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SuperStorm Sandy destroyed the Casino Pier in Seaside Heights, N.J., and left the Jet Star roller coaster stranded offshore. Before construction of the new pier could begin, the Jet Star had to be dismantled. *Photo: Chris Spiegel Blurrevision.com*

RESILIENT REBUILD

BETTER THAN EVER, THRILLS CONTINUE AT THE JERSEY SHORE!

By Richard C. Maloney, P.E., and Maraliese Beveridge

TO THOSE UNAFFECTED by SuperStorm Sandy's devastation, her wrath is just a blurred memory. But to local New Jersey residents and businesses still rebuilding, destruction from the storm, which chomped its way through their shoreline like Godzilla on a foody rampage, lingers five years later.

The photo of the iconic Seaside Heights steel roller coaster left derelict offshore in the Atlantic Ocean became a worldwide symbol of the storm. But the coaster's cold steel skeleton left a real chill in the hearts of the locals as it was slowly dismantled, leaving a giant hole in the famous Seaside Casino Pier.

Enter 2017, and the future of this Jersey Shore hot spot is planned to make its official comeback debut by Memorial Day. After wrapping up the final design, permitting, and approvals to rebuild last year, owners of the Casino Pier have been busy planning restoration and expansion of the damaged pier and roller coaster — its features to be bigger and better than ever before!

Casino Pier history

Originally constructed in 1932, the pier has progressed through ownership, fires, rebuilding, additions, and modifications that were continually focused on configuring the boardwalk to connect into one continuous venue with a wide variety of amusements and vendors.

The pier's first major roller coaster, The Wild Mouse, stood on the pier until 1969 when it was replaced by the iconic Jet Star roller coaster that was built on a perpendicular segment of pier that jutted out 650 feet from the boardwalk into the Atlantic Ocean. Designers took full advantage of this spectacular view, designing the coaster to take riders' breath away as it swerved at the pier's end.

In 2012, SuperStorm Sandy put an end to all that, smashing up the pier and spitting the roller coaster out into the ocean. But even Sandy's

Lift tower foundation reactions exceeded 50 tons of uplift and downward forces resulting from the 72-foot-tall tower's ocean wind exposure and narrow base. The tower required a foundation unique from the rest of the coaster. *Photo: Chris Spiegel Blurrevision.com*

devastation was not enough to quell the desire in the hearts of New Jerseyans, who are known for their passion for the seaside and tenacity for rebuilding.

Jet Star versus Hydrus

The main difference between the original Jet Star roller coaster and the new Hydrus coaster is thrill, design, and more thrill. Back in the day, the features of a steel-style Jet Star were unique but did not have the wow factors of the newer model designs. Whipping around turns, coasting up and down hills, and launching people out toward the water with such a magnificent ocean view was thrill enough. The Jet Star could never have supported the g-forces, height, or twisting, turning loops found in today's super-thrill mega and giga coasters that maximize the thrill threshold of contemporary audiences. As a result, roller coaster manufacturers have been designing a new genre of extreme roller coasters that continually push the limits of "scary," like the Kingda Ka roller coaster at Six Flags Great Adventure in Jackson, N.J. (Zumanjaro: Drop of Doom – How Scary is Built, Civil & Structural Engineer, Sept. 2014, http://csengineermag.com/article/zumanjaro-drop-of-doom-how-scary-is-built).

The new Hydrus roller coaster is a Euro-fighter signature model designed by Gerstlauer Amusement Rides (Germany). With an overall length of 1,050 feet, it has a vertical chain lift tower rising up to 72 feet that shortly becomes an inverted drop (vertical angle of 97 degrees) while leading to three inversions at a speed of 45 mph. The inversions include a loop, Immelman turn (half loop, then half roll) and cutback, and a heartline roll, which puts it in the extreme category.

Hydrus has a little bit of every trending thrill and, unlike others, the advantage of an ocean view. Because it was proposed to sit atop a traditional boardwalk pier, the foundation had to be designed to include steel framing that connects many of the column bases together to counteract each other, and also includes several steel-framed, car-sized pallets filled with heavy stone that work as dead load counterweights (ballast) to the coaster's large uplift and lateral foundation forces. All parties worked closely with the ride designer to ensure the ride column base and the corresponding pier foundation were bolstered enough to handle the combined loads of the pier, ride, g-force, and Mother Nature.

