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Insight and Techniques into Mechanical Offsite Inspections for the Rumson Road Movable Bridge Replacement Project

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Introduction to the Rumson Road Movable Bridge Replacement Project

Bridge S-32 Over Shrewsbury (Rumson Road) Location

Bridge S-32 Over Shrewsbury (Rumson Road) Movable Bridge project serves as a vital link between Rumson, New Jersey, and the coastal town of Sea Bright, positioned on the Jersey Shore. The existing bridge will be replaced with a new double leaf trunnion bascule movable bridge. The bridge will feature a modern span drive machinery system, span locks and trunnion span support system.

Photo No. 1: Movable Bridge Location on a map.

Mechanical Scope of Services

WSP was retained by Monmouth County to perform Construction Engineering Inspection including the inspection of the movable bridge mechanical components. Mechanical inspectors acted as the representatives for the owner and often were consulted by the Engineer of Record (EOR) on issues related to the components being fabricated at the shops. The inspection team's role was to perform quality assurance based on the manufacturer quality control's program and to observe the fabrication of mechanical components. The objective of the shop mechanical inspections is to ensure the intent of the design and future operation of the bridge was met, and that the fabrication of the mechanical components met industry standards and project requirements. The inspector's movable bridge experience helped with the critical eye necessary to anticipate potential issues before they arose, in addition it allowed the inspectors to analyze each component within the context of the entire structure. This complete approach was helpful in guiding and providing recommendations to the contractor, their manufacturer, and the bridge owner. The efforts thereby assisted a continuous and efficient construction process, which ultimately contributed to the successful completion of the fabrication of the mechanical components.

The New Bridge's Mechanical Systems Design

The mechanical system of the bridge will consist of several different types of components. These components include trunnions, bearings, and bushings to form the pivot points. Integral pinion shafts and rack segments engage to facilitate the transfer of power to rotational control. Electrical motors, brakes and enclosed reducers are connected to couplings and floating shafts. The span locks, along with their corresponding guides, receivers, actuators, and lock bars aid in locking the two spans in place in the lowered position.


Photo No. 2: Rumson's Movable Bridge Pier under construction.

These components, along with the machinery supports and the trunnion supports are to be manufactured in a way to ensure that the Contract Document requirements are met. The manufacturing of these parts ranges from initial forging/casting to final machining, with inspections at every stage to guarantee their integrity. Once assembled in the shop or in the field, these components form a functional working assembly that is accessible for inspection.

Schedule Requirements, Milestones, and Deadlines

The detailed planning of construction projects, particularly when it comes to the integration of mechanical components within structural and other project milestones is important. The installation of these components is not merely a matter of placement but a critical path event, heavily contingent on precise timing of fabrication, procurement of materials, and shop testing which can cause extended lead times. This necessitates a clear communication procedure for inspections, which ensures that every requirement is transparent and preemptively addressed. Any lapse in preparedness can cascade into costly delays, emphasizing the need for proper communication.

Quality of Product

In the construction process, adherence to the Contract Documents is required, and the role of the inspectors is significantly important to ensure that mechanical components align with the Engineer of Record's (EOR) design intentions. The bridge plans and detailed Technical Special Provisions serve as the governing guide for acceptable standards. Inspectors act as the authoritative interpreters of these documents, translating the technical language and complex drawings into actionable insights for the contractors on-site. When discrepancies arise, whether through direct observation or testing, it is the responsibility of the inspectors to notify the Engineer. This communication allows for informed decisions on real-world manufacturing outcomes not explicitly planned for by the contract documents.

The ultimate objective of the inspectors is to assist with the constructability of components, determining their compliance with the contract documents and deciding when the Engineer's input is necessary. Beyond mere compliance, inspectors also facilitate a mutual understanding between the manufacturing contractors and the Engineer, often guiding the former towards meeting the project's Special Provisions. The inspector’s deep knowledge of the project's constraints and requirements positioned them as a valuable advisor, bridging the gap between the written contract and its practical execution.

Inspections

Trunnion Components: Dowel Pins

Inspection of the forging and machining processes of the dowel pins was conducted and its adherence to the approved Shop Drawings, Technical Special Provisions, and quality checks such as temperature consistency and Brinell hardness tests was verified. This inspection process was done in accordance with the ASTM A668 standard for forgings for carbon and alloy steel. Brinell hardness testing helps to evaluate the strength, ductility and other material properties of the dowel pins so that they serve the intended purpose of securing the trunnion hub during assembly.

