United States Coast Guard Station Castle Hill Boathouse Design
(April 2018)

Casey A. Cruzpino, Benjamin A. Gonski, Kathryn M. Haerr, Yuexing Hu
U.S. Coast Guard Academy
15 Mohegan Avenue, New London, CT 06320

Abstract - The current boat maintenance facility at Coast Guard Station Castle Hill in Rhode Island is struggling to keep up with over 200 search and rescue and law enforcement missions per year in the surrounding Newport-Narragansett Bay area. The newly constructed projected facility will account for the space required to properly maintain the 29’ Response Boat-Small II (RB-S), along with creating an accessible boat ramp on site. Space allocation for this new facility will be based on station needs and will be in accordance with the Coast Guard Shore Facilities Standards Manual. Careful consideration will be given to a functional layout of the space and will include: boat bay, wet room, machinery shop, boatswain shop, offices, and restroom. Several options for a sewage treatment system will also be considered, including a holding tank, lift station, and leach field. With regard to the boat ramp, options range from building a gravel ramp located next to the boathouse to constructing a ramp that will be integrated into the new building. Being located on Narragansett Bay, wind loads will be calculated through the use of established procedures in the American Society of Civil Engineers Standard (ASCE 7-16). A spatial layout of the entire building including essential rooms, boat ramp design, septic system design, and 35% design of the structure itself will be presented in the report. These designs will be created and chosen based on various decision matrices that compare cost and feasibility of alternative options in each facet within the scope of the project.

II. BOAT RAMP DESIGN

Station personnel stated that a boat ramp would drastically increase mission effectiveness, which includes quicker methods of maintenance. The decision matrix was centered on whether a side ramp or an integrated ramp was to be constructed. After much research and perspective shared by the crew at Station Castle Hill and Station Menemsha, it was decided that a side ramp would be the best option to be constructed.

The first issue was deciding whether the boat ramp was to be constructed on site or continue using and off site public ramp. It is apparent that the missions of search and rescue and launching services are still being met despite the absence of a ramp. However the benefits of having a ramp on site drastically outweigh taking no action and continuing with the same conditions. Due to the constant demand for the station to conduct search and rescue missions in the spring/summer and the need for launching services in the winter, on-site maintenance of the small boats is essential to the success of the missions. The vessels need to be constantly brought ashore to be inspected for problems to ensure that they will still be able to function properly all year round.
The main decision was whether to choose an integrated ramp, shown in Figure 1, or a side ramp. At first the integrated ramp appeared to be the beneficial option due to ease of access and crew preference; however, the cost difference was too great because new piles would have to be constructed and the existing piles and pier would need to be reconstructed. Additionally, the design factors for an integrated ramp are more complex. Because the ramp is directly connected to the boathouse; either the boathouse or the ramp experiences could potentially have an effect on the other. The design of the side ramp would be more feasible, but most importantly it would be the most cost effective as the station owns an ideal area adjacent to the boat house that would be perfect for a boat ramp. Ease of access is another factor that must be taken into account in the design. The location of the ramp should be relatively close to the maintenance house so that in the event of a search and rescue case or other mission requirement, the response would be carried out quickly and effectively. In the case of Station Castle Hill, the side ramp would be constructed directly to the side of the boathouse. The ease of access would not be a concerning issue because the trailer can easily transport the RBS’ 29’s via a “K” turn.

The primary material used for ramp designs is concrete. Wood and natural surfaces may also be used, however, concrete is by far the most reliable and durable as it is resistant to all types of weather conditions. The concrete strength should be between 3,000-5,000 psi and typically 6-8 inches thick. The two options for concrete design are precast slabs and cast-in-place (Design Criteria for Boat Ramps). The best option will most likely be precast concrete because the slabs are already prepared and will not be subject to uneven settling due to the downward slope of the ramp. Using the cast-in-place method, the cement is directly poured onto the foundation, which is difficult to result in an evenly layered ramp. The concrete ramp should also receive corrugated finish to increase the friction between the tires on the truck and the surface.

III. WASTEWATER SYSTEM

Station Castle Hill utilizes one portable toilet adjacent to the existing boathouse, and they have requested a design to have a permanent restroom facility within the boathouse. This request will require installation of a new sewage system to manage waste water. The top three wastewater system options investigated are a lift station, holding tank, or septic system. A lift station allows for wastewater to be pumped from a lower elevation to a higher elevation. The scenario at Station Castle Hill depicts that of a lower elevation boathouse to a higher elevated Station House. The components of a lift station include: wet well, controls, and sewage. The wet well is a catch basin where the wastewater is collected and the pump discharges. A control room is needed for the operations of a lift station. Sewage is collected underground and contained; however, once the tank reaches its capacity, the pumps will activate to pump it out to the higher elevation.

