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Metropolitan Avenue Bridge Emergency Contract – Project Challenges through the Eyes of the Client and the Contactor

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METROPOLITAN AVENUE BRIDGE EMERGENCY CONTRACT – PROJECT CHALLENGES THROUGH THE EYES OF THE CLIENT AND THE CONTRACTOR

BRIDGE HISTORY AND EXISTING CONDITION

The Metropolitan Avenue Bridge (ID 2-24029-0) carries four lanes of traffic from Metropolitan Avenue and Grand Street over the English Kills in Brooklyn, NY. Since it's original construction in 1931 for $635,000, the double leaf bascule bridge with a total span of 110ft and width of 65ft, has significantly changed through multiple rehabilitation projects. Modifications included upgrading the mechanical and electrical systems, replacement of the deck, bridge rail, and fenders, and replacement of the roadway stringers. Additionally, the span was originally constructed as a twin double leaf bascule with four independent machinery sets. As part of a rehabilitation project in the early 2000's, the twins of each leaf were joined to operate together, however the twin machinery layout remained the same.

Rehabilitation in Early 2000's

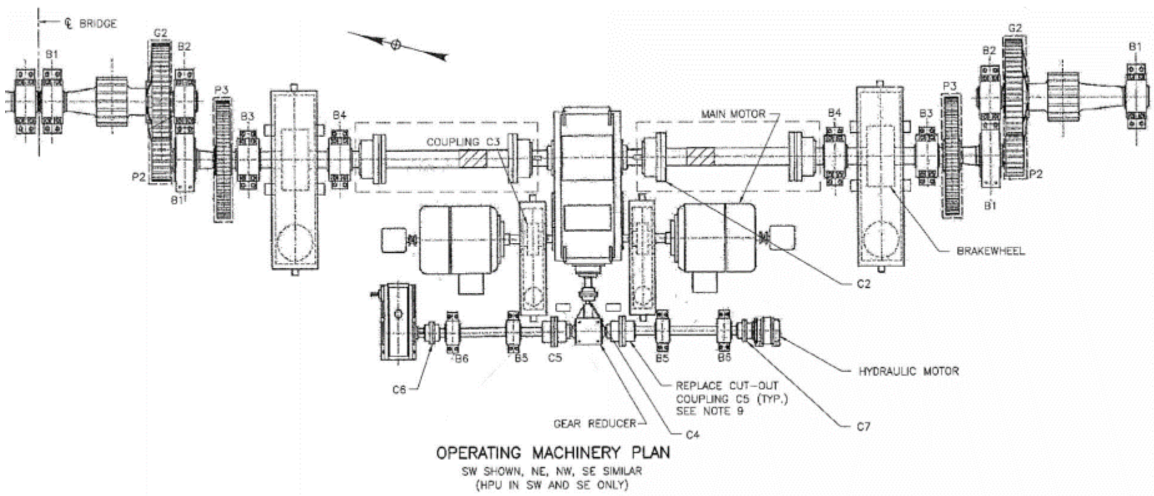
The bridge is one of the most heavily operated span for marine traffic in the New York City Metropolitan area with approximately 400 openings per year. A high percentage of the openings are for delivery of oil barges to a nearby depot providing heating oil for homes and businesses in the New York City area. As a result, the majority of the 400 openings per year occur in the winter months. Additionally, due to shallow water levels in the English Kills, passage for deliveries is tide dependent, requiring around-the-clock operation of the bridge by the NYCDOT.

