Sakonnet Point Lighthouse Restoration

Owner: Friends of the Sakonnet Lighthouse, Inc.
Prime Consultant: Structures North Consulting Engineers, Inc.
Consulting Architect: EinhornYaffee Prescott
General Contractor: Joseph Gnazzo Co.
Submitted by: John M. Wathne, PE

During the spring of 2006, Structures North was retained to conduct an inspection of a cast iron, “spark plug” type lighthouse off of the coast of Rhode Island. We would later be retained to design and monitor the repairs.

Construction and History-

Constructed during the 1880’s,Sakonnet was typical of a variety of lighthouses that was used extensively throughout coastal waters of the US.

The construction consisted of multiple courses of curved cast iron plates that were stacked in a “running bond” type fashion and were bolted together at inward-turned flanges along the four edges of each plate, forming a semi-rigid shell. The plates were battered inward at a rate of 4” per level, typically starting atop a widened, concrete filled cast iron caisson at the base, and running up to a cantilevered platform at the “watch” level, above which would be a raised “lantern” level with a Fresnel lens.Sakonnet had four courses of plating, under a watch level gallery and a lantern, above it.

Behind the cast iron shell was often a brick liner, which at Sakonnet was 12” thick at the first level, and decreased in increments of 4” to counter the batter at each level above. The fourth level, as well as the watch and lantern levels did not have brick, but just wood-furred walls in some places to cover the iron.

Unlike most of the other, more protected locations where this type of lighthouse was typically built, Sakonnet was erected on a wave-swept rock that was directly exposed to the open ocean. This has been a notoriously rough location, most dramatically described by a William Durfee, who was the lighthouse keeper during the great hurricane of 1938:

> “At five o'clock all outside doors had been carried away and all windows from the first floor to the third floor were stove in, so that we were practically flooded out of our home….”

> "At five-thirty I went into the tower to light up. While there, we took what was called a tidal wave. There were seas that went by that completely buried the tower… And it hit with such a force as to knock me off my feet. . . ."

This historical account would prove significant to both the evaluation of the lighthouse, and the design of the repairs.

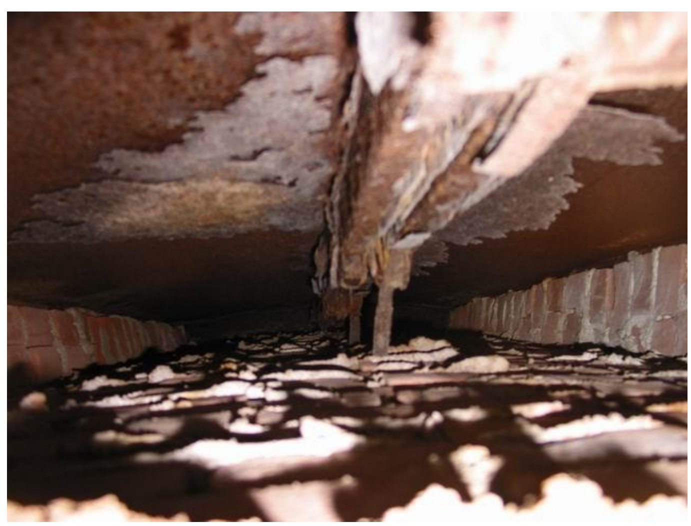
In 1954Sakonnet was decommissioned, and then after nearly a decade of little or no maintenance it was purchased at auction by the "Friends of the Sakonnet Light", a local non-profit group that took on the responsibility of protecting and maintaining the lighthouse, and who would become our client.

Structural Conditions-

Before beginning our inspection I was told by some of the members of the "Friends", that the most concerning condition regarding maintenances was that even though they would frequently clean and paint the exterior, the paint coating would crack and rust-streak along the vertical joints between iron plates, and that even several of the plates had begun to inexplicably crack. The Friendshad commissioned a contractor to run several stainless steel cables around the structure, in an attempt to stop what appeared to be circumferential spreading from within the ironwork. This would be another important clue.

As we began our investigation of the interior, it became obvious that there was extensive rust throughout all of the lower and midlevel elements of the iron structure.

Concerned about the noted external movements, we made small excavations through the brick liner in order to view the back surfaces of the wall plates, and were shocked but not surprised to find that literally all of the bolts that once held the wall flanges together had either failed or had rusted away, and that the now no longer connected plates were being pried apart by large volumes of rust that was packed tightly between all of the flanges. Some of these had even cracked. It was immediately apparent that the entire cast iron shell had become a precarious stack of disconnected elements, most of which were held in place by no more than their own weight and whatever limited adhesion iron oxide can provide.



