Replacement of the Sandy Hook Front Range Light

A thorough understanding of geographic, hydrographic and meteorological environments, as well as improved contracting procedures, can result in more timely and less costly construction of offshore structures.

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Mariners have used aids to navigation (ATONs) since man first started plying the seas. As millennia have passed, these ATONs have evolved from well-known landmarks and fires on beaches to steel towers with solar-powered electronics and optics capable of being seen for tens of miles. As the keepers of the U.S. ATON system, the United States Coast Guard (USCG) is responsible for the installation, maintenance and administration of approximately 50,000 federal aids. The USCG also manages the permitting process for approximately 50,000 privately maintained aids.

Background

In their simplest form, ATONs are characterized as fixed aids – i.e., daybeacons, lights and lighthouses, and floating aids such as buoys. ATONs can be further grouped as being either lateral or non-lateral. Lateral aids are identified by their shape, color and numbering and their purpose is to mark the limits of the "maritime highway" and show mariners safe travel routes. For example, most sailors and many laymen are familiar with the saying "red, right, returning" – which means that a vessel returning to port leaves red aids off the right (starboard) side, and green aids off the left (port) side. Non-lateral aids are typically information signs or mark-isolated dangers.

A maritime range, such as the one at Sandy Hook Channel, off the northeast coast of New Jersey, is a specialized lateral aid that consists of two fixed towers acting in tandem (see Figure 1). Using the basic geometric principle that two points define a line, the two towers of the range are located to mark the mid-line of a shipping channel. Rectangular boards of alternating color bands are used to mark the channel in daylight and lights on the tower are used to mark the channel at night. A mariner transiting the chan-

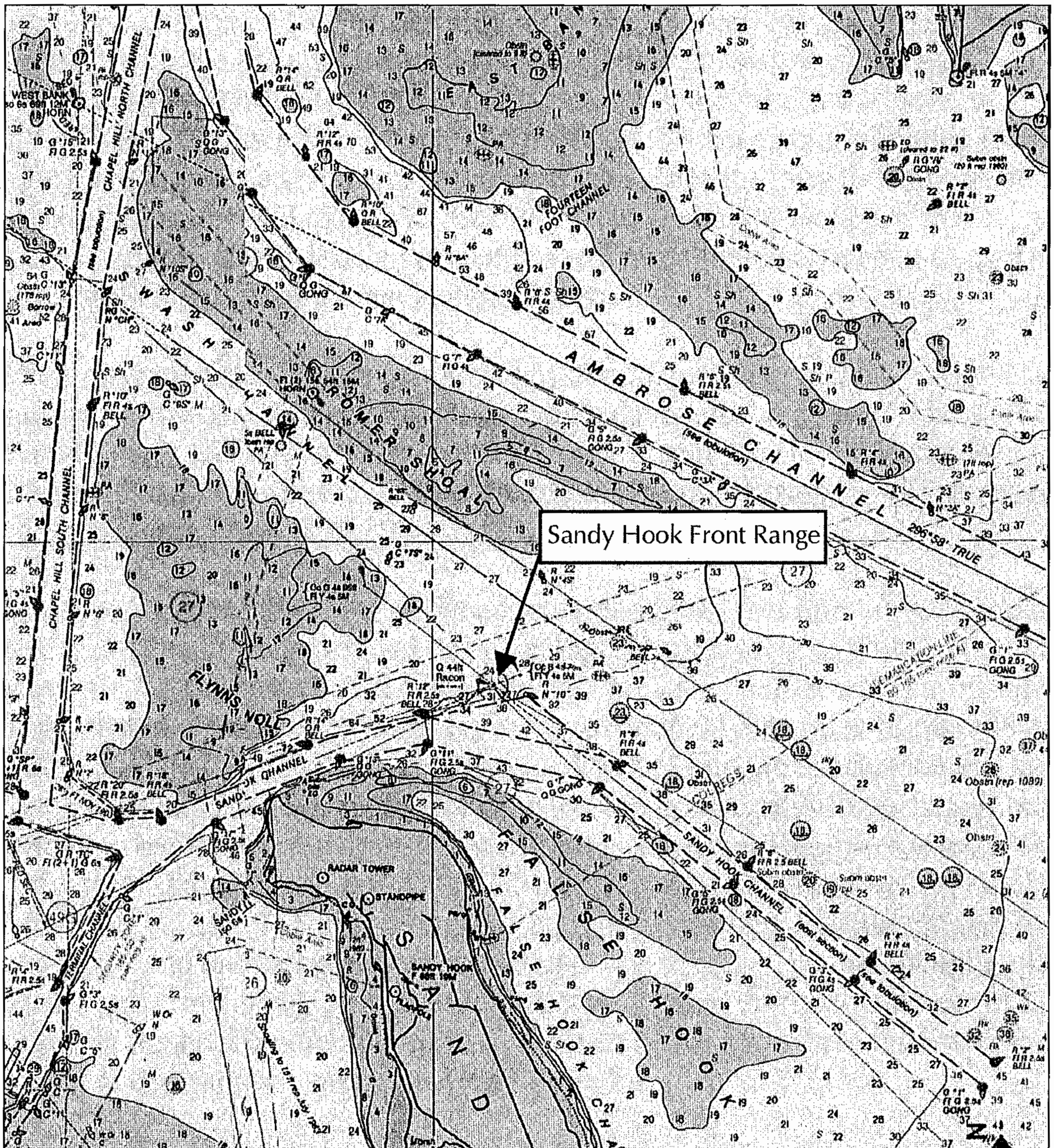

FIGURE 1. Location of the Sandy Hook Front Range (NOAA Chart 12327).

