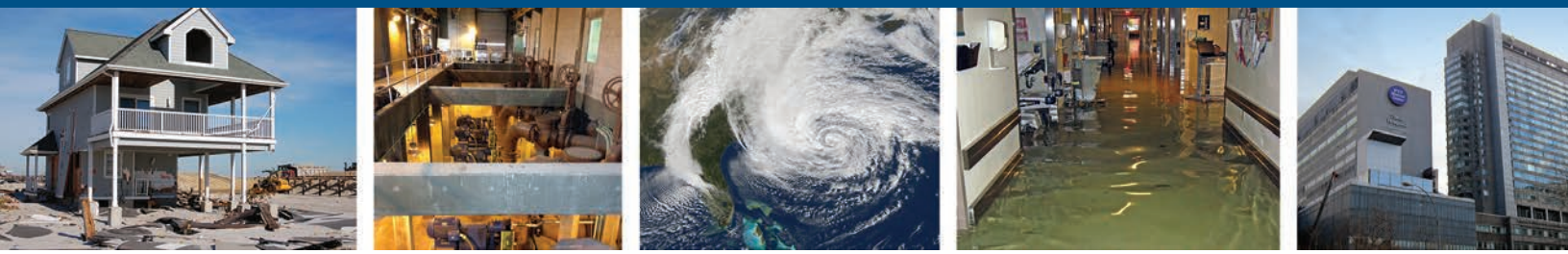


HURRICANE
SANDY
IN NEW JERSEY
AND NEW YORK

3 Performance of Low-Rise Buildings

Most of the buildings structurally damaged or destroyed by Hurricane Sandy were one- and two-family low-rise buildings.

In New York City, more than 70 percent of the structurally damaged or destroyed buildings were low-rise, combustible structures constructed before 1961 of lighter, stud-frame (wood joist) materials (New York City 2013c). The MAT visited select one- and two-family low-rise buildings across New Jersey and New York that were impacted by Hurricane Sandy. Based on their observations, the performance of these buildings during Hurricane Sandy was similar to the performance of similar building types in previous MAT investigations in which the flood and erosion conditions were comparable.

Flood information accompanying the figures within this chapter includes what is shown on FEMA flood maps relevant to the site location: the Effective FIRM and the ABFE map (where applicable). The information includes the FIRM and ABFE zone designations for the sites pictured and the FIRM/ABFE 1-percent-annual-chance elevation presented in parentheses. The approximate maximum stillwater elevations resulting from Hurricane Sandy are also presented. Refer to Section 1.4 for more information about FIRM and ABFE maps. All elevations are presented in NAVD88 unless otherwise noted.

Summary of General Observations

Other MAT observations on the performance of low-rise buildings during Hurricane Sandy are as follows:

- Buildings on strong foundations elevated above the flood level performed well, but those below the flood level either sustained inundation damage (inland and sheltered water shoreline areas) or were damaged by hydrodynamic, wave, or floating debris loads associated with high-energy storm surge (buildings near the oceanfront).

- Although dune erosion was widespread throughout the region, the presence of wide beaches and tall, wide dune fields reduced damage to buildings and infrastructure situated landward of the dunes, both low-rise buildings and other buildings. Low and narrow beaches and dunes were completely eroded in many areas, and buildings and infrastructure landward of the dunes were subject to damaging wave action and/or high-velocity flow.

EROSION CONTROL STRUCTURES DO NOT ALWAYS WITHSTAND STORM FORCES

Erosion sometimes occurs during storms despite the presence of erosion control structures such as dunes, seawalls, revetments, and toe protection. Storm waves frequently overtop, damage, or destroy poorly designed, constructed, or maintained erosion control devices. Land and buildings behind an erosion control device are not necessarily safe from coastal flood forces and storm-induced erosion or scour.

- The effectiveness of erosion control structures (e.g., bulkheads, seawalls, revetments) varied widely, depending on the height, age, and condition of the structures, and on the beach condition seaward of the structures.

Summary of Observations in New Jersey and New York

The MAT observed several issues that were more common after Hurricane Sandy in New Jersey and New York than in other recent storms investigated by MATs:

- Many buildings affected by flooding from Hurricane Sandy had basements with finishes, contents, and MEP systems that were damaged.