We also found many cracked iron floor plates, most of which we attributed to the accumulation of caked rust, but some of which may also have been attributable to the impact of waves at this unprotected site.

In addition to the rusted floor and shell structures, there were also significant structural cracks in the brick liner, which now had to resist all of the lateral forces on the lighthouse to make up for the loss of integrity suffered by the shell.

In the report that we finally submitted to the Friends, we enumerated all of the damage that we had found, along with recommended solutions. In the conclusion, we stressed that we could in no way guarantee that the structure in its deteriorated state could survive even in a moderate storm, and if something were not done in short order it would probably be lost.

The Friends diligently sought and successfully secured sufficient funds from private donors and the Rhode Island DOT to undertake an extensive restoration, for which we would proudly be the Prime Consultant and Engineer of Record.

Bases of Design-

Following an extended period of design and specification writing (extended due to the arduous RIDOT review and approval process), we put a set of contract documents out to bid. This set included complete stripping and re-coating of all iron, replacement of windows and seals, and repairs to handrails and stairways, but most importantly, the complete stabilization of the structure.

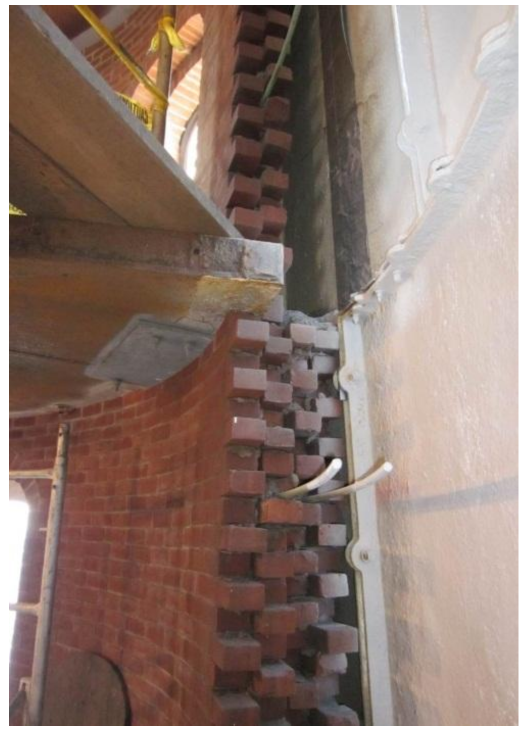
When considering the design intent of the structural repairs, we tried to calculate the anticipated wave loading by present-day methods, which not surprisingly had the structure theoretically failing, even in a fully repaired state. The historical reality, however, was that the structure HAD performed successfully for 130 years, and under the most severe local weather that had ever been recorded. Having even been submerged by up to its entire height, albeit sustaining damage, the structure had still remaining intact and stable enough to protect some terrified human occupants who lived to tell that tale. We decided, based upon this performance history, thatif we restored the structure to its as-originally-built condition of strength, it would be ready for all the exposed site could reasonably subject it to.

Another consideration was longevity. This structure was not originally built to be a museum piece, but was built to serve a functional purpose, that of guiding ships safely around an outward-jutting land mass. There was probably an assumed design life, which had we not intervened would have eclipsed at about the same time if not shortly after the time of our repairs. Coincidentally, the functional need for lighthouses was reduced by the implementation of LORAN several decades ago, and all but eliminated by the development of present-day GPS (for which it actually still provides a good back-up as a navigational aid). This timing suggests that Sakonnet, even with limited maintenance and the exceptional severity of its siting, hadbeen ready serve for even longer than thebasic technology that required it, and were it not for its historical and local social significance, could have slipped under the waves proud of a job well done.

Because of its present-day “museum piece” status, something that the original builders would never have anticipated, Sakonnet must now serve a different purpose- that of being local navigational icon and testament to times past. Unlike its original job, which spanned perhaps 100-years, this job must be served in perpetuity.

Therefore the second major intent of the project, that being from a Preservation Engineering standpoint, was to detail all of the work in such a way as would protect and prolong the life of the original historic fabric, even if it meant reducing the life of the new components- which had to be sacrificial, and in the extreme case, replaceable.

