DESIGNING A "MODULAR FORTRESS" HOME ON LONG ISLAND SOUND

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INTRODUCTION

The challenges of building on an island demanded elements of green building technology. Since there are no utilities for life support systems such as heat, hot water, and electricity, the design approach needed to be comprehensive and efficient.

We were commissioned in 2004 to design a 4,200-square-foot vacation house on a small island off Branford Connecticut. This island, less than one acre, is only 10 feet above sea level at the maximum high point. The challenges were not only to produce enough energy as efficiently as possible, but to build a structure resistant to storm surges potentially 11 feet above sea level and 3 foot waves that could inundate the island. The home has seen three severe storms since it was constructed, and indeed, the ocean did completely inundate the island, leaving only the home and the mechanical building to stand alone in the open and violent ocean.

The island prior to 1938 had a luxurious mansion built on it constructed of masonry and by conventional means. The 1938 hurricane swept over Long Island Sound in that year making a direct hit to the island. The mansion was leveled, leaving only debris, and for 67 years there was no meaningful building on the island other than a storage shack and lean-to over the remains of the foundation.

The only life support brought to the island was a water pipe. The island, named Sumac Island, is only a half mile off the southern Connecticut shoreline in Branford, just a few miles west of a chain of islands called the Thimbles Islands.

The owner bought this island in part for the spectacular views—and of course the privacy any island gives—but he knew it presented many challenges, mainly generating its own power. This required sophisticated mechanical systems to be built—off the grid (see Figure 1).

KEYWORDS

island home, modular building, hurricane resistant building, storm surge protection

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APPROACH

First we had to design the building as efficiently as possible with a budget in mind. Since this was going to be primarily a vacation home used during the summer, we were not so compelled to overinsulate. The home was built to the latest energy codes for purposes of insulating. The energy saving came from specifying Energy Star appliances and LED lighting. A blower test was not conducted, as the full Energy Star program was not in place at this time.

The home was designed to be elevated, with the first floor almost 20 feet above sea level, so the underside of the building was insulated to complete the building envelope. The owner planned on using the house during the "off season," but not on a regular basis, so the heat would be set at a minimum temperature of 50 degrees during the winter so the pipes would not freeze. The prime source of energy generation selected was solar power. The photovoltaic panels were placed on the upper gambrel roof facing the southeast. These panels were designed to charge batteries that would then power the home's mechanical systems, lights, and appliances. A propane-powered generator was calculated in as a backup to anticipate loads from a week's stay with extended family and over a week of cloudy weather, which sometimes happens in this region of the country. It was determined that the batteries and the generator would be housed in a mechanical building 100 feet away. This building was also designed to be elevated and storm resistant. Some consideration was given to wind generation but it was determined by the engineers that it would yield little power compared to the solar panels. The wind is rather minimal for much of the day in Long Island Sound during the summer. Most of the days in the summer, the air is calm and only picks up in the afternoon from around 3:00 PM until 7:00 PM. The owner was also concerned about the noise a wind generator system would make. The electrical cables and gas lines from the mechanical building to the house were buried underground and protected with adequate cover. This would be important in the event of a storm engulfing the island.

Every project requires different energy solutions and this one was no different. Our firm has done several projects on the mainland where geothermal was specified and installed. Factors such as aesthetics and available land are what made these choices compelling.

The mechanical engineering firm selected was Steven Winter & Associates. Steven Winter was one of the founders of the Green Building Council and has been an advocate of alternative green building technologies for over 40 years.