Concerns of a lift station include maintenance cost and harmful gases. Maintenance costs are routinely taken into account because the wet well has to be drained and cleaned on a routine basis in order to prevent a clogging of solids and grease. Power is also a costly activity because it is about 85-95% of the operation costs. Furthermore inspections are required because the system may release gases such as methane and hydrogen sulfide, which may pose a health hazard.

The system quality is a priority. Accidental spills can cause severe problems and concerns, and odor control is necessary to monitor. The pump determines the overall success of the system with the
capacity, head, power, and overall efficiency of the system.

The other sewage system considered is a holding tank. Holding tanks in their simplest form hold the wastewater to be collected later and treated at a separate facility. Sewage pumping, hauling, and disposal all have to be completed at an approved site facility. There are limitations to the collection method and disposal site, and the holding tank must have a warning device to indicate when the tank is 75% full. The initial tank cost is relatively low at around $500 for a 300-gallon tank or $2000 for a 1500-gallon tank; however, the pumping service can range anywhere from $150-330 per pumping service. For a long-term solution, this cost for maintenance can rapidly accumulate. Even before installation can occur, a permit is required and a maintenance upkeep plan is needed to discuss the frequency of the pumping service. Overall, a holding tank is not the most ideal long-term solution.

The sewage system that appears most ideal for Castle Hill is a septic system with a leach field. A leach field which contains both a septic tank and a leaching field, stores the wastewater and uses anaerobic bacteria to help breakdown organic matter and separate floatable matter and other solids from the wastewater.

The costs for a leach field include a high installation fee and initial cost, but maintenance is relatively reasonable. The initial cost for a 5000-gallon tank is about $10,000, and the installation labor costs range from around $10,000-$15,000. The most costly initial investment is the leaching pit installation which is roughly $30,000. Drain fields only have to be replaced if swampy areas begin to occur, and this can cost anywhere from $2,000-$10,000. A tank pump may be needed for the site because the septic tank will more than likely be located lower than the drain field, which may require a pump to bring the discharge to the drain field. A pump ranges from $800-$1,400. Every 2-3 years the solid waste will need to be pumped at a cost around $400.

IV. SPACE ALLOCATION

Station Castle Hill is located in an area where coastal disasters like flooding may occur. In order to prevent extensive damage from flooding events, the habitable (offices) and electrical/mechanical spaces should be situated on the upper levels of the facility above the floodplain. In turn the workshop areas should be located on the lower levels. One downside to this option is the risk of a leak in the roof that may allow water to penetrate the building and damage electrical machines. There are a lot of spaces that the boat maintenance facility needs; however, there is a limited amount of space. As a result the Coast Guard developed the Shore Facilities Standards Manual (SFSM) which gives standard sizes of specific spaces pertaining to different facilities, in this case a boat/cutter maintenance facility. Some of the space sizes are below, in Figure 2.

![Figure 2 - Space requirements for boat maintenance facility (SFSM).](image)
desk work along with tables and chairs should also be added to the facility.

Each department has different spatial needs. For the deck department, a boatswain shop containing adequate work space and storage for lines and other tools should be included in the design of the building. For the engineering department, a machinery/engineering work area should be in the building to repair parts and store tools as well. The station needs specific storage for small boat gear, so that the gear can easily be organized and accounted for. Lastly, offices for the Engineering Petty Officer/Engineering Officer (EPO/EO), and First Lieutenant (1LT) and Assistant Engineering Petty Officer (AEPO) are required in this facility. The EPO/EO should have his/her own office, while the 1LT and AEPO can share the same office (Cole 2017). The proposed layouts for the first and second deck are exhibited below in Figures 3 and 4.

![Figure 3 - First Deck Layout - Plan View](image-url3)

![Figure 4 - Second Deck - Plan View](image-url4)

The SFSM states size changes are allowed as long as the proposed entire square footage of the building is within a 10% difference of the total required size. Figure 5 shows the proposed versus required space sizes.