nel knows his or her position via the vertical alignment of the boards or lights. Range systems are typically the most precisely designed and positioned of all ATONs. As may be inferred, the design and location of the range must be precise because minor variations in location can be exacerbated over long channel distances. Groundings and other accidents have occurred due to incorrectly located ranges.

Many factors impact range location and characteristics such as channel length and width, water depth and design vessel parameters. For several years, the USCG has been using range design software to determine tower locations and heights, tower separation and equipment outfitting. Although the outfitting of a range is completed with standard USCG equipment, the foundation structure of the range is typically designed on a case-by-case basis using standard civil and ocean engineering practices that are based on the chosen location. Near and onshore locations of most ranges allow for relatively simple and inexpensive designs and installations. Unique locations (such as Charleston, South Carolina, and the Chesapeake Bay) have required significant design and construction efforts costing upwards of $2 million for a single range system.

Sandy Hook Bay supports a number of important commercial, industrial and military facilities. Sandy Hook Channel serves as the primary transit way for a major oil storage facility in Perth Amboy, New Jersey, and more importantly the Naval Weapons Station in Earle, New Jersey. Due to the critical nature of both facilities and the hazardous nature of the cargoes transiting the waterway, Sandy Hook Channel is extremely well marked with various fixed and floating aids. The Sandy Hook Front Range serves as the linchpin in the system since it is used as a common range tower that marks a bend in the channel and, therefore, defines two ranges (see Figure 1). Without the range identifying the constraints of the waterway and the hazardous nature of the cargoes involved, the risk to the mariner would be high enough to potentially result in additional transit regulations or exclusions. During high fuel oil demand periods or wartime conditions, any impacts on shipping capabilities would have serious consequences on the economy or national defense.

Initial Damage Assessment

The Sandy Hook Front Range Light was damaged from a vessel impact in August 1997. An engineering consultant was contacted on August 15 to perform an incident inspection of the damaged range structure and to make recommendations for its continued service. Two days later the engineering consultant mobilized a crew of engineer divers to perform an inspection the following day. However, weather conditions from a passing storm complicated the logistics of the dive operation. The dive vessel had to contend with 15-knot winds and 5-foot seas, which made the approach to the structure difficult. Upon arriving on site, it was apparent the structure had sustained heavy damage that had been caused by the impact of a large vessel. The structure was translated about 15 feet to the southwest and the platform had sustained significant damage.

After the dive vessel was secured, the divers entered the water and experienced powerful tidal currents and a strong sea surge that extended close to the harbor bottom. These conditions produced less than a foot of visibility. The divers wore specialized diving equipment to contend with the difficult inspection environment, which consisted of drysuits and full-face dive masks that were outfitted with ultrasonic upper single-sideband wireless communications. The divers were aided with underwater inspection tools that consisted of hands-free high-powered lights, an underwater camera, ultrasonic thickness measuring equipment and tools for cleaning marine growth from the structure. The inspection progressed slowly as the divers removed 8 inches of mussel growth from the structure in order to perform the detailed inspection and to take the measurements needed to assess the structural condition of the navigational range.

The front range structure was composed of two major components: a tripod substructure, and a pipe tower that supported the range's dayboards and light. The tripod substructure extended 60 feet above the seabed. The instrument pipe tower was attached to the top of the tripod and elevated the range light 20 feet above the tripod. This inspection focused on the tripod portion of the front range.

The tripod substructure was designed to extend 30 feet into the subsurface of fine to coarse silty sand. The original design called for placement of a 3-foot-thick stone scour mat on the seabed. As-built drawings indicated that the mat had not been installed. The legs of the tripod were 24-inch-diameter extra-strong steel pipe piles filled with concrete and battered at 3:12. The piles were driven a few feet into the subsurface and steel HP14x73 foundation piles were driven down the inside of the pipe piles to 30 feet below the seabed to anchor the range structure in place. The tripod legs were connected by a network of diagonal