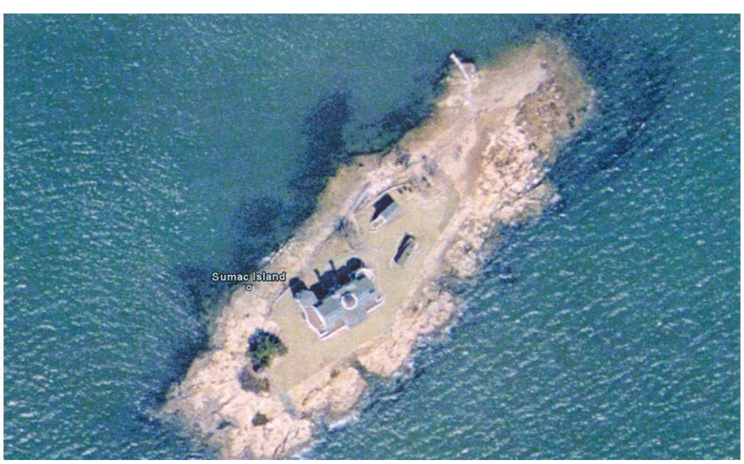


FIGURE 1. Sumac Island.

Solar panels were used and careful calculations were made. The building has worked as designed, without flaws, and the owner has a very easy time maintaining and operating the system (see Figure 2).

FIGURE 2. Solar Panels.

SEWAGE

It was determined by the civil engineer that the island was big enough and the composition of soil was adequate enough to handle an on-site septic for this four-bedroom house. The island is composed primarily of rock, much exposed around the perimeter. There were, however, considerable areas in the center of the island composed of sand, gravel, and finer soils. This soil was sufficient in quantity and quality to support a safe on-site sewage system.

LANDSCAPING

There are several areas of low scrub trees and larger trees on the island. Other than the main house and the mechanical building, the site has been left natural and pervious to rainwater. Of course there is no garage or need of a driveway. Access to the island is by boat, so a small dock is the only other construction on the island. Consideration was given to more indigenous plantings around the perimeter of the island and the existing low scrub trees and lager trees were preserved. The owner wanted some lawn so his children could play sports—after all, it was a vacation home and they had three children to entertain. The lawn and some planting did receive damage during the three big storms since the construction, especially Hurricanes Irene and Sandy. Finding the right species of saltwater-resistant grass was a challenge. Since there was a water line to the island from the mainland there was no need for a water tank. Some consideration was given to a cistern for rainwater to water the landscape vegetation, but there were concerns that if a storm ever did inundate the island, the tank may float to the surface if it was not filled enough or properly weighted.

CONSTRUCTION

Modular building methods were selected for several reasons. First, this offered quicker erection time and less trips made to the island by the work crews and vendors. The side benefit was a greener approach. This approach would save energy wasted on travel, shipping in materials, and reduce the construction debris that would later need to be hauled back to the mainland. It also made for a cleaner job site on this tiny island. Less debris meant fewer pollutants were carried into the fragile Long Island Sound by rainwater runoff.

Modular building also has more consistent quality control because the modules are built in a factory environment. The redundancy of the structure—for example, the double-marriage walls in the interior and the separate ceiling framing for the first floor and floor system for second floor—makes for a stronger building. This is all constructed by default when employing modular methods. This added strength was critical in the 120-mile-per-hour wind zone where the island is located. Of course additional design measures, such as specially engineered shear walls, were also incorporated, but it would have been more so if conventional building methods were selected (see Figure 3). The transverse walls going across the shorter dimension of the building were selected as shear walls. These walls had plywood on both sides of framing with nail spacing at 6-inch intervals. Hold down straps and through rods were used to anchor the building to steel and microlams below.

Other benefits of this approach were cost savings, as the total project cost was over $3 million. The modules were built in Claremont, New Hampshire, at a modular manufacturer called Customized Structures Inc. (CSI). They were shipped 100 miles south to New London, Connecticut, along the western riverfront, for partial assembly. Considerable work was carried out here, with siding and most of the trim being installed. Easy access to this temporary staging area by the numerous subcontractors from the mainland just made more sense for the contractor. So much of modular building is about logistics. The economic theory behind this is that the remote location of the factories from the building location allows much of the labor to take place in low-wage states, so that the builder and customer can ultimately benefit. The factories benefit because they get work from outside their local market, which benefits their local economy. Typically, the bigger the house in the most expensive areas yields the biggest cost savings.

The modules were 16' wide in various lengths set double wide. The second floor had a triple wide layout with the Master Bedroom built over a porch on the southeast-facing façade. The total length was approximately 80' long.