![Figure 5 - space allocation for boathouse maintenance facility](image-url5)

V. LOADING ON STRUCTURE

As mentioned earlier, Newport is notorious for having heavy winds and the material researched below will assist in the calculations for the design. In addition to the typical live and dead load calculations, the information regarding wind loads will give the capstone group a more in depth idea of multiple ways to determine the wind loads on a structure. Knowing these loads will allow the team to accurately design the structure based on the loads applied.

The American Society of Civil Engineers (ASCE) has provided a standard, ASCE 7-16: Minimum Design Loads for Buildings and Other Structures, to provide minimum loading criteria for the design of structures. ASCE 7-16 also offers factors to be applied to the loads that account for deviations of the real load from the nominal load. This standard also assists in the determination of loading based on geographic location when it comes to wind, earthquake, and snow loads.

High and low pressure regions are caused by temperature variances in the atmosphere; these pressure differences in turn cause wind to propagate through various locations. Wind loads typically are forces that act in the horizontal direction and perpendicular to the surface of the structure. The sign
The convention for wind loads shows that winds acting toward the surface are positive, while the winds that act in the opposite direction are considered negative. The units for winds loads are force over area, like pounds per square foot (psf). The three major types of wind loads include uplift load, shear load, and lateral load (Coulbourne & Mehta 2010). Uplift load is a pressure generated by the flow of wind that produces a significant effect on the buildings similar to the concept of lift on airplanes. Shear loads and lateral loads are loads that act horizontally. Shear loads act parallel to or along the surface of the building. Lateral loads act perpendicular to the surface of the building and are responsible for placing pressure on the surface that can have undesirable effects on the structure such as overturning. Furthermore, variable forces on structures can be produced by gusts which can lead to significant dynamic motions.

In order to determine the wind loads on a structure, the basic wind speed, \( V \), needs to be found by utilizing Figs, 26.5-1 and 26.5-2 in ASCE 7-16. These figures are broken down into subcategories for Risk Category I, Risk Category II, Risk Category III, and Risk Category IV. A building’s risk category can be determined by using Table 1.3-1 in ASCE 7-16. Figure 6 displays a typical wind speed map, specifically the basic wind speed map for Risk Category I.

Once the basic wind speed for a desired location has been found, the effective velocity pressure, \( q \), can be calculated using the following equation:

\[
q = 0.00256 K_z K_{zt} K_d V^2 \text{ (lb/ft}^2\text{)} \quad \text{(Eq.1)}
\]

where,
- \( K_z \) = exposure velocity pressure coefficient
- \( K_{zt} \) = topographic factor
- \( K_d \) = directionality factor

The effective velocity pressure is then used in future calculations to find the design wind pressure.

The Main Wind Force Resisting System (MWFRS) is the “assemblage if structural elements assigned to provide support and stability for the overall building or other structure. The system generally receives wind loading from more than one surface” (ASCE 7-16). In other words, the MWFRS is a component of the building that is designed specifically to resist loads that occur due to the wind during the lifetime of the structure. The wind loads can be calculated using the directional procedure.

The directional procedure is used to calculate the wind loads on structures based on wind tunnel testing of ideal building models. The previous wind tunnel tests are where the external pressure coefficients are based on for the corresponding direction of wind (ASCE 2010). This method focuses on external pressure coefficients and explicit wind directions of buildings of all heights. The directional procedure is broken up into two categories. Part 1 relates to “buildings of all heights where it is necessary to separate applied wind loads onto the windward, leeward, and sidewalls of the building to properly assess the internal forces in the MWFRS members” (ASCE 7-16). Part 2 explains enclosed simple diaphragm buildings, where \( h < 160 \) feet. When using this procedure, the wind pressure diagrams are based on the different directions of the winds. In Figures 7 and 8, \( C_p \) is the external pressure coefficient, and \( G \) is the gust effect factor.
The equation used to determine the design wind pressure, \( p \), is shown below:

\[
p = qGCp - qi (GCpi) \text{ (lb/ft}^2) \quad \text{(Eq. 2)}
\]

where, \( q \) = effective velocity pressure
\( GCp \) = internal pressure coefficient

The internal pressure coefficient differs based on the enclosure classifications described in ASCE 7-16 Table 26.13-1. There are 4 types of classifications: enclosed buildings, partially enclosed buildings, partially opened buildings, and open buildings. The boathouse will utilize a steel moment resisting frame with rigid joints that will resist the loadings on the structure.

The steel frame is broken up into two bays. The boat bay does not contain a second deck in order to ensure clearance for the truck, trailer and small boat. Figure 9 displays the steel frame of the structure.