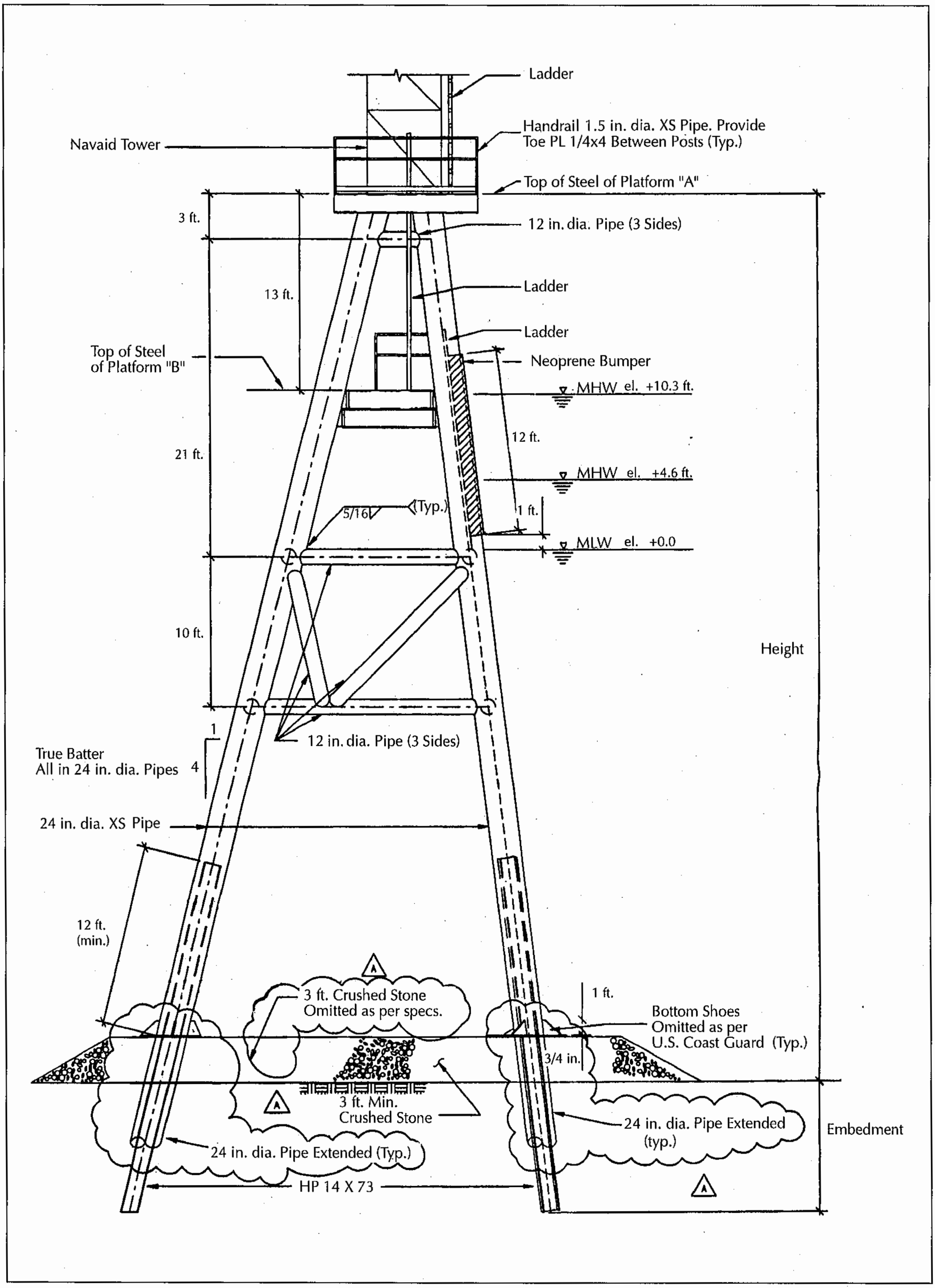

FIGURE 2. As-built construction drawing of the damaged tower (typical tripod elevation).

FIGURE 3. Underwater photo of the exposed foundation pile.

and horizontal 12-inch-diameter pipe bracing from mean low water to 10 feet below. The tripod supported a platform used for boat landings 10 feet above mean low water and another platform at the top of the tripod. The boat landing platform allowed personnel to access the range structure by sea for maintenance. A ladder connected the boat landing platform to the tower platform where the tower ladder provided access to the ranges instruments (see Figure 2).

The divers observed that the north and south 24-inch-diameter pipe legs of the structure terminated approximately 1 foot above the seabed, exposing the HP14x73 foundation piles (see Figure 3). The east pipe leg terminated approximately 8 feet above the seabed. No marine growth was attached to the bottom 7 feet of the exposed foundation pile and only a thin layer of adhered soil remained. The lack of marine growth on the foundation pile indicated that the east leg had recently pulled 7 feet out of the subsurface due to the vessel impact. The engineers observed that the concrete fill within the pipe legs did not extend to the bottom of the pipe. This evidence suggested that the pipes were driven some distance into the subsurface before the concrete fill was added and scour then removed the soil at a later date. Lead line measurements confirmed that 5 to 6 feet of scour had occurred since construction in 1991. No yielding or buckling of the foundation piles or distress of the interconnecting bracing was found. The lateral load applied when the ship struck the structure put the east leg into tension and the remaining north and south legs into compression. It is postulated that the north and south tripod legs yielded around their points of fixity below the seabed.