Bascule Span in Open Position

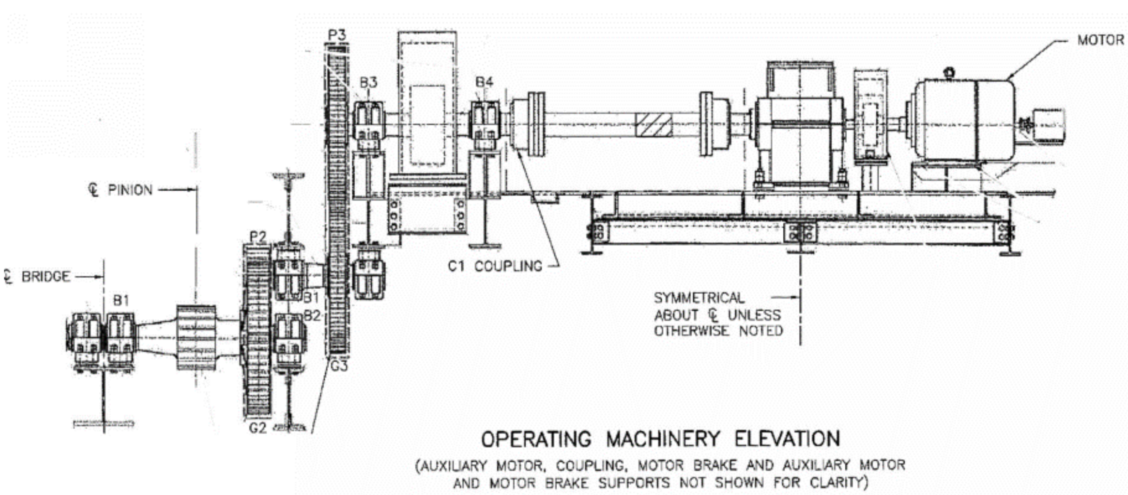
Mechanical Systems

The current mechanical component of the bridge is made up of four separate systems; operating machinery, emergency hydraulic machinery, tail lock machinery, and span lock machinery. The figures below shows a general schematics of these systems.

The operating machinery is made up of two identical machinery sets side by side for each of the two bascule leafs. Each machinery set contains two electric motors, one primary and one auxiliary. The motor shaft is connected to a main helical bevel gearbox, which rotates two main machinery shafts. Each of the shafts operate two sets of open gearing and a pinion which engages a curved rack on the underside of the main bascule stringers. The girders rotate about trunnions with a counterweight at the heel for balanced loading during operation.



Plan View of Operating Machinery Set



Elevation View of Operating Machinery Set

The emergency hydraulic operating system is made up of one hydraulic power unit per bascule span. This unit is powered by a diesel motor, independent of the electrical system of the bridge. The unit sends hydraulic oil to two hydraulic motors located at the behind each set of operating machinery. The hydraulic motors operate a shaft which also connects to the main helical bevel gearbox. A shifter coupling on the emergency drive shaft is used to engage the hydraulic machinery for use.

The tail lock system is made up independent locks at the heel of each bascule girder, 4 per leaf or 8 total. A helical bevel gearbox with an electric gearmotor drives a crankshaft which pushes a pulls a lock wedge under the seat on the bascule girder. This wedge locks the girder to prevent movement while vehicular traffic crosses the span.

The span lock system is similar to the tail locks, however there are only 4 locks total located at the toe of the span. Each span lock has a helical bevel gear box with electric gearmotor which powers a crankshaft. The crankshaft pushes and pulls a lockbar which enters a socket on the opposite leaf to lock both spans together in the closed position.

Existing Condition of Tail Lock Machinery

Electrical Systems

The electrical control system for the bridge is made up of four main components, the PLC, MCC, drive control panels, and the control desk. Each of these components, along with multiple limit switches and encoders, work to control each of the mechanical systems for operation. The Programmable Logic Controller (PLC) is the center of the system, using a logic program to send signals and receive data to control individual components of the bridge. Additionally, the use of program logic allows interlocks to be introduced which prevent operation of the machinery components in an order or manner that is unsafe or can cause physical damage.

The Motor Control Center (MCC), is a large panel made up of individual MCC buckets where each bucket controls a single machinery component. There is a bucket for each tail lock, span lock, machinery brake, motor brake, warning gate, and barrier gate. The PLC sends control signals to each of the MCC buckets, which in turn provide power to the component to operate.

The two drive control panels are used to control the electric motors for the operating machinery. These Hubbell drives are used to allow for highly customizable control of the motors for characteristics such as ramp time, ramp speed, speed and torque control, amperage draw, etc. Control of these characteristics are critical in making the span operate in a manner that is highly repeatable without damage to any of the machinery components, the span, or the motors themselves.

Finally, the control desk is located on the top floor of the control house and is used by the operator to control the span. Buttons and dials are used operate the individual components in sequence to operate the span. Due to the program logic, a button will not operate that component if it is pressed out of order. However, keyed bypasses are present to allow for the operator to override the interlocks in the event of a malfunction.