- Many older buildings did not have continuous load paths because of the original construction or because the load paths had been modified or had degraded. This issue was the result of the fact that a large portion of the building stock was several decades old.

- The use or modification of pre-existing foundations in the buildings observed by the MAT added to load path continuity problems because the old foundations were not constructed to newer codes that provide better resistance to hazard forces and risks associated with the sites of the buildings.

- Load path connection failures between the foundation and the building were common in both New Jersey and New York. Older and newer homes both typically lacked a designed load-path connection. Failures of older homes that had load path connectors were the result of insufficient connection points, undersized connections, or significant corrosion.

- Many of the strap connections hindered only uplift and did not address the shear loads. When the houses with load paths constructed to resist primarily uplift were subjected to shear forces during the storm event, they were susceptible to failures from connectors rolling and fasteners pulling out, failure of the connection, or beams failing from insufficient strap length.

- Many buildings were located within 10 to 20 feet of a shore-parallel erosion control structure (e.g., seawall, bulkhead, revetment), many of which were overtopped by storm waves and/or surge during Hurricane Sandy. The overtopping resulted in flood and/or erosion damage to nearby buildings even when the erosion control structure survived. The proximity of the buildings to the erosion control structures is apparently a result of the age of the waterfront communities, many of which are more than 100 years old. Shoreline erosion has been ongoing during this time, resulting in the construction of many erosion control structures.

- Wind damage to buildings was observed even though Hurricane Sandy was not a design wind event. Most of the damage was to building envelopes and was related to the presence of multiple layers of building siding that appeared to have been added over time. Although most of the damage was minor, envelope damage such as this can create wind-borne debris and allow water intrusion into the building.

- There were burned residences in some of the communities visited. Other MATs deployed over the past few decades have only rarely observed fire damage after a storm event. The causes of the fires are outside of the MAT's purview, but the prevalence of older, densely packed buildings likely contributed to the spread of fire once a fire was initiated.

3.1 Performance Relative to Flood and Erosion

Several building characteristics determined the nature and extent of flood and erosion damage: the location of the building (siting), elevation of the lowest floor, building foundation, load-path connections, presence or absence of subgrade areas, and location of MEP systems.

3.1.1 Effect of Siting on Building Performance

Building location plays a major role in determining the type and severity of flood hazards to which buildings may be subjected. The MAT observed examples where each of the following siting parameters was an important contributor to building damage:

- Building location and wave exposure
  - Location of the building relative to the flood source
  - Exposure to storm-generated waves
- Beach and dune condition
  - Beach and dune conditions seaward of the building (for buildings near the open coast)
- Barrier island breaches

- Location of the building relative to potential barrier island breaches and overwash areas

- Features and structures that focus flow
  - Location of the building relative to natural features, buildings, or structures that could focus or channel flow toward the building

- Proximity to erosion control structures
  - Location of the building relative to an erosion control structure, and the characteristics and condition of that structure

- Proximity to flood-borne debris sources
  - Location of the building relative to flood-borne debris sources (e.g., other buildings, boardwalks, marinas, boats)

3.1.1.1 Building Location and Wave Exposure

For buildings with similar elevations, the location of the building relative to the shoreline and its exposure to storm-generated waves determine the severity of wave forces that impact a building or building site.

In general, buildings close to the ***ocean*** shoreline are subject to more wave, velocity flow, and erosion damage (Figure 3-1) than buildings far from the shoreline (Figure 3-2), where inundation is the dominant flood hazard.

Figure 3-1: Wave, storm surge, and erosion damage to oceanfront house at Belle Harbor, Rockaway, NY

Flood Hazard Data: FIRM = Zone X
ABFE = Zone A (11 feet)
Sandy floodwater elevation = 11 feet NAVD88

Flood Hazard Data: FIRM = Zone AE (13 feet)
ABFE = Not available. ABFEs were not released for Nassau County because the FIRMs are up to date.
Sandy floodwater elevation = 11 feet NAVD88

Figure 3-2: Inland flood inundation resulted in damaged contents but no structural damage to this house in Long Beach, NY

Buildings close to ***bay and sheltered water*** shorelines can be damaged by locally generated waves even when those buildings are protected from ocean waves. However, wave damage in these locations is usually limited to those buildings closest to the shoreline.