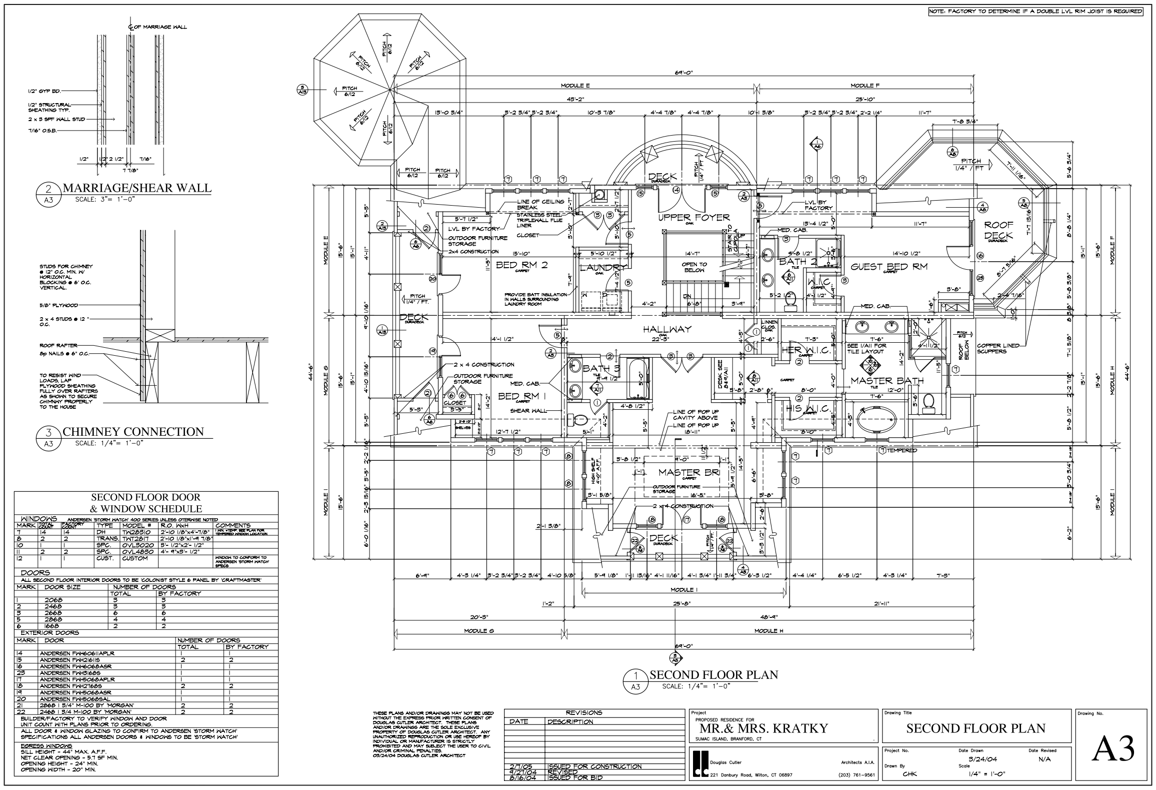
A separate module 12' wide was used to house the generator and batteries. This separate structure was set north of the house, shielded by evergreen trees.

The builder decided to ship the house to the island in a near-completed state (see Figure 4). This completed state is from the sill plate up to the roof, rather than in the separate 16' wide modules. This made more economic sense than making ten separate trips. The strategy was to have this near-completed home rolled onto a barge in New London. To save trips, the homeowner even brought much of the furniture to the temporary job site in New London and set the items in place in the rooms. The Home was designed with 4 bedrooms and had a den. The primary living space was a big great room at the southwest end, opening onto a large deck with a gazebo-like structure attached to the main building. The decks and gazebo were built on site.

When the home was moved on the barge it was quite a sight to see. In 2006, on a morning in July, the home sailed under the New London Bridge and out into Long Island Sound. The house on the barge made a left and was towed 75 miles east to the destination on Sumac Island. The sailors at the Groton submarine base, typically up early, couldn't believe their eyes as this house sailed by on the first leg of the trip.