The lift tower's foundation required 24-inch-diameter steel pipe piles beneath the tower pile cap. *Photo: Jim Elliott*

Original versus new pier

The biggest difference in comparing the old and new piers is progress and know-how. The original pier was an all-timber structure that stretched from the eastern edge of the Seaside Heights boardwalk into the Atlantic Ocean. The dense design of the pier structure solidly stood the test of time — until SuperStorm Sandy with its historic storm surge, deadly crashing waves, and destructive winds that bashed the coastline to bits.

Due to the extent of damage, she set new precedents for shore protection, building codes, FEMA flood zone delineation, insurance policies, emergency response, and flood awareness. Since then, all coastal construction has become more scrutinized and code compliance has been stepped up. Flood zones have been adjusted to improve resilience for the "next big one" as some weather models question whether or not Sandy was indeed a fluke or the new potential norm.

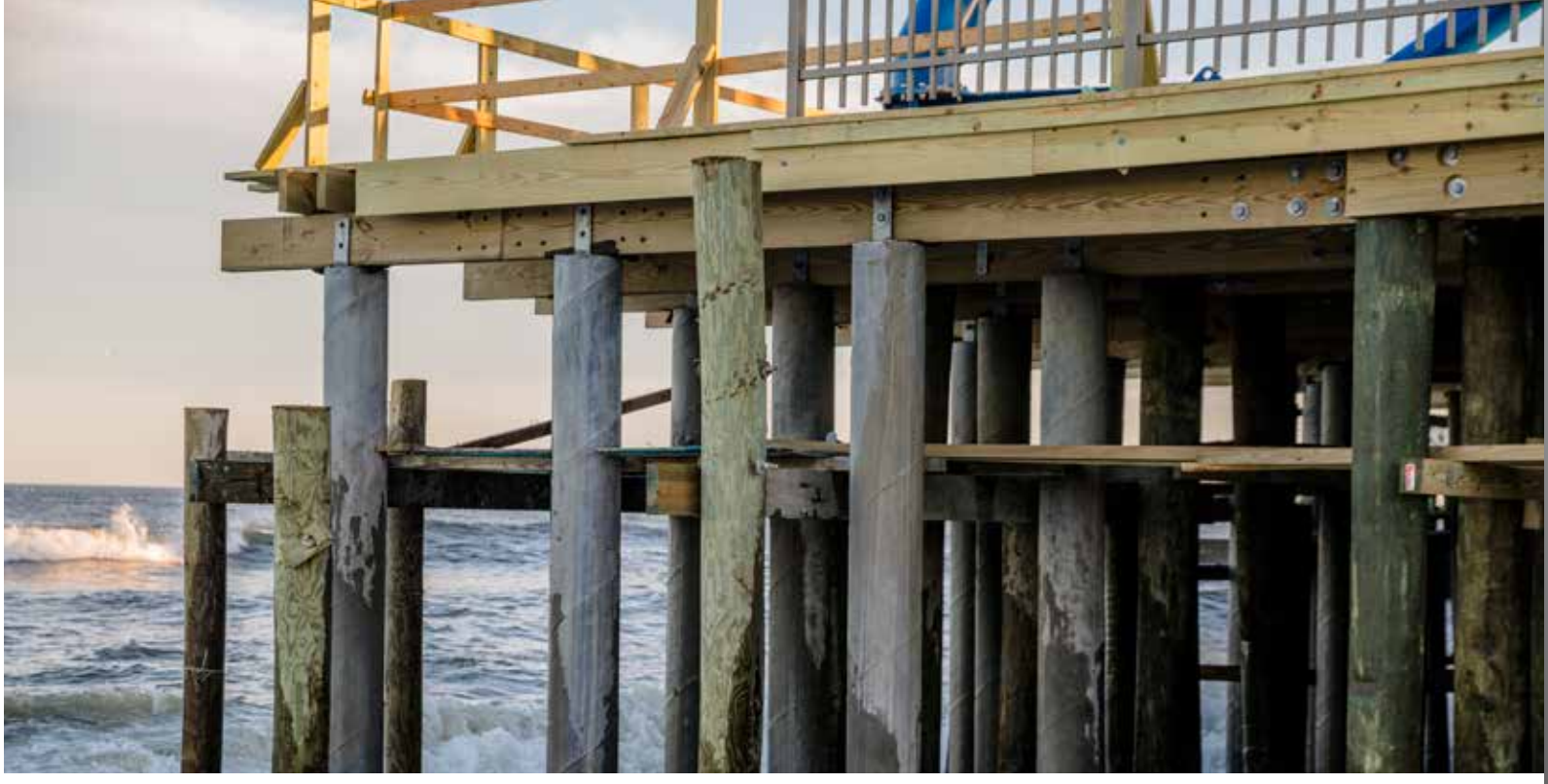
Taking all of this into account, Maser Consulting's structural team; Jim Elliott, construction manager for Casino Beach Pier LLC as well as the Jenkinson's Organizations; and the Hydrus ride manufacturer (Gerstlauer) analyzed the coaster design, its loads, and foundation requirements — from the wind-catching lift tower to its many stone-filled pallets. While design stayed with the timber pile and frame design of a traditional boardwalk pier, specific modifications and additions were made to address the non-traditional loads (g-forces created by the tower, looping, and spiraling of the ride track).