The MAT observed some wave damage on bay shorelines not subject to ocean waves. However, on very small or narrow water bodies, the wave heights are small and the wave periods short, which typically causes inundation-type damage with water sloshing against a building rather than wave-action damage.

This distinction between wave and inundation damage was confirmed by the DOB, whose personnel examined building damage and identified the cause and severity of flood damage by general location (New York City 2013c):

- Areas along Staten Island, the Rockaways, Coney Island, and the south shore of Long Island in Brooklyn and Queens were subject to damage caused by inundation and wave action
- Areas in Manhattan, the Bronx, and the north shore of Brooklyn and Queens were more likely subject to damage caused by floodwater inundation

Of the buildings that were identified as suffering severe damage (red tagged[1] or destroyed), 97 percent of the damage was from surge and wave action.

1 "Tagged" refers to the following designations: red tag = damage (often structural) that prohibits re-entry or re-occupancy; yellow tag = damaged, restricted re-entry, or reuse.

3.1.1.2 Beach and Dune Condition

All other factors being equal, beach and dune condition plays a central role in the degree of wave and flood damage to landward and upland buildings. The presence of wide beaches and tall, wide dunes prior to a storm are often the best defense, whereas narrow beaches and smaller dunes provide little protection against design-level coastal flood events. Dune volume above the 1-percent-annual-chance and seaward of the primary dune crest is a critical factor in determining the protective capacity of a dune. Two examples are discussed below, one in New Jersey and one in New York.

Two New Jersey beachfront communities separated by approximately 1 mile from each other—Seaside Park and Ortley Beach—illustrate the role that beaches and dunes play in damage reduction. Ortley Beach had a relatively narrow beach and low dune and sustained some of the most severe wave and erosion damage observed by the MAT (Figure 3-3). In contrast, Seaside Park had a wide beach and large dunes that protected landward areas, and observed damage was caused mostly by inundation (Figure 3-4). The Richard Stockton College Coastal Research Center report (2012) summarizes damage to the two dune systems and communities (see text box on page 3-7).

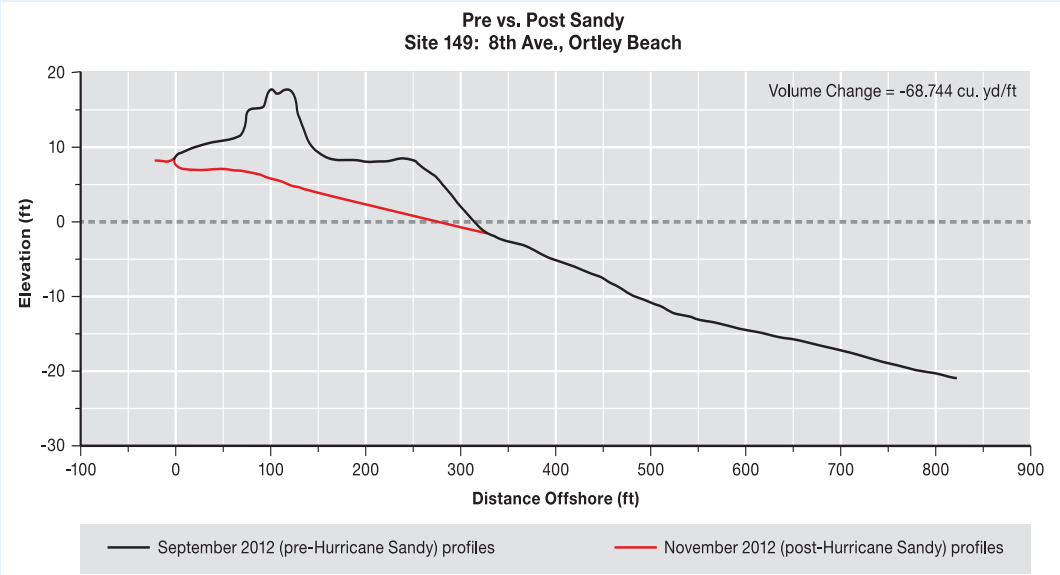
Flood Hazard Data: Sandy floodwater elevation = 8 feet NAVD88