Photo No. 3: Forged rods that were machined into the trunnion dowel pins in the furnace undergoing tempering.

Additional inspections for the nondestructive testing on the twelve trunnion dowel pins were performed. The inspection included a magnetic particle and ultrasonic testing which adhered to the ASTM E709 and ASTM A388 respectively. Ultrasonic testing and magnetic particle testing identify internal cracks, voids, porosities and other discontinuities that were caused during the forging of the dowel pins.

Photo No. 4: Finished trunnion dowel pins undergoing magnetic particle testing.

Trunnion Components: Backing Rings

An inspection of the rough machining of the four (4) trunnion backing rings was conducted. The rough machining consisted of material removal, surface finish and Brinell hardness checks of all the surfaces of the ring. The surface finish and Brinell hardness requirements were outlined in the Technical Special Provisions and the approved Shop Drawings submitted by the mechanical fabricator for the project. Surface finish tests help to ensure that the surface between the backing rings and the trunnion is smooth, even and consistent. Brinell hardness tests were conducted to confirm the strength of the backing rings to serve its purpose in the trunnion assembly.

Photo No. 5: Trunnion backing rings being tested for surface finish.

A comprehensive nondestructive examination was conducted and witnessed on four trunnion backing rings. The inspection's findings were derived from thorough visual assessments during the magnetic and ultrasonic testing phases. The Magnetic Particle Testing was performed in accordance with ASTM A275 and ASTM E709 which presented special requirements during the testing inspection. The above-mentioned non-destructive testing was intended to identify any internal discontinuities in the trunnion backing rings.

Photo No. 6: Trunnion backing rings undergoing hardness testing.

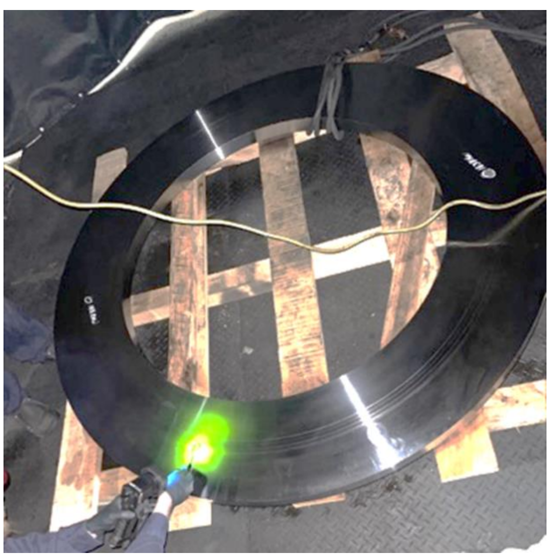

Photo No. 7: NDT Magnetic particle testing being performed on trunnion backing rings.

Photo No. 8: Trunnion backing rings undergoing machining.

Trunnion Components: Shaft

Inspection of the raw material was performed. The rough cut of the raw steel for the trunnion shaft material was inspected at the forging shop and was heat treated in preparation for the forging process.


Photo No. 9: Rough trunnion shaft forging.

Material examination for the forging process was conducted on the four trunnion shafts and was overseen. The testing, which included hardness, tensile strength, and charpy impact assessments was performed in accordance with ASTM A668 standards.

A bend test was conducted on trunnion shaft material for noticeable splitting of the metal or failure of the material.

The material testing for the trunnion shafts which included tensile, charpy, and Brinell hardness tests. Material tests help to determine the ductility, strength and wear resistance of the trunnion shaft.


Photo No. 10: Samples of trunnion shaft material machined down to charpy test samples.


Photo No. 11: Sample of trunnion shaft material undergoing a bend test.

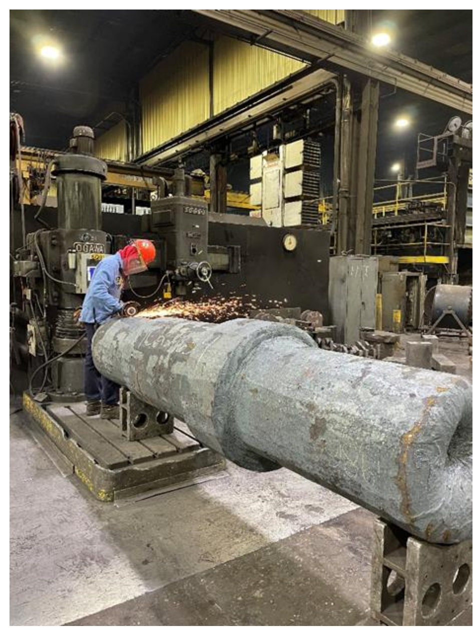
Photo No. 12: Trunnion shaft undergoing Brinelle Hardness Testing.