Critical Structural Repairs-



We determined that the only way to restore the iron plate shell to its original strength would be to fully expose it at the interior, remove all rust, re-drill bolt holes, and re-fasten the plate flanges together. This would unfortunately require the incremental removal and replacement of the brick liner that obscured the back surface of the iron, the same shell that provided the structures only lateral support. Therefore, we had to further weaken the already weakened structure before we could make it stronger. This would be done in sequential, vertical strips.

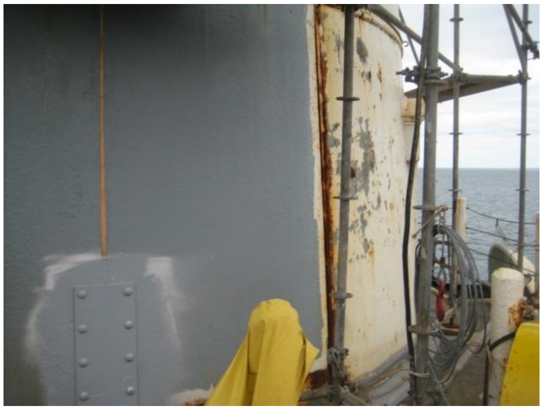
Faced with the fact that a threatening storm could come through at any time, we considered the option of adding an external or internal structure to macroscopically stabilize the shell while the work proceeded within. It was soon apparent that the tight budget of the project would not permit this. We then considered the fact that, were a storm to occur, the structure would be empty of occupants and so would be no human endangerment or potential loss of life. We settled on requiring an emergency bracing system that would only make up for the weakening caused by removal of the brick liner in section being worked on. This would be implemented on an as needed, short-notice basis, under an allowance in the contract, should a well-documented and confirmed threat come up the coast. Beyond this mutually agreed to compromise, we all simply hoped for the best.

As the first section of brick was removed, it became immediately apparent that conditions were even worse than expected, and that the flanges had been rust-jacked apart in some places by more than an inch. They had also been necked down, frequently cracked, and their surfaces were roughened and irregular.

Having specified the obligatory, "last forever" stainless steel bolts and shims with hard plastic insulators, we became immediately concerned that the increased "wobble" on the bolts caused by the widened flange gaps would soon fail the insulation, and that direct stainless on iron contact would galvanically "eat" the less noble iron. We also recongnized that there was no way that these bolts would be able to engage in a straight bearing/shear type application, without significant movement between the plates that would cause unaccounted-for transverse stresses between them while ultimately shedding most of the lateral load into the brick.

We decided to change our design to use hot dip galvanized A325 bolts and three-piece plastic Korolath shims. Zinc is less noble that cast iron. The A325s would be epoxy painted, to prolong their lives, and the shims could be milled down in the field to accommodate the varying gap widths between the existing plates. In order to secure full bearing of the shims, the outer two pieces at each joint would be epoxy-adhered to the rough and pitted plate flange surfaces (like non-shrink grout under a bearing plate) and the milled shim would be wedged between them. The bolts were then installed and torqued to engage the shims and plates as friction-type connections, the required bolt tension being back-figured from the equivalent capacity of the original low grade steel or iron bolts divided by the coefficient of friction between the plastic shims.

In many places, flange damage required that torques and bolt sizes be reduced to avoid additional damage to already cracked or thinly necked plate flanges, most prevalently at the first level, which had sustained the most severe corrosion ans was ironically the most critically loaded. Curved tie plates were added at the base of this level to make up for these losses, and galvanized steel reinforcing was added circumferentially within the first and second levels of the brick liner to strengthen it.



All exposed iron, both inside and out, was water-blasted down to bare metal, and then protected with two coats of epoxy primer and a top coat of urethane paint.

The construction schedule was entirely weather dependent, as the rock could not be landed upon during heavy weather. The contractor sunk four boats during the two seasons that the work progressed, winding down during the fall of 2011.

Load Test-

We completed our inspection of the critical structural work at the end of August, 2011, pleased and confident that the original as-built integrity of the structure had been more than restored. Amazingly, within one week Hurricane Irene approached on a rare, northeasterly track, being the strongest storm to hit the New England coast in deckades. The storm predictably blew out all of the window coverings, tore off the 3/8” plate steel door, and partially filled the lighthouse with water, all but mimicking the account by William Durfee in 1938. A follow-up inspection found absolutely no sign of structural damage of any type, and we were pleased that our work had withstood at least this initial test.