Elliott, a general building contractor for more than 30 years, has worked for the Casino Pier, on and off, for more than three decades on many projects. Sandy so devastated their properties that he was asked to work exclusively for them, directing, supervising, and expediting the reconstruction effort. He has been responsible for installation of almost every extreme ride that sits on the pier, including a new 131-foot Ferris wheel that is currently being constructed adjacent to the Hydrus roller coaster.

Before construction of the new pier could begin, the Jet Star had to be dismantled in the ocean, accessed from the water by tug and barge. Nearly 300 feet of pier that previously extended into the ocean was removed. To help sustain the pier's longevity, the new section was built alongside the remaining pier, making it wider, but not reach as far — or as romantically — into the ocean. While the original timber pier structure stood the test of time, it did finally reach its limit, succumbing to the attack of the monster Sandy.

Today's codes require design upgrades, not only to structural reinforcement of the pier members, but also to the integrity of the member connections. Additionally, due to the effect on the ride (particularly the lift tower) of the coaster's g-forces, the incredible load from the ballast pallets, and winds and waves, the pier design was beefed-up to resist the vertical downward force of the pallets, the large overturning forces from the narrow lift tower, and the horizontal forces resulting from each time the coaster turned.

Relocating the pier to higher ground made great strides in reducing the magnitude of wave forces the original pier withstood. Most of the standards that the new pier was built in accordance with didn't exist the last time the pier was built — certainly not to the same degree. The new pier fully complies with the design requirements of not only the adjusted FEMA Flood Elevations and the many updated FEMA Technical



Steel sentinel pilings along the seaward side of the pier (prior to the removal of the timber piling sub-scaffolding) fend-off the extended hydrodynamic forces of moving water, wave action, and the large potential impact forces from storm debris "floatables." *Photo: Chris Spiegel Blurrevision.com*

Bulletins, but also to the American Society of Civil Engineers' (ASCE) design standards for coastal construction, ASCE-7 – Minimum Design Loads for Building and Other Structures, and ASCE 24 – Flood Resistant Design and Construction. The design also reflected decades of experience with waterfront designs and post-disaster inspections that Maser Consulting engineers have witnessed over the years — learning from disasters and improving designs to better withstand the next one.

One such improvement was the use of steel sentinel pilings for the first two rows on the seaward edge of the pier. Designed to support the pier while sustaining the unique weight and loads of the new roller coaster, they fend-off the extended hydrodynamic forces of moving water, wave action, and the large potential impact forces from storm debris "floatables" that have the force to break a timber piling into two. Installation of steel pilings at the water's edge also removed the need for lateral cross bracing typically seen on taller timber pilings, which would receive damage from perpendicular wave forces. The piling design also took into consideration the ebb and flow of beach sand that occurs along the shoreline, which can shift as much as 6 feet under normal weather conditions at this beach.