HURRICANE SANDY DAMAGE

On October 29, 2012, Hurricane Sandy struck the northeast United States, causing $71.4 billion in damages due to the destruction caused by heavy rains, high winds, and extreme flooding. In the New York City Metropolitan area, storm surges of surrounding waterways were recorded up to 14ft above high water levels resulting in damages estimated at nearly $42 billion for the city alone.

During the storm surges of Hurricane Sandy, all of the mechanical and electrical systems of the Metropolitan Avenue Bridge were flooded. The high water levels completely filled both bascule pits and submerged all of the operating, tail lock, and emergency hydraulic machinery. Additionally, the main electrical room was flooded with approximately 3ft of water and the emergency generator located on the exterior of the building was flooded. As a result of the flooding, all of the primary, secondary, and emergency operating systems were unusable immediately following the storm, leaving the bridge inoperable.

Temporary Control Board

Immediately following the storm, the NYCDOT Division of Bridges assessed the damage and applied emergency repairs in stages to bring some of the systems back online. In the first stage, the emergency hydraulic power units and main reducers were drained, flushed, and refilled to remove water infiltrated oil. Additionally, all open gearing and bearings were checked for damage and regreased. With these repairs, the emergency hydraulic system was made operable, which allowed the bridge to be opened without electrical power. However, the warning and barrier gates were still inoperable, requiring crash trucks in all lanes to stop traffic for all openings. The bridge remained in this condition for several months.

In the second stage of emergency repairs, the primary electrical systems were made operational. A temporary transformer was installed to restore incoming power to the bridge and control house. Due to damage to the PLC, MCC, and drive cabinets that could not be immediately repaired, as well as flooding of conduit and electrical boxes, temporary wiring and controls were installed to bypass the primary systems. At each machinery set, the electrical motors were removed, rebuilt, and reinstalled. Temporary wiring was run to the motors, brakes, locks, traffic gates and traffic lights. A temporary board was constructed in the electrical room which housed the breakers and contactors for each of the components, and a temporary control desk was built next to the existing control desk. Following these repairs, the bridge was operable from the control room, rather than requiring crews below each end of the span at the hydraulic power units.

While most of the systems were back online following the emergency repairs, all eight of tail locks and two of the four span locks were still inoperable and remained unused. Additionally, the bridge was controlled by the temporary control panel which bypassed the PLC. Without the PLC, no interlocks were utilized, requiring operation of the span to be fully dependent on the operator.

REHABILITATION PROJECT AND SCOPE

Advertized in early 2014, the NYCDOT initiated a contract funded under the FHWA Emergency Relief (ER) Program to rehabilitate the mechanical and eletrical systems of the bascule span to pre-Sandy conditions. The emergency contract was awarded to Kiewit Infrastructure Co. for $23.1M and notice to proceed was issued in late July of 2014.

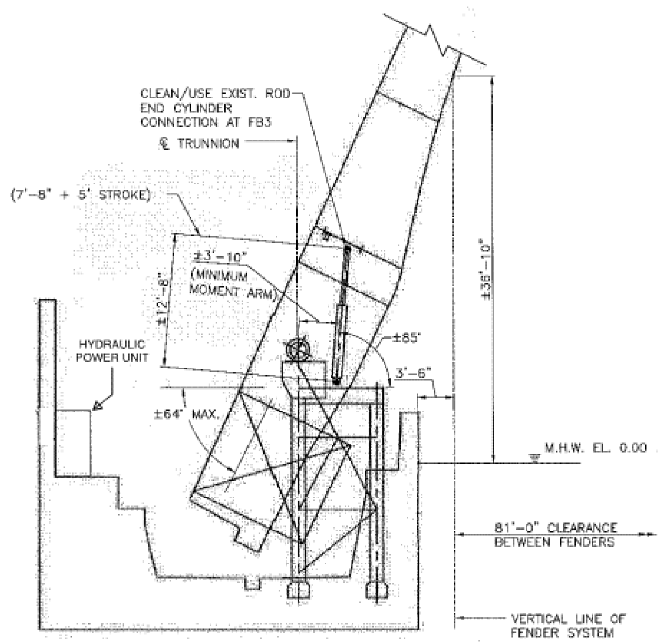
The Metropolitan Avenue Bridge was the first of several movable bridges in the city to receive permanent emergency repairs projects, due to level of damage to the span as well as its high operation rate compared to other movable bridges in the city.