Interim repairs were performed to the structure by cutting and refitting the pipe tower in a plumb position (see Figure 4). Due to the critical nature of this type of navigational aid, the USCG decided to replace the front range structure and solicited bids based on the original construction drawings since time did not permit exploring repair alternatives. However, the contractor that was awarded the project defaulted before con-

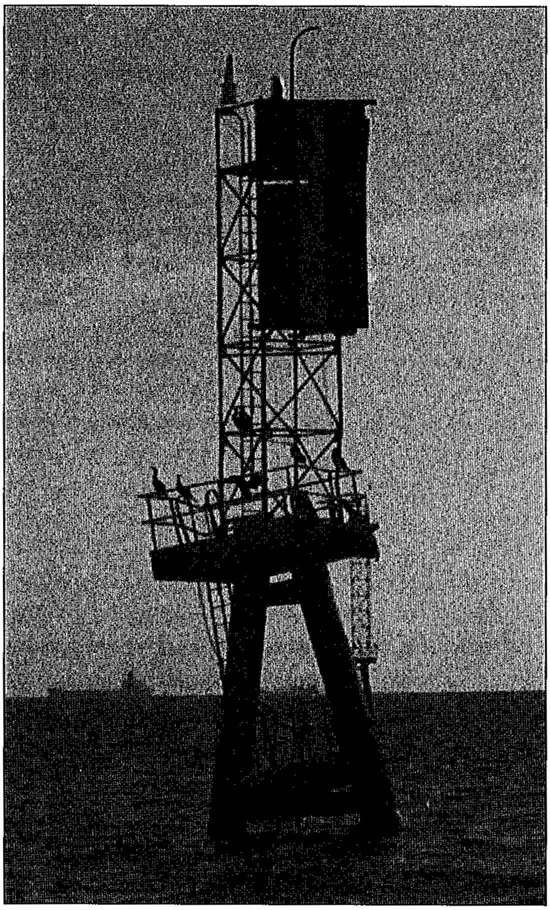

FIGURE 4. A view of the damaged navigational range after adjusting the tower portion.

struction started. Meanwhile, the front range structure functioned satisfactorily for a year with the interim repairs. The USCG charged its engineering consultant with the responibilities to conduct surveys, inspections and develop repair alternatives.

Reassessment

The engineering consultant mobilized a team of engineer divers and a survey crew in September 2000 to perform an in-depth inspection of the damaged front range structure and to locate accurately its deflected position. This detailed information of the damaged structure was collected to develop feasible repair alternatives.

The survey crew set up a differential global positioning system (DGPS) station on shore from which measurements of the offshore structure could be referenced to assure Third Order, Class 1 standards. To perform this survey, a positioning system was utilized. This positioning system offered an accuracy of 1 centimeter horizontal and 2 centimeters vertical. The survey was reported in the New Jersey State Plane (2900) System and it determined that the front range structure with interim repairs was 14.17 feet out of position.

The underwater inspection collected detailed measurements of the exposed foundation pile legs in order to determine the remaining capacity needed to anchor the structure from laterally induced loads. Measurements obtained utilizing an underwater ultrasonic thickness-measuring device determined that the foundation piles had corrosion losses on their web and flanges of up to 14 percent based on the original section properties of an HP14x73.

Repair Alternatives

Concepts were developed, with their associated costs, to restore the front range light. The restoration concepts needed to address two major problems associated with the damaged light: the reduced capacity to resist overturning forces due to the seabed scour, and loss of embedment of the east tripod foundation pile. (The latter issue is the translated position of the range.) Each concept that was developed to restore the front range structure was investigated for its viability.

The initial concept was to straighten the existing structure by attaching a large vibratory hammer to the east leg and simultaneously jet the tower back into position. This option proved to be the least expensive. However, it raised substantial concerns. The success of this option was not guaranteed and overstressing existing members of the structure would be likely. If overstressing were to occur, the entire light would have to be replaced.

Four other concepts were thoroughly investigated to replace the lost overturning capacity of the structure. These alternatives included a gravity encasement, soil anchors, addition of a pile and a complete redesign of the structure.

A gravity encasement would provide additional ballast to resist the overturning forces.

This concept consisted of a prefabricated cofferdam lowered into place around the tripod, which would be then filled with rock and concrete. The added ballast could affect the navigational aid's position due to long-term settlement of the foundation. The construction of the gravity encasement was also relatively expensive due to the costs of transporting ballast rock offshore.

Soil anchors attached to the head of the tripod and turned into the subsurface was another method of obtaining the required overturning capacity. The soil anchor alternative was very cost effective due to the relatively low cost of the materials needed. However, soil anchors have limited impact resistance, which is typically required for a structure in an offshore environment.

A third option entailed driving an additional pile among the tripod to replace the lost capacity. This concept was cost effective and satisfied the durability requirement of an offshore structure. However, developing adequate overturning capacity was difficult due to the significant scour at the site.

The position of the restored structure would be addressed by cantilevering the tower platform and bracing it back to the tripod legs. (This technique would work with all of these three concepts and would place the tower in range.)