Once the house arrived at the island, it had to be moved off the barge and into its final position over the partially completed foundation. The builder contracted with an experienced house moving company called Expert House Movers. They had moved many notable buildings, such as the Block Island Light House and the Newark Airport Terminal, to name a few. The moving mechanisms were hydraulically-powered wheels and levelers that worked like a charm. Considering where the house began its journey in New Hampshire, the process was orchestrated by the builders without any real problems. The builder was Evergreen Builders, located in Stonington, CT. They had built several coastal homes in the area, but this project had to be the most challenging.

FIGURE 3. Floor Plans.



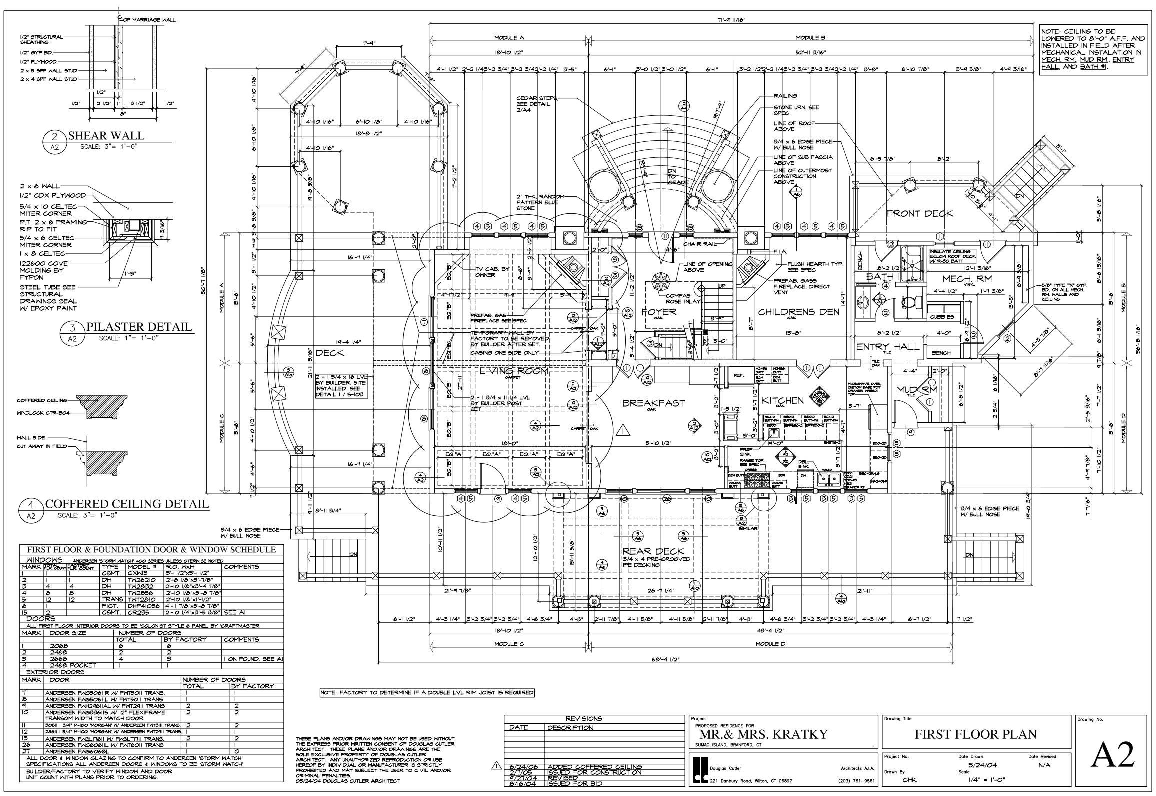


FIGURE 4. Put on barge in New London and shipped 75 miles west to Sumac Island.

FOUNDATION

The foundation was a rather unique configuration able to withstand the fury of hurricanes, if one should occur. The island is located in what FEMA (Federal Emergency Management Administration) calls a "V" Zone. "V" means velocity, as it relates to waves hitting the structure of the building. As a result of these forces, the building had to be elevated from sea level so the nearest underside of the structure would be a minimum of 16 feet above sea level. More importantly, a continuous foundation wall was not allowed to be designed, as the forces to resist the wave would be too great to engineer. Steel reinforced concrete piers were designed to hold up the building. These were about 6 feet above the final grade but went below grade nearly 5' and attached to a large concrete reinforced mat foundation (see Figure 5).