Of the new pier's more than 1,400 pilings, most of the more than 500 timber pilings dedicated solely to supporting the coaster are a traditional 12-inch, Class-B piling that support typical pier loads. However, 14-inch Class-A piles were provided directly under every roller coaster bearing location to provide direct vertical support to the new roller coaster loads. The coaster's steel foundation framing and associated ballast pallets rest on 300-mm square bearing pads throughout the coaster profile. With loads as great as 20 tons under different load cases, 14-inch timber pilings were required to be precisely located directly under each bearing pad. Using timber girders to transfer the coaster loads to a typical piling grid would not prove adequate due to the high point loads of the coaster.

While these pilings addressed the overall downward loads of the general roller coaster and ballasted pallets addressed uplift loads from the coaster, the boardwalk's horizontal framing and decking was relied upon to distribute the coaster's lateral loads across a field of timber pilings. The coaster's pallet design removed the need for direct horizontal force connections, as the forces were transferred through friction from the pallet to the timber framing pier. From here, the timber's blocking, strapping, and detailing enabled a proper transfer of the horizontal sway into the many lateral braced timber pilings.

Although the timber framing was able to address most of the coaster's loads, the 72-foot lift tower contained foundation overturning forces that far exceeded the possibility of using timber framing. The tower foundation reactions exceeded 50 tons of uplift and downward forces resulting from the tower's ocean wind exposure and narrow base. The tower design did not contain the luxury of diagonal ride columns with an interconnected steel frame and loaded pallets at its base seen in most other areas of the ride, and along with a few other ride columns, required a true moment-resisting foundation system. This was accomplished by installation of a traditional combination of deep steel pilings supporting a reinforced concrete cap. Ten concrete caps fit right up into the boardwalk framing, flush with the surrounding decking, and are virtually invisible to the untrained eye. Nine of these piling caps were supported by a group of 12-inch steel or timber piles; however, the extremely large uplift forces of the lift tower required the use of 24-inch-diameter steel pipe piles underneath the tower pile cap.

Steel-framed, car-sized pallets filled with heavy stone provide dead load counterweights to the coaster's large uplift and lateral foundation forces. *Photo: Chris Spiegel Blurrevision.com*

The sand at these depths below the Jersey Shore beachfront can typically become extremely dense and refusal is typically found at 45 to 50 feet below the surface. With this experience in hand, the 24-inch pilings provided the additional surface area required for friction with the sand, without having to go any deeper than necessary. Experience and construction expertise worked together to make this newly constructed pier safely support a new coaster like no other along the entire Jersey Shore.

Conclusion

More than just a portrayal about an amusement ride, this story is about the survival of a township. For the most part, Seaside Heights is a tourist town with about 3,000 residents and closer to 30,000 during the summer months when it fills with vacationers. Many of the residents are also business owners, depending on the revenue from those who patronize the Casino Pier. After Sandy left her mark, many businesses were left floundering, which is why the success of this project and boardwalk was so essential.

Ultimately, the differences between the old pier and new are irrelevant because what's more important are the similarities: To sustain a family friendly environment by the ocean, where people can come to enjoy themselves for an entire day while supporting commerce within the township. New Jerseyans are resilient by nature, particularly when it comes to their beloved coastline. The heart of the boardwalk is finally back — proof that the thrills will continue at the Jersey Shore!

RICHARD C. MALONEY, P.E., is a principal associate and department manager of the Structural Group at Maser Consulting P.A. He has more than 25 years of experience leading a team of structural engineers that has provided the local structural engineering services for amusement rides in various locations for Six Flags Great Adventure and other major theme park clients. He has provided services for five out of the top six roller coasters in Time magazine's "2013 Top Ten Roller Coasters in the U.S." list. Born and raised at the Jersey Shore, he lives there today.

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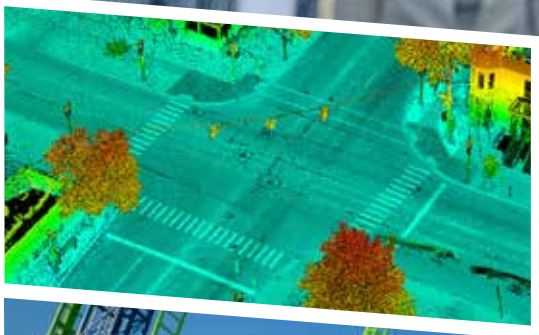

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