Figure 3-3: Post-Sandy photograph of Ortley Beach, NJ, in the vicinity of 8th Avenue and New Jersey Beach that shows the loss of a dune, boardwalk, and road and severe damage to homes

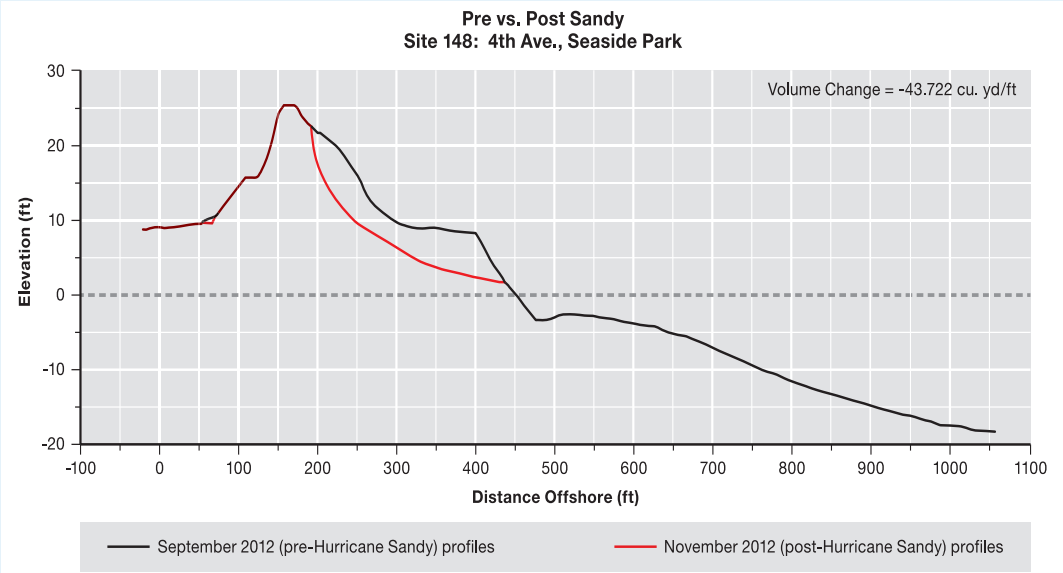
RICHARD STOCKTON COLLEGE COASTAL RESEARCH CENTER REPORT

Taken from Richard Stockton College, Coastal Research Center report (2012) on Hurricane Sandy damage to Northern Ocean County, NJ.

Ortley Beach: "Ortley Beach had a 25-year history of shoreline retreat and sand volume loss as determined by the Coastal Center's 8th Avenue survey site. Ocean Avenue, the boardwalk and many homes were completely destroyed in this segment. Site #149 located at 8th Avenue showed a sand volume loss of 68.7 yds^3/ft with over 10 feet of dune removed and pushed landward in overwash deposits. Everything was stripped away leaving a flat, featureless beach sloping into the sea. This was the site of the worst and most widespread structural damage in Northern Ocean County."



Seaside Park: "The pre- and post-storm analysis for site #148 at 4th Avenue showed that a portion of the fore-dune was removed during the storm; however, the remainder of the dune provided protection to the landward structures. No overwash occurred at the profile location. The dune's approximate 25-foot elevation (NAVD88) and 150-foot width (at the base) combined with a 150-foot wide beach provided adequate protection from tidal surge and wave action… While homes sustained flood damage in this segment from Barnegat Bay, loss of infra-structure and homes was minimized due to the larger beach-dune system hindering waves crossing over land."