PROCESS

There were several reasons for using a mat foundation. First, the piers and columns had to be tied together to a base, as a pier could be kicked out from a wave or debris during a storm. It was calculated that these forces could be as much as 850 pounds per-square-foot laterally. Having piers and short wall segments—many 2 feet in dimension—meant the surface area of force from the ocean would be easier to resist. The water could easily flow under the building and not damage any vital mechanical components. The second reason for mat foundations is to mitigate what is called underscoring. The moving water from waves has an erosion effect on a foundation. Placing the footings below the anticipated erosion line preserves the integrity of the building and its ability to withstand the storm. We did build over part of an old stone foundation left by the old mansion's out building after the 1938 hurricane. The owner had us design breakaway walls and a double door that would be sacrificed if a storm would occur. The owners used this space for temporary storage for kayaks and jet skis.

Other design concerns were the wind loads on the roof and walls. The leading and trailing edges of the roof and wall corners typically have the greatest wind loads. The positive and negative pressures on the skin or sheathing can be double in these areas. The roof can often

FIGURE 5. Mat Foundation.

act like an airplane wing on the lee side, potentially lifting up the roof. The design measures taken were to use coil nails 4" on center to keep the sheathing down in these vulnerable areas. Shingles were also chosen to resist 120 mph winds so they would not blow off.

The ultimate challenge was to position the house precisely over the foundation, level it, and then proceed to build the concrete piers up to the bearing points of the house superstructure. This was like building the house backward. The mat foundation was built first on site, and in selected areas of exposed ledge rock, the mat was pinned to the rock. The concrete was mixed on site. The builder was able to find a World War II surplus Landing Craft large enough to carry back hoes and front end loaders. The builder also brought the necessary concrete mixing equipment, along with the gravel and aggregates for the concrete's final mix.

There was really no other way to build a foundation any cheaper that would also resist these forces of nature. Piles would not have worked, as there was ledge rock either at the surface or not far below the surface of the island. Salt water corrodes exposed steel, so epoxy-coated steel reinforcing bars where specified within the whole foundation system.

The anchoring system consisted of coiled steel straps, bolts, and embedded straps into the concrete foundation. These galvanized anchors were strategically placed to resist uplift and overturning moments. The shear walls, designed through the center of the building, were key to the resisting of wind loads, particularly broadside to the home. Steel was used in parts of the foundation and perimeter to span greater distances and cut down on the number of vertical concrete piers required. The underside of the home was of course insulated, but then covered with marine grade plywood, painted to seal out moisture and any water that might splash up if a storm should run under the building.

EVENT

The shipping of the house and setting in place was quite the event, drawing curiosity seekers and the press. The builder, owner, and builder's subcontractors watched as the building slowly moved and creeped down the ramps from the barge and onto the rocky island. A groomed gravel path to the site had to be created to let the moving devices travel smoothly to the final resting place. Pleasure boaters surrounded the island for a look-see along with a few helicopters above taking photos.

Some of the mechanical systems were shipped to the site separately. The solar panels were mounted on the southeast side on the shallow pitch of the gambrel roof. The mechanical building was also brought in and set on a much smaller foundation, but on reinforced concrete piers just the same. Concealed under the mechanical building were propane tanks providing fuel for the gas-powered generators, in case they need them to provide power and charge batteries. The tanks were screened by the stairs and lattice. The tanks were small enough so that the owner could take them to the mainland and easily fill them. The solar panels charging the batteries made for the infrequent use of gas to power the backup generator.

SACRIFICE

It was understood certain parts of the building would be damaged and or swept away in a storm if the event should occur. The decorative lattice below the deck and main building could get ripped away by flowing water and debris. There were several stairs that went from finish grade up to the decks. These stairs could certainly get destroyed to for the same reasons. All in all these small elements to the building would be relatively inexpensive and could be replaced in just a few days.