The final alternative was the redesign and replacement of the front range structure. This alternative would satisfy design forces and desired design life. This alternative proved to be the most viable to satisfy the environmental loads during the design storm.

Redesigning the Structure

Historical wave and water levels were taken from the National Oceanic and Atmospheric Administration (NOAA) data, based on the nearby Ambrose Light Station. For that location, the significant wave height (H_S) for the 50-year storm event is 24 feet. The design wave was determined to be the largest wave that could propagate over the shoals surrounding the tower. The design wave was determined to be an 18-foot wave with an 8- to 10-second period. The other forces acting on the structure consisted of wind and current. The combined lateral forces were determined to be 45,000 pounds (see Figure 5).

The redesign of the replacement structure eliminated all bracing by sizing the piles to resist bending forces. Vertical plates were designed to connect the pile heads and resist shearing forces between the individual piles. The steel pipe pile legs extended 50 feet below the seabed, eliminating the additional HP foundation piles as well as the need for a scour mat. Portions of the original platforms were salvaged from the damaged structure to reduce overall construction costs. The contract required that the tower be completed within a five-day period because of the importance of this navigational range.

The contract documents were approved for construction on May 10, 2001. The project was put out to competitive sealed bid on June 12 after the mandatory announcement period. Four bids were received ranging from $395,600 to $697,000. The contract was awarded on September 10 to the low bidder. (Almost four years passed since the initial incident due to the default of the first contract and other delays.)

The prolonged time needed to contract this work out again resulted in having the work scheduled to start on the project when the weather in the area turned foul. Due to that fact, plus limited availibility during that season for the heavy equipment needed for the project, as well as expected delays in obtaining necessary materials at that time, the USCG, with the contractor's concurrence, issued a contract suspension soon after award. However, the contractor proceeded during the suspension with obtaining the required materials and conducting other required work to ensure that the on-site construction could be started and completed in a timely manner once the weather improved.

Construction

On May 13, 2002, the contract suspension was lifted and the contractor began staging equipment and materials in Elizabeth, New Jersey. The contractor utilized the staging area to splice together the 24-inch-diameter pipe piles for the supporting legs, thereby avoiding having to complete that work on the water. It was during this first week that the USCG delivered

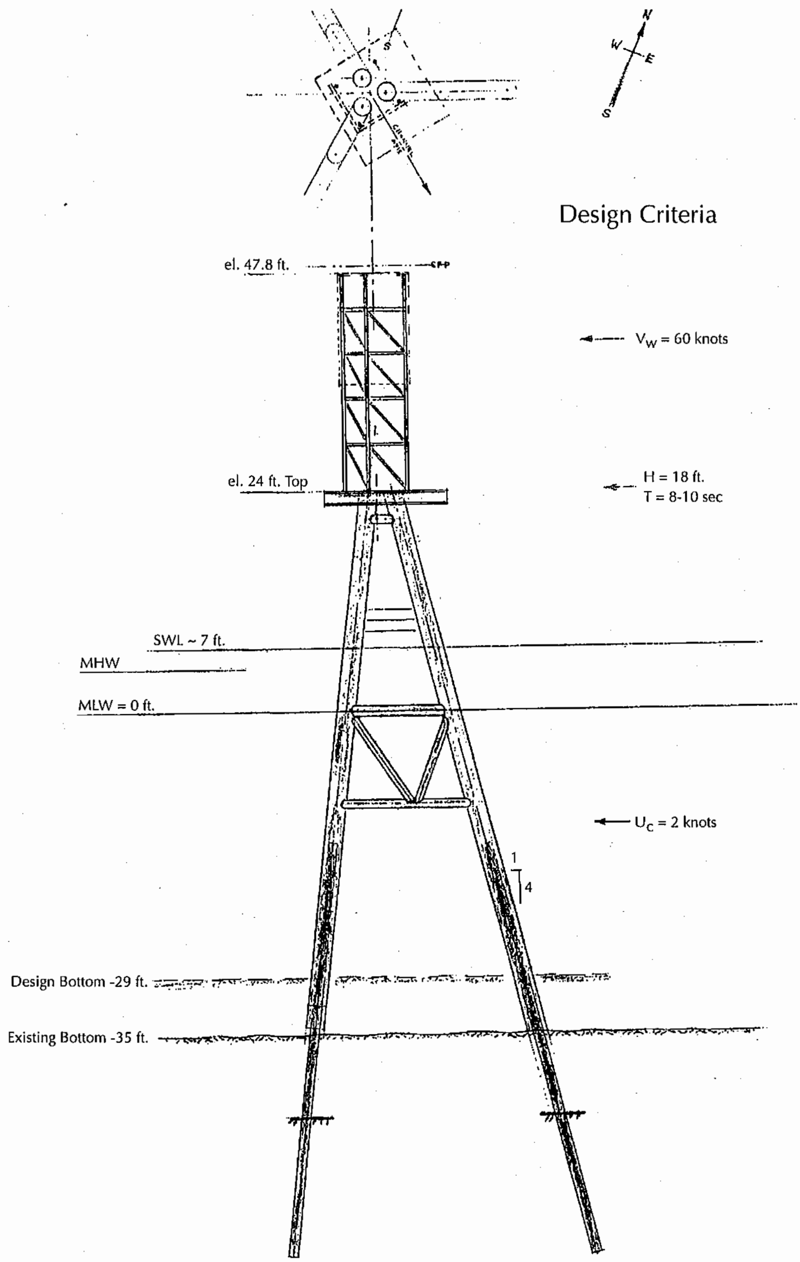

FIGURE 5. Environmental forces acting on the tower.

government-issue upper tower sections. The USCG's construction inspector discovered at that time that the tower provided by the USCG was the wrong size (15 foot versus the required 20 feet).