Trunnion Components: Hub/Bearing Base

Witnessing and inspection of the casting process for the four trunnion hubs and eight trunnion bearing bases were conducted at the casting foundry. Before starting, Project Special Provisions, Shop Drawings, and ASTM standards were reviewed. The stages of the casting process included mold making, pouring, shakeout, blasting, grinding, non-destructive testing, weld mapping, weld repairs, and heat treatment. The first step involved creating sand molds from plastic patterns shaped like the trunnion hub or bearing base. Next, steel was melted in a furnace and poured into the molds. After cooling for a couple of days, the castings were removed from the sand molds and smoothed.

Photo No. 13: Furnace heating casting materials.

Grinding, arching and blasting of the castings was done to ensure that the castings have an even surface in preparation for machining. Heat treatments of the castings, which include normalizing and quenching was performed to improve the strength and durability of the castings. This was done in between the various stages of the entire casting process. Weld mapping and weld repairs were performed to correct the visible significant surface defects caused by the casting process. These defects are usually caused by poor riser/gate designs, incorrect sand bonding agents used and high melting/pouring temperature. The final stage of the casting process is the non-destructive testing. Magnetic particle and ultrasonic testing help to identify internal defects in the casting components. The castings were accepted or rejected based on the results of the non-destructive testing.

Photo No. 14: Trunnion bearing base casting shaken out of the mold.

Photo No. 15: Casting undergoing arching and grinding to remove excess casting material.

Photo No. 16: Trunnion bearing base casting refinement.

Trunnion Components: Bushings

The bronze castings machining was inspected and the compression testing was witnessed for the trunnion bearing bushings and bearing caps. Compression testing was required by the Project Special Provisions on bronze castings and was witnessed per ASTM B22 requirements for the specified bronze material. Compression tests on bronze castings help to determine the properties of the bronze material under pressure.

Photo No. 17: Trunnion bushings visual and dimensional inspection.

Drive Machinery: Pinions

Inspection and witnessing to oversee the process for the initial setup and machining of the main pinion shaft and gearing were performed. This set up was done prior to the cutting of the gear teeth which was performed at another facility after the forgings were completed and machined.

Photo No. 18: Pinion shaft undergoing Brinelle Hardness testing.

The Non-Destructive Testing (NDT), heat treatment and Brinell hardness testing of pinion shaft/gear segment forgings was witnessed. The NDT comprised of ultrasonic and magnetic particle testing. The Ultrasonic Testing was performed in accordance with ASTM A388. The magnetic particle testing was also executed in accordance with ASTM A275 and ASTM E709. Magnetic particle and ultrasonic testing help to identify internal discontinuities that were caused during the forging process.

Photo No. 19: Pinion shafts being machined down to size.

Photo No. 20: Ultrasonic testing of pinion shafts in process.

Drive Machinery: Racks and Pinions

A detailed visual inspection of rack gear teeth and rack gear teeth measurement verification was conducted.

The five (5) pinion gears were scheduled for gear tooth measurement verification and inspection. There was a total of five (5) pinions each with eighteen (18) machined gear teeth. Span tooth thicknesses, gear tooth surface finish and pinion bearing diameters were verified and confirmed with calibrated micrometers. The keyway sizes on the pinions were verified against the approved Shop Drawings. Pinion gear teeth were cleaned and inspected for defects and other wear marks and no defects were noted.

Photo No. 21: Visual and dimensional check performed on finished rack segments.

Photo No. 22: Visual and dimensional checks performed on machined pinion shafts.

Photo No. 23: Dimensional verifications in progress on the integral pinion gear teeth.

Drive Machinery: Enclosed Reducers

Photo No. 24: Primary reducer testing set up on testing platform for runtime tests.

The witnessing of the reversing unit reducer testing was conducted over two days per the procedure approved by the Engineer of Record (EOR).
The reversing unit testing consisted of a no-load and load test under specific revolutions per minute (rpm), horsepower (hp) and torque requirements specified in the Special Provisions and the testing procedure submitted by the enclosed reducer fabricator. The inspectors witnessed and recorded measurements of reducer bearing cap temperatures, ambient temperatures and noise levels. Also, visual inspections of the gear tooth surface, and contact were conducted. The testing was also observed for excessive noises and vibrations during the testing process.

Photo No. 25: Secondary reducer setup for runtime test under load.