The major scope of work for the emergency repairs project included installation of a temporary operating system, removal, rehabilitation, and reinstallation of the mechanical and electrical systems, relocation of electrical equipment above the 500yr flood line, and flood proofing of the existing electrical room. Additionally, the span was to remain operational to both vehicular and marine traffic throughout the project, and the contractor was responsible for operation and maintenance of the movable span throughout the duration of the contract.

Temporary Operating System

Due to the requirement for continuous operation of the span, an independent temporary hydraulic operating system was required to be installed and commissioned prior to the decommissioning and disassembly of the existing emergency repaired systems.

The temporary operating system (TOS) consisted of a temporary hydraulic power unit and hydraulic cylinders to lift each leaf of the span. The design of the temporary system was the same as was previously used on the bridge for a rehabilitation project in the early 2000's. Following fabrication, testing, and commissioning of the TOS, the existing mechanical and electrical systems were disabled so that rehabilitation work could begin. Following the reinstallation and commissioning of the original mechanical and electrical systems, the TOS was removed and provided to the NYCDOT for future use.



TOS Schematic

Mechanical Rehabilitation

Following the commissioning of the temporary hydraulic operating system, the mechanical rehabilitation scope of work was able to begin. The major scope items included:

- Replacement in-kind of all machinery shafts and spherical rollers bearings
- Rehabilitation or replacement of couplings on shafts
- Rehabilitation of all reducers – included full disassembly of interior components, cleaning, replacement of bearings, reassembly, realignment, and shop testing
- Rehabilitation of machinery and motor brakes – including replacement of hydraulic actuators and brake shoes
- Replacement of emergency hydraulic power units and motors

General rehabilitation work of all machinery included disassembly, removal of all grease, cleaning, reassembly, re-greasing, and touch up paint repair. Additionally, all machinery was to be reinstalled and aligned using the existing body bolts and drilled holes.

Electrical Rehabilitation

The major scope of work for the electrical rehabilitation of the bridge included replacement of all components, conduit, and wire below the flood line of the storm. Specifically, these items included:

- Procurement and installation of all damaged components below the flood line in the electrical room. Major items include MCC buckets, transformer, and drive control boards.
- Procurement and installation of new secondary resistors above the flood line
- Procurement and installation of a new emergency generator above the flood line
- Replacement in kind of eight (8) main drive motors
- Replacement of all minor components including limit switches, encoders, and tachometers.
- Replacement of all junction boxes, conduit, wire, service lighting, and receptacles below the flood line in the electrical room and machinery pits.
- Removal of all temporary wiring and controls.

Following the replacement of all items listed above, all systems were to be returned to original control desk using the existing PLC and PLC programming with all interlocks restored. All systems were to be fully tested prior to commissioning.

Miscellaneous Work

Along with the major mechanical and electrical rehabilitation work, there were other work items to reduce or prevent damage from future storms. The electrical room received a new flood-proof door and windows, as well as flood proofing of all wall penetrations. Additionally, new structural steel platforms were installed outside of the control house to support the new emergency generator and secondary resistors above the 500 year flood line. Finally, new sump pumps were installed in each bascule pit, with control panels relocated inside the flood-proofed electrical room to prevent loss of function during a storm.

PROJECT CHALLENGES

As with any project, there were challenges which were encountered during the development and execution of this emergency repair contract. For this project, as issues arose, the client and contractor worked together to come up with solutions that suited both parties and helped to progress the project. The list below notes some of these challenges encountered as well as how they were resolved.

Client Challenges

1. Initial clean-up of the bascule pits immediately after the storm and getting the movable span operational on hydraulic system and temporary electrical system
2. Obtaining approval for Emergency Declaration for this structure from the City of New York Law Department and the Comptroller's office to accelerate procurement of the construction and design contracts
3. Expeditiously prepare contract documents for bidding the emergency contract in accordance with the requirements of the FHWA Emergency Relief (ER) Program

4. Resiliency of proposed Electrical Systems in the emergency contract

Contractor Challenges

1. Rehabilitation of Mating Parts
2. Buy America Restrictions
3. On-Site Bearing Replacement
4. Final Alignment – Establishing Criteria/Challenges

The following sections will highlight and further discuss some of the challenges encountered during construction. Through communication of these issues, it may be possible to reduce or eliminate similar occurrences on future rehabilitation projects throughout the country.