In order to complete the work of installing both a new structure and removing the damaged structure, the contractor initially used a relatively small floating barge and to fabricate a fixed falsework platform from which to work. The floating barge was equipped with a vibratory hammer and power pack, 200-ton crane and materials, and was ready for deployment May 15. The barge arrived on site the next day. During the mobilization, an appropriately sized ATON tower was located at the USCG Station in Saugerties, New York.

Due to the required accuracy for the front range, precision surveying of the falsework had been completed during staging. Surveying was accomplished using precise DGPS equipment with portable stations set at known USGS benchmarks on shore. As soon as the position was located, the king pile was driven and the remaining falsework installed. As the falsework was being installed, USCG personnel busily removed the USCG ATON signaling equipment from the damaged tower. The contractor's personnel drove to Saugerties for the new tower, brought it to the barge by launch and assembled it during this phase. However, the tower inventory was incomplete; several key pieces were missing, causing further delays in hunting for replacement parts. The contractor agreed to use the USCG tower plans included as reference drawings with the contract documents to fabricate missing parts.

With the falsework installed, the surveyors returned to the site to locate the exact center of the new structure on the falsework. When the framing and surveying had been completed, the contractor was ready to commence pile-driving operations. It was at this time that the inadequacies of the floating barge became evident since the predominantly southwesterly sea swells made it both dangerous and impractical to attempt to lift, locate and drive the large bearing piles. Several days were lost due to the weather, and the USCG and contractor immediately began discussing the impact of the five-day reconstruction requirement. With the consent of the district ATON manager, who had spoken to the local maritime organizations about the construction, the USCG waived the five-day limit, thereby eliminating the contractor's need to work at night under difficult conditions. The contractor realized that the floating barge was inappropriate for the job, and rented and brought a jack-up barge to the site. Overall, approximately two weeks of construction time was lost.

Once the jack-up barge arrived on site, construction continued with only minor additional challenges that were easily overcome. The bearing piles were driven to depth without incident. However, the falsework, as expected, needed to be cut and reassembled to accommodate the third pile. Once the piles had been installed, the contractor's staff was able to work on both the new and old structures simultaneously (see Figure 6). Several pieces of the old tower, including the boat landing, were salvaged for reuse. As the pieces were removed, they were inspected, cleaned and repaired as necessary. The piles were cut to near-final elevation, and the remaining upper tower platform work that could be done prior to concrete pour was completed and the upper falsework was removed. During this stage of the work, the contractor's staff was busy performing a significant amount of welding.

On June 25, the piles were filled with a total of 20 cubic yards of concrete that had been placed with the help of a commercial helicopter ferrying between trucks staging at the Sandy Hook USCG Station and the work site – an operation that required nine hours of on-scene helicopter support. Upon completion of the concrete pour, the upper platform was installed.

As soon as the upper platform was installed, the contractor removed the remaining falsework and focused on the lower platform. The access ladder from the lower to upper platform, lower platform clip angles and the lower platform channels were welded to the structure and the lower platform was reinstalled. The USCG tower was then mounted to the upper platform. With the platforms and tower installed, the jack-up barge was no longer required on site and it left on June 30. As the structure neared completion, the contractor focused on touching up the corrosion protection coating system while the remaining welding and installations were being done (see Figure 7).

The remaining construction of the new tower proceeded uneventfully as the remains of the former structure were removed on July 10 and 11. The light bracket was welded to the top of the tower, and on July 12 the surveying crew arrived to measure the final position and tower height. Final detail work and touch ups were completed and the contractor departed the work site on July 15.

After the contractor's departure, the USCG ATON team arrived on July 17 to reinstall the