Photo No. 26: Reversing reducer undergoing runtime testing under load.

The witnessing of the reducer testing for the two primary reducers was conducted over five days per the procedure, approved by the Engineer of Record (EOR). Similar to the reversing unit, the primary reducer testing consisted of a no-load and load test under specific rpm, hp and torque requirements specified in the Special Provisions and the testing procedure submitted by the enclosed reducer fabricator. The inspectors witnessed and recorded the measurements of reducer bearing cap temperatures, ambient temperatures and noise levels. A visual inspection of the gear tooth surface, and contact was conducted. The testing was also inspected for excessive noises and vibrations during the testing process.

Each reducer testing for the two secondary reducers was performed over two days per the procedure, approved by the Engineer of Record (EOR). The procedure for the secondary reducers was similar to that of the primary reducer, which consisted of the no-load and load tests with different torque and rpm requirements.

Enclosed reducers are tested at the manufacturer's facilities to ensure that thieir loading and reductions of the internal gears is according to the AASHTO standards and the Project Special Provisions, so that they run properly during bridge operation.

Stabilizing Machinery: Span Lock Assembly

Bronze castings measurements for the final machined span lock guide and receiver shoes were verified per the Shop Drawings and visually inspected. The dimension checks help to identify any deviations in dimensions from the Contract Plans and Shop Drawings before the span lock guide and receiver shoes are shipped out to the field. Span lock actuator, limit switches and brakes functional testing was performed per the approved procedure. Systems were actuated and voltages verified to meet Contract Documents. Functional testing is performed to verify that the AASHTO designed span lock actuator features work as intended to.

Photo No. 27: Span lock functional check performed on actuator and lock bar components.

Photo No. 28: Visual and dimensional checks performed on lock bar shoes after final machining.

What Makes a Successful Inspection

Resolution of Issues

The main goal of the offsite shop inspections was to ensure that any issues associated with the manufacturing, machining and testing of the mechanical components are identified and resolved in the shop prior to field installation to minimize any construction scheduling delays. A successful offsite inspection aims at identifying faults with the mechanical components, and communicating any identified issues with the machine shop, EOR and all parties involved so that they are resolved before components are shipped out to the construction site. This avoids any setbacks during field installation by reducing delays and also preserves the integrity of the bridge's mechanical system.

Communication

The cornerstone of success for the inspected components discussed in this paper was the effective communication established among all stakeholders. It was crucial for inspectors to coordinate their efforts with the contractors to stay informed about progress in the manufacturing process. This coordination was facilitated through the mechanical fabricator who acted as a channel, relaying updates and notifications to the inspectors. Upon receiving the notifications, inspectors engaged in direct communication with the contractors to find detailed information, such as the specific shift timings, the contact person upon arrival, and the expected timeline for the manufacturing of the components under inspection.

It was critical that the mechanical fabricator notified the inspection team at least two weeks prior to the scheduled date of the inspection to give the inspection team adequate time for preparation and travel arrangements. This notification was vital for the scheduling of inspectors at different manufacturing locations. This was done to avoid delay in inspections and project schedule as a whole.

Scheduling and Planning

Efforts were consistently made to inspect as many components as possible within the same timeframe to prevent delays in other production lines, while also conducting periodic checks on components not currently in production to detect any new defects that might have happened due to storage or accidental damage.

Open discussions with contractors about the client's requirements for acceptance, coupled with providing clarity to the workers, who sometimes had limited understanding of the component's significance, were influential in fostering a culture of thorough manufacturing and mutual respect between the contractors' workforce and the inspectors. By acknowledging that their presence was not only to identify faults but also to highlight positive outcomes, inspectors found that promoting a positive narrative contributed to a collaborative and successful working environment was important. This even led to workers coming to inspectors in some cases and pointing out the discrepancies prior to the inspector finding them.

Conclusion of Shop Inspection and Witnessing Experience

There are different techniques utilized by inspectors when witnessing the mechanical component manufacturing and testing in the manufacturing facilities. It is important for inspectors to ensure that the requirements pertaining to each mechanical component outlined in the Contract Plans, Special Provisions, approved Shop Drawings and ASTM Standards be strictly adhered do that quality and standard products are used for the sustainability of the bridge machinery and prolonged life of the bridge. The shop inspections were done to verify and guarantee the owner that the manufacturing, testing and verification of each component was done according to the Contract Documents and industry standards and also to eliminate any construction delays from issues identified in the field. After several inspections, it was a great accomplishment that these requirements were met for all the mechanical components.