The wind loads were calculated based on the directional procedure. The effective wind velocity pressure was calculated based on a Category III building classification, Exposure Category C enclosed structure. The importance factor used was 1.15. And based on the Basic Wind Speed Map for Risk Category III, the velocity used was 140 mph. The design wind pressure \( q_z \) and \( q_h \) were calculated to be 49.24 lb/ft\(^2\) and 48.07 lb/ft\(^2\), respectively. The design wind pressure on the windward faces were computed to be \( P = 24.83 \text{ lb/ft}^2 \).
VI. ENVIRONMENTAL AND HISTORIC CONSIDERATIONS

The geographic location of Newport is about eleven square miles about 30 miles south of Providence at the southern end of Aquidneck Island in Narragansett Bay. The boundaries include: south and east bounded by the Atlantic Ocean, Narragansett Bay on the west side, and Middletown in the northeast. It is the largest island in Narragansett Bay and is comprised mostly of rounded hills and valleys, with altitudes that range from about sea level to 100 feet or so above sea level. The Station is located in the more rural area in the southernmost/Ocean Drive area. (Newport Comprehensive Land Use Plan 2017). Coast Guard Station Castle Hill was built in 1941 after the destruction of the original Brenton Point station. It was rebuilt next to the Castle Hill Lighthouse reservation on the east side of East Passage near the entrance to Narragansett Bay. This site relocation was to ensure a more protected area for the Station. It was constructed with a “Roosevelt Style” station house, a separated boathouse and marine railway that was located at the head of Castle Cove. (Station Castle Hill, Rhode Island 2001).

About 55% of the Newport area falls under the Historic District Commission. The Historic District Commission (HDC) appoints local areas to historical zoning in order to capture a time period with the surrounding buildings, enhance tourism, and strengthen and ensure the local economy. All construction must be approved by the HDC staff prior to building. Review of the design is initiated by an application, or Certificate of Appropriateness, to the Office of Planning, Zoning, Development, and Inspection, and then this application is placed on the NHDC schedule for review and a site visit. Once these have occurred, a representative must attend the NHDC meeting to answer any pressing concerns from the community. Building materials, paint color, and maintenance and upkeep of the structural appearance of the building is regulated by the HDC and should be considered prior to construction. (Standards and Guidelines for the Newport Local Historic District 2017).

When the structure is over 50 years old, NHPA (National Historical Preservation Act) must be used before the site may be disturbed. Section 106 is recommended after Section 110 is observed and analyzed. Other concerns include water resources and aquaculture. Endangered species in Section 7 of the FWS (Federal Wildlife Service) must be consulted prior to disturbing coastline. The state of Rhode Island has specific regulations for sediment and control requirements, as well as environmental concerns for possible lead paint and asbestos. Public Health Codes for septic area must also be referenced prior to installation of a leach field.

VII. CONCLUSION

The projected new boathouse maintenance facility for Station Castle Hill will be capable to house and properly maintain the 29’ Response Boat-Small II (RB-S), along with creating an accessible boat ramp on site. Space allocation, in accordance with the Coast Guard Shore Facilities Standards Manual, provides a functional layout of the space. A boat bay, wet room, machinery shop, boatswain shop, offices, and restroom will all be included. Analysis of the different options for a sewage treatment facility concludes that a leach field will be the most cost beneficial investment for long-term needs. With regard to the boat ramp, a gravel ramp located next to the boathouse is ideal for both the station needs and the structural integrity of both the ramp and house. Environmental and historical concerns were taken into account in order to be within the necessary Newport Historic District and Rhode Island regulations. Loading calculations ensured that the structure would withstand wind loads and snow loads. This report accounts for 35% design of the structure itself and will be visually presented as well.

VIII. REFERENCES

ASCE. (2010). “Minimum design loads for buildings and other structures.” ASCE 7-10, Reston, VA.

ASCE. (2016). “Minimum design loads for buildings and other structures.” ASCE 7-16, Reston, VA


Healy, J., Hueller, R., Wieland, E., Lentine, J.-D., and Braxton, M. “U.S. Coast Guard (USCG) Hurricanes

Katrina, Ike, and Sandy Resiliency Reconstruction.” U.S. Coast Guard (USCG) Hurricanes Katrina, Ike, and Sandy Resiliency Reconstruction | Ports 2016,


Newport, Newport Historic Districts Commission, (Dec. 6, 2017).