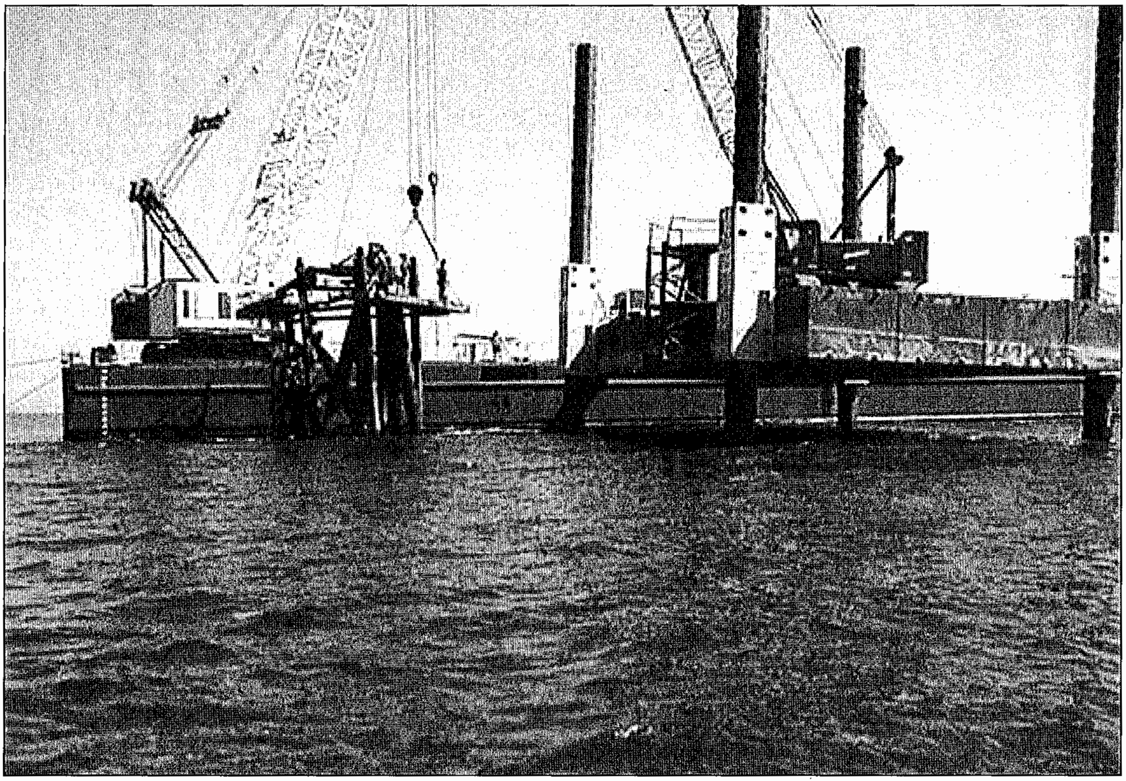

FIGURE 6. Construction progress on the new navigational aid.

light, power equipment and range boards. However, the team found that the tower was rotated slightly and, using the previous brackets, the boards did not face perpendicular to the channel midline. The contractor was notified and, after various discussions and delays, agreed to fabricate and install new brackets. The new brackets were finally installed and construction was completed on November 21, (see Figure 8). Final contract cost was $438,772.

Conclusions

Every engineering project is different and has its own set of unforeseen challenges. The Sandy Hook Front Range Project presented valuable experience for the engineering consultant, the USCG and the contractor.

Poor inventory control of the government-provided towers resulted in contract modifications and, hence, additional costs. The USCG has fabricated and maintains a limited stock of standard skeleton towers and, in turn, issues these towers to units annually or on an as-needed basis. On more than one occasion, the USCG has found that the tower issues have been incomplete. Such occurrences are typically when they are stored in unprotected or uncontrolled areas where parts can be lost, stolen or damaged.

As a result of this project, the USCG Civil Engineering Unit in Providence, Rhode Island, is in the midst of revising its tower issuing and inventory storage practices, and is revising the manner in which towers are bundled for shipment (including the use of more durable packaging for the hardware and fasteners). In addition, depending on the project site, contractor and contract cost, it may be more appropriate to have the contractor provide and fabricate any required tower instead of issuing one from stocks on hand.

Equipment used in maritime construction not only needs to have the capacity to perform the construction, but it also should be selected with a complete understanding of the local geographic, hydrographic and meteorological environments. Significant project delays and