1. Rehabilitation of Mating Parts

A major concern following the flooding of the operating machinery of the bridge, was corrosion of the spherical roller bearings due to salt water found inside the bearing housings. Therefore, the emergency contract called for all bearings to be replaced. However in many locations, the bearings were located between two mated objects on the shaft, most often open gears or couplings. In order to remove and replace the bearings, these gears and couplings would need to be removed. Due to the FN2 interference fit of the gears and couplings on the shaft, it was anticipated that some damage could occur during removal. As a result, the contract called for the existing open gears and couplings to be reused, however new shafts were to be fabricated.

Gear Assembly Prepped for Jacking

Prior to the start of the removal work, a procedure was submitted to the owner outlining the plan for removal of the open gears and couplings from the existing shafts in a manner that would prevent any damage to the bore of the component. As is standard industry practice, the procedure was to brace the gear or coupling, apply heat using a torch to allow it expand uniformly, and use a hydraulic jack to press the shaft out. This submittal was reviewed and approved prior to the start of work.

At the start of the removal work, it was found that this procedure worked for some of the existing components, but not for others. With collaboration from the client and the engineer, multiple iterations of the method were attempted, changing variables such as the heating duration, maximum heat applied, and maximum force applied by the jack. Calculations were also checked to determine the required jacking force required to overcome the friction between the shaft and gear due to an FN2 interference fit.

Using the various methods, all parts were successfully removed, however in some cases scoring occurred, requiring bore weld repairs and other fixes. Working with the client, engineer, and fabricators the issues found were resolved to provide a quality end product without affecting the job schedule.

2. Buy America Restrictions

Due to the fact that part of the funding for this emergency contract was provided through FEMA, a Federal Agency, the specifications called for all newly procured material for the project to comply with the Buy America Act. The Buy America Act, enacted in 1982, requires that all steel material used for the fabrication or manufacturing of any components for transit related project must be domestically produced. The act began as and continues to be a requirement on all federally funded public project with the goal of boosting the steel industry in the United States.

While the purpose of this act is useful for large infrastructure projects in the country, it was a challenge for the procurement of materials for this emergency contract. When the Metropolitan Avenue Bridge was rehabilitated in the early 2000's, there was no Buy America clause in the specifications of the contract. As a result, numerous mechanical components were purchased from companies which were either based outside of the United States, or were US based companies which sourced their materials from around the globe. On the contrary, the specifications for the emergency contract required that for all equipment being rehabilitated or replaced, the components were to be replaced in kind to the greatest extent possible.

While this was a challenge to satisfy both the Buy America Clause and the specification, we worked together to submit a waiver which permitted the purchase of non-domestic steel material. However, the process of collecting the required information for a waiver and receiving approval is a process that can takes months to complete. With the short schedule duration of the project, and long lead times on many of the mechanical components, waiting for approval for the materials prior to procurement would have resulted in significant delays.

The contractor and client met to discuss this issue early on and the client recognized the issue. While the client agreed that a waiver would be needed to complete the work as specified, they could not provide a guarantee that it would be approved. Ultimately, the contractor made the decision to procure the major long lead time mechanical components while the waiver was still in the approval process. This was a large risk assumed by the contractor in order to progress the project and ensure timely completion. In total, two waivers were submitted, both being approved towards the end of the project schedule.

3. On-Site Bearing Replacement

As previously discussed, all of the spherical roller bearings for the operating machinery were required to be replaced in kind. For this work, it was intended that the contractor would remove the gear assemblies from the bridge and send to a machine shop for rehabilitation. However after the start of work, the contractor found that the main set of pinion/gear assemblies could not be removed from their existing location without first removing the racks. There was no work in the current contract to remove the racks, and doing so would result in a large amount of additional work and more importantly, would greatly increase the risk of alignment issues upon reinstallation.

Removal of Existing Bearing from Shaft

The bearings for the main pinion/gear assemblies were located on the ends of the shafts; therefore no other rehabilitation work was required per contract aside from cleaning and painting. Following research with the bearing manufacturer, SKF, the contractor proposed a procedure to the client to replace the bearings in location on site, to which they agreed.