STYLE

The style was a Georgian Gambrel, inspired by the Westport Rowing Club. It did make for more complicated construction, but when finished it gave the house a special grandeur and respect. The integration of heavy Doric columns reinforced the Georgian vernacular. A stone veneer base on some of the wall segments anchored the house to the island despite the short length of the walls. A large cascading half-radial stair with stone veneer cheek walls embraced the main entrance. Other features were recesses in the second floor gable ends that incorporated decks off some of the bedrooms. The favorite feature for the owner is a roof deck cupola that wraps around 270 degrees, offering panoramic views of Long Island Sound. High-end waterproofing products were used to seal the main house from water infiltration that the deck might create. Much of the exterior trim and architectural details were made from a closed cell PVC. This gave the house a durable trim not requiring painting and suitable to stand up to the saltwater.

INTERIOR

All the windows and exterior doors specified were low-E storm-resistant windows made by Andersen. These windows are made to take the impact of a 2 × 4 traveling 100 mph to resist breaking the window. This window choice also makes window shutters unnecessary. Traveling out to the island can be difficult at times just as a storm is brewing, so installing shutters, either roll-down or fixed, could be more challenging. The window arrangement was generous, as the views on all sides of the house were spectacular. A sidebar on storm-resistant windows: during a fire the fire department is unable to break in through the windows, and at the moment, solutions have not been worked out to fix this problem. The window arrangements also gave generous daylighting to all the rooms, giving little reason to have lights on during the day (see Figure 6). Since the building was only 32 feet wide, light penetrated easily through the open plan. All rooms had an exterior exposure, except the laundry room and two bathrooms.

In the master bedroom there was a pop-up ceiling about 12' × 12', just above the master bed. On the east high gable there was an oculus-shaped window that flooded in morning light. This feature gave drama to the bedroom, along with the views. Many of the south-, east-, and west-facing windows had either recesses or covered porches to shield the summer sun. The Long Island Sound can get hot in the summer, at times reaching over 90 degrees. The mornings can be still and humid. Other feature elements were crown moldings and a coffered ceiling in the great room.

The interior gypsum board was really a green board used for bathrooms, as on this island conditions can get humid. A standard gypsum board could get mildewed over the years, even though the house did have air-conditioning and a dehumidifier.

The owner had children and wanted a low-VOCE paint that had some mildew resistant properties.

Most of the floors were hardwood oak, with tile and stone in the laundry, kitchen, and baths. A variety of stone and marble was used as countertops in the kitchen and baths to give the high-end look and maintenance-free performance. No particular attention was given to locally milled hardwood floors and locally quarried stone for floors, as product availability and time constraints were of a greater priority. Nearly all the light fixtures were LED lights, which draw much less of a current than normal incandescent or fluorescent lights.

FIGURE 6. Living Room Interior.

STORMS

In September of 2011 and October of 2012, two of the biggest storms on record hit the northeast United States. The first was Hurricane Irene and the second was Hurricane Sandy. The storm surges were so great each time that the island was completely submerged and 3-foot waves regularly swept over the island and under the house and mechanical building. The owner was in the building during Hurricane Irene and reported the waves just missed the underside of the building by about 2 feet. Wind gusts were reported to be in excess of 100 miles per hour. Even though Sandy was reported to be a bigger storm, Irene was more concentrated and had more of a direct hit. Sandy had a slightly greater storm surge. The septic tank was designed and weighted down with concrete so that it would not lift up during the sea level rising. The only damage was to some of the lattice and steps. The breakaway lattice panels were meant to be sacrificial and are expected to be replaced. We hope these 100-year storms don't occur every other year however. The building superstructure repelled the wind and wind-driven rain just fine.

In the end, this off-the-grid house has performed very well and is a testament to a near Net Zero design. Necessity is truly the mother of invention when you have little connection to the mainland. The propane tanks are rarely used, and if so, mostly for cooking. More importantly, the family has enjoyed vacationing in this unique location and has a sense of confidence that the home is secure.

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