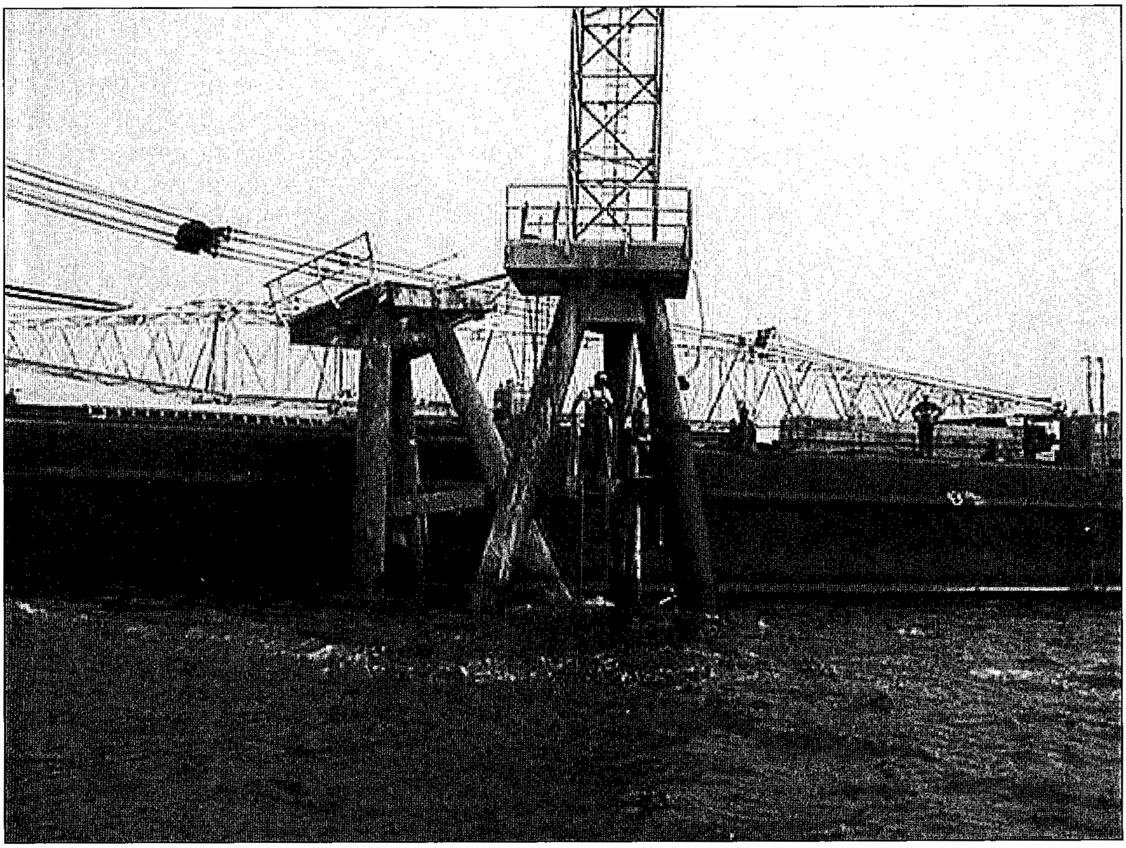

FIGURE 7. The new navigational aid nearing completion.

additional costs were incurred by the contractor due to initially selecting a floating barge as the primary construction platform. The front range's position off the north end of Sandy Hook and at the mouth of the bay put it directly in the confluence of the tidal and river currents. The wave action at this site makes the initial selection of a floating barge inappropriate to meet the contract completion requirements. In retrospect, the contractor should have initially selected a jack-up barge, which would have provided a stable platform to complete the construction.

Constructing a new structure in close proximity to an existing structure requires significant in-depth advance planning and attention to detail during actual construction. The contract constraints originally called for minimal downtime of the range structures to ensure that vessel navigation was not negatively impacted. As such, the contractor chose to build the new tower without removing the existing tower. Due to the positioning tolerances required, this construction method was only possible due to the translated position of the existing tower. In order to fully accommodate the new tower, it had to be rotated several degrees from the position specified on the plans. However, the contractor did not adjust the mounting brackets for the tower to reflect this rotation. When the USCG was reinstalling the range boards, this change was discovered. On the original structure, the tower faces and brackets were fabricated and installed so that the range boards were perpendicular to the mid-channel line. Once the new tower was rotated, the tower faces and brackets, which had been salvaged for re-use, no longer were aligned with the channel. The contractor was informed of the problem, and ultimately agreed to fabricate and install new brackets, resulting in an additional delay between completion of the construction and the range actually returning to full operation.

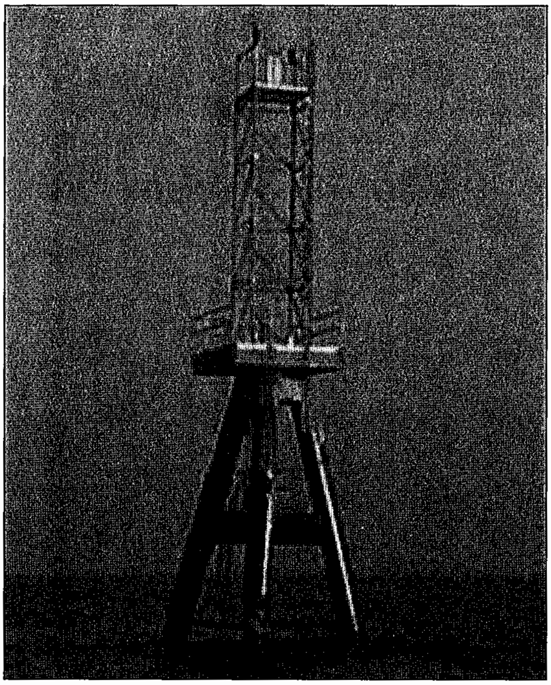

FIGURE 8. The completed navigational aid.

Typically, there is a four- to six-month gap between completion of the construction documents and the contractor's notice to proceed for federal projects costing over $100,000. Although, the USCG was well aware of these contracting restraints and attempted to account for the typical long contracting period, the project award was delayed repeatedly until the best construction weather window had passed. No sooner had the project been awarded, than a contract suspension had to be issued in order to await good weather. During annual project programming and scheduling, better planning and interaction between the project managers, designer and contracting officer is necessary to ensure that projects are awarded and, therefore, completed at the appropriate time.

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