While the procedure to remove and install bearings is not overly difficult, there were some challenges which needed to be resolved in order to complete the work on site.

1. The millwright crews on site had minimal experience installing this type of bearing. In order to properly train them, the contractor sent a staff member to a refresher training session being conducted by an SKF representative at one of the machine shops completing the other bearing replacements. The training was recorded and a detailed installation and documentation procedure was developed which was relayed to the on-site crews prior to the start of work. Additionally, the same SKF representative came to site for the start of the operation to witness the installation and ensure all work was completed correctly.

2. Bearing installation is typically completed in a shop setting in order to prevent debris from entering the bearing prior to closing the housing. In order to mitigate this, the contractor installed temporary enclosures above the work area to prevent roadway debris from contaminating the work zone. Additionally, the structural steel surrounding the bearing was power washed prior to the start of work to remove existing collected material.

3. While there was some room to move the P1/G2 assembly from final location, there was not enough room to move it so that it would be completed unmeshed from the rack, which moved with the bridge during openings. This meant that the procedure of removing an existing bearing and installing/aligning the new bearing had to be completed between consecutive bridge openings. As a result, the completion of this work was moved to the summer months when bridge openings were less frequent. Additionally, crews worked longer hours when necessary to ensure that the bearings for each gear set were replaced, aligned, and greased prior to the next scheduled bridge opening.

New Bearing Installed on Shaft

These additional measures led to a successful operation in which the client was extremely satisfied with the workmanship of the end product. All 16ea bearings were replaced to within contract requirements with no quality issues.

4. Final Alignment – Establishing Criteria

For a rehabilitation project of this nature, it was understood by the client that reinstalling all of the operating machinery to standard industry installation tolerances would not be feasible at all locations. For this reason, the specification was written in a manner that required the contractor to complete detailed as-builts of all machinery components prior to disassembly in order to create a baseline alignment tolerance. When the machinery was reinstalled, it was required to meet or exceed the as-built alignment measurements. However some components, such as new couplings and bearings, were required to meet installation tolerances.

In addition to the as-built requirements, the specifications required that the machinery was to be reinstalled using the existing hole patterns, turn bolts, and shims so that the previous alignment and hole tolerances could be maintained as best possible. In order to ensure that each bolt and shim was returned to its original location, a tagging identification system was created prior to disassembly. Bolts were labelled for their machinery set, component, and location; shims were labelled for machinery set, component, and orientation. All bolts and shims were sent to a machine shop for cleaning and paint/rust removal with tags being carefully maintained throughout the process.

Despite the detailed specification requirements which allowed for some alignment flexibility, there were some challenges during reinstallation. For each case, the contractor was able to work together with the client to establish agreeable criteria for acceptable conditions.

Couplings

As previously stated, new couplings for all machinery were required to be aligned to the manufacturer's installation tolerances. In some locations however, these tolerances could not be achieved using the original hole pattern and shims/bolts. Shims were adjusted and machinery realigned to best possible conditions. For any location still out of installation tolerance, the manufacturer was contacted. Additionally, tables were created and submitted to the engineer, detailing the previous alignment conditions, installation requirements, and reinstallation conditions. Following review of the data for these special cases, the alignment tolerance was adjusted to meet or exceed previous conditions. All locations were able to meet the adjusted criteria and were approved.

Open Gearing

Prior to disassembly of the operating machinery, a third party engineering firm was brought on site to complete detailed as-builts of each of the 24 gear sets (2 leafs x 4 stringers per leaf x 3 gear sets per stringer) on the bridge. For each gear set, backlash, cross mesh, tip to root, and tooth contact (blueing) measurements were taken at 8 positions around the full rotation of the gear. This data was compiled into a report, along with photographs of the blueing, and submitted to the owner for approval. Review of this data revealed that the open gearing in its existing condition contained varying levels of tooth contact.

While this data provided a good baseline and theory for acceptance following reinstallation, the execution proved more challenging. After installation and alignment of the open gearing following rehabilitation, initial similar data was collected and compared to the original data set. Similar results were found with varying levels of tooth contact, however the variations were found to be in different locations. Two simplified scenarios are shown below:

Scenario 1

Position	Existing Condition		New Condition	
	Gearset A	Gearset B	Gearset A	Gearset B
1	90%	40%	70%	60%
2	90%	30%	70%	70%
3	100%	50%	80%	50%
4	90%	40%	60%	60%

In this scenario, existing conditions show one gear set with much higher tooth contact than the other. Following re-installation, Gearset A contact declined, however Gearset B contact improved by approximately the same percentage. Additionally, it was understood that further attempts to improve Gearset A would result in reducing contact at Gearset B. In this case, what would the baseline for approval be?

