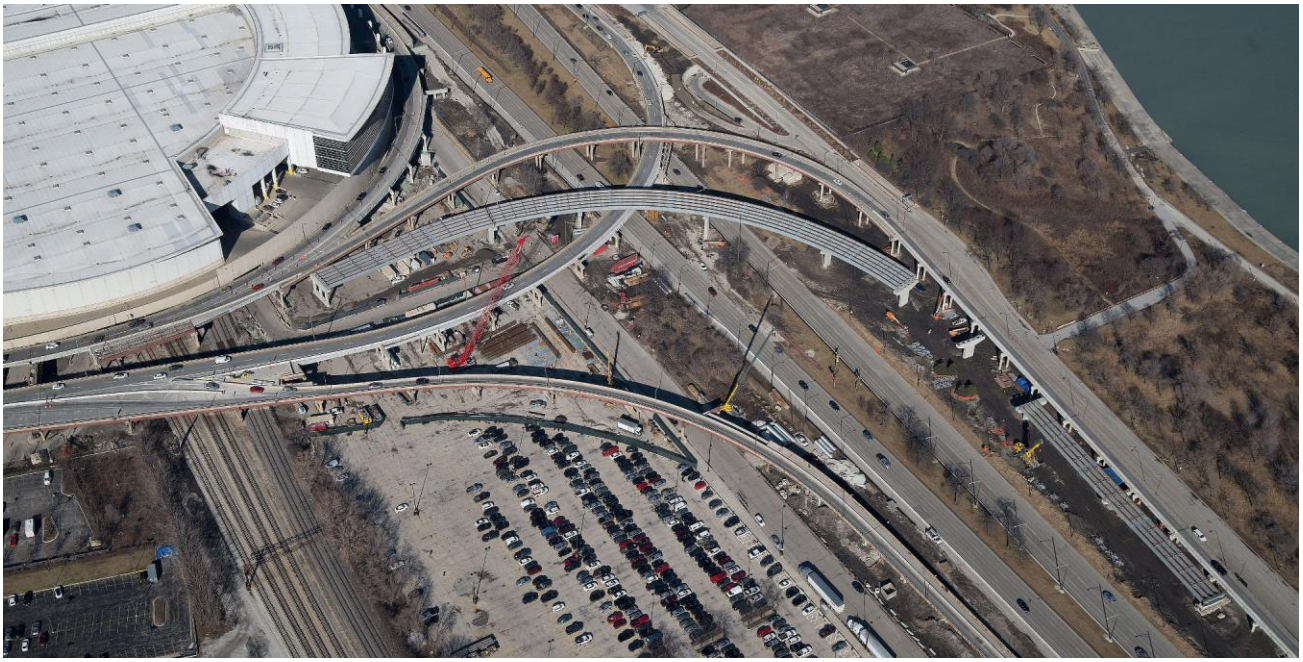


Figure 24: Proposed I-55 & Lake Shore Drive Interchange under Construction

Acknowledgements

Owner/Client:	Illinois Department of Transportation (District 1)
Prime Consultant:	AECOM Technical Services, Inc.
Structural Subconsultant:	Rubinos & Mesia Engineers, Inc.
Surveying Subconsultant:	Dynasty Group, Inc.
Outbound Contract:	
General Contractor:	IHC Construction Companies, LLC
Resident Engineers:	IDOT (District 1) & Ardmore Associates, LLC
Structural Steel Fabricators:	Industrial Steel Construction, Inc. & Munster Steel Company, Inc.
Structural Steel Erector:	S & J Construction Company, Inc.
Expansion/Fixed Bearing Suppliers:	Tobi Engineering, Inc. (elastomeric) & Con-Serv, Inc. (HLMR)
Modular Expansion Joint Supplier:	Watson Bowman Acme Corp.
Shaft Subcontractor & CSL Tester:	Michels Corporation & GRL Engineers, Inc.
Cellular Concrete & MSE Suppliers:	Aerix Industries, Mix-On-Site, & The Reinforced Earth Company
Inbound Contract:	
General Contractor:	Kenny Construction Company
Resident Engineers:	IDOT (District 1) & Omega Associates, Inc.
Structural Steel Fabricator:	Industrial Steel Construction, Inc.
Structural Steel Erector:	S & J Construction Company, Inc.
Expansion/Fixed Bearing Suppliers:	Tobi Engineering, Inc. (elastomeric) & R.J. Watson, Inc. (HLMR)
Modular Expansion Joint Suppliers:	Hennegan & Associates, Ltd.(D.S. Brown Co.) & D.S. TechStar, Inc.
Shaft Subcontractor & CSL Tester:	Michels Corporation & GEI Consultants, Inc.
Cellular Concrete & MSE Suppliers:	Geo-Cell Solutions, Inc. & The Reinforced Earth Company

References

(1) AASHTO (2013). *AASHTO LRFD Bridge Design Specifications, 6th Edition with 2013 Interim Revisions.* American Association of State Highway & Transportation Officials, Washington, DC.