Scenario 2

Position	Existing Condition	New Condition

	Gearset A	Gearset A
1	70%	90%
2	70%	90%
3	50%	20%
4	30%	40%

In this scenario, existing conditions showed a condition of high contact in positions 1 and 2 with decreasing contact at positions 3 and 4. In the new condition, contact was improved in 3 of the 4 positions, however in position 3, contact lower than any value in previous conditions was found. In this case, average tooth contact across the gearset improved slightly but a lower value at one location than in previous conditions was found. Would this alignment be acceptable?

To further complicate this issue, the final gear alignments for lower gearsets would need to be approved prior to beginning final alignment of the next gearset in the line of action. Due the schedule restrictions and manpower on the project at the time, this allowed for one to two days for review and approval of gear alignments before work would be impacted.

To resolve the issue, the contractor and client worked together to revise the procedure and tolerances for approval. Following each shift, the contractor would assemble data for all gearsets aligned that day with a comparison sheet to the pre-existing condition data. The contractor would meet with the mechanical inspector for review with immediate approval or rejection. The criteria for acceptance were not hard parameters but looked for patterns of improvement as well as lowest value comparison. If rejected, the contractor would attempt another iteration of alignment the following shift and present again. In any case where multiple iterations of alignment were completed and conditions were not improving, the results were sent to the engineer for analysis.

The collaboration of the contractor and client in this process proved successful, with all gearsets being approved without any major adjustments requiring re-drilling or oversizing of the existing bearing hole patterns. Both the client and contractor were satisfied with a timely, inexpensive, and high quality end product.

CONCLUSION

Following recognition and review of the challenges encountered on the Metropolitan Avenue Bridge Project, it becomes evident that there are clear lessons to be learned for both clients and contractors engaging in similar projects in the future.

Clients

It is advisable to set up contingency budgets for unknown issues that **will typically** arise on emergency contracts. Inspections prior to developing a contract scope will identify a majority of the rehabilitation required, however disassembly of systems upon start of work will surely uncover additional issues that will need to be fixed. For this project, NYCDOT had the foresight to include budgets to cover additional work originating from these types of issues which made the process of identifying and approving additional work efficient and timely to progress completion.

Additionally, the specifications for the rehabilitation work were developed to reflect realistic tolerances for this emergency project, which allowed room for the engineer to analyze existing vs .final conditions. The specifications for Metropolitan Avenue did exactly that, which allowed the client to work together with the contractor to quickly adjust tolerances and complete the difficult gear alignments while providing a product acceptable to all parties.

Contractors

For rehabilitation work of this nature, it is critical to spend the time and money up front to as-built and document the existing conditions of machinery prior to disassembly. Record any and all measurement and data possible, as it may not be evident exactly what information will be needed later in the project. If needed, enlist the help of other experienced engineering firms to help analyze what may be needed. This data will prove invaluable during the installation/alignment process. At Metropolitan Avenue, had the contractor not provided detailed coupling alignment as-builts, the client may have been forced to hold the contractor to standard manufacturer installation tolerances.

Additionally, communicate issues early and openly as they arise. In most cases, the client, engineer, and inspectors on a project contain a wealth of experience and knowledge that can be utilized to help investigate solutions. Many of the solutions to challenges discussed previously were a result of open communication and collaboration with the client in meetings held to review the issues.

Summary

The Metropolitan Avenue Bridge Emergency Repairs Project was a unique and challenging project needed to bring a relatively new structure back to working order following a natural disaster. Typically when contractors and clients consider rehabilitation projects, they are for upgrades to deteriorated or outdated systems. In this emergency situation, replacement in kind was economical and appropriate, however it posed some unique challenges.

Through open communication and well written contract specifications, the client and contractor were able to come to timely resolution of all issues on the project. The final result was that contract work was substantially complete on time and within budget for both parties. The NYCDOT resumed the responsibilities of maintenance and operation of the bridge on April 21, 2016.