Flood Hazard Data: Sandy floodwater elevation = 6 feet NAVD88

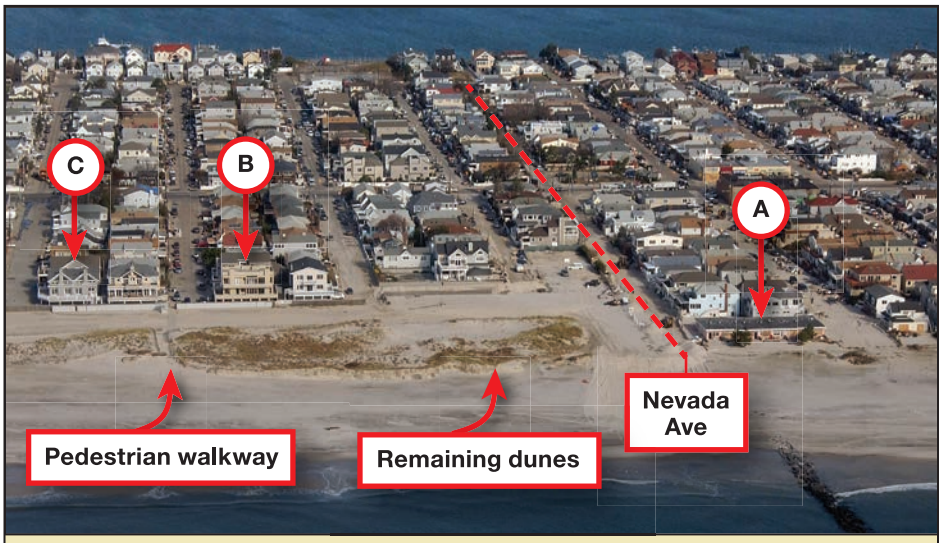
Figure 3-4: Post-Sandy photograph of Seaside Park, NJ, in the vicinity of 6th Avenue and two blocks south of New Jersey Beach. Note the intact dune with scarping, which protected the boardwalk, road, and homes.

The second example of the value of wide and tall dunes—and siting buildings farther from the shoreline—is from New York near the Village of East Atlantic Beach, located west of Nevada Avenue and east of the City of Long Beach. Figure 3-5 shows a pre-storm photograph of the area and Figure 3-6 is a photograph of the area after the storm.

Three buildings are marked on Figures 3-5 and 3-6. Building A is a one-story motel between the seaward ends of Nevada Avenue and Ohio Avenue in Long Beach, NY, and Buildings B and C are houses at the seaward ends of Rochester Avenue and Buffalo Avenue in East Atlantic Beach, NY. Building A is situated approximately 200 feet seaward of Buildings B and C. All buildings had seaward dunes prior to Hurricane Sandy, but the dunes in front of Buildings B and C were wider and located farther from the water line.

Flood Hazard Data: Building A: FIRM = Zone AE (15 feet)
Buildings B and C: FIRM = Zone AE (14 feet)
Buildings A, B, and C:
ABFE = Not available. ABFEs were not released for Nassau County because the FIRMs are up to date.
Sandy floodwater elevation = 11 feet NAVD88

Figure 3-5:
Area near Village of East Atlantic Beach, NY, showing beach and dune conditions before Hurricane Sandy
SOURCE: GOOGLE EARTH



Flood Hazard Data: Building A: FIRM = Zone AE (15 feet)
Buildings B and C: FIRM = Zone AE (14 feet)
Buildings A, B, and C:
ABFE = Not available. ABFEs were not released for Nassau County because the FIRMs are up to date.
Sandy floodwater elevation = 11 feet NAVD88

Figure 3-6:
Post-Sandy dune loss near Village of East Atlantic Beach, NY, including the near-complete loss of dunes in front of Building A
SOURCE: USGS

Figure 3-6 shows a post-storm photograph of the area. The dune seaward of Building A was largely removed by Hurricane Sandy, and sand overwash penetrated several hundred feet up Nevada Avenue. In December 2012, the MAT observed flood HWMs indicating that flood and overwash levels reached approximately 3 to 4 feet near Building A, which sustained surge and inundation damage that necessitated replacing some doors, a window, and interior walls (Figure 3-7). As shown on Figure 3-6, the seaward side of the dune in front of Buildings B and C eroded, but the landward section remained and offered substantial protection to houses landward of the dune. There was no evidence of significant flood or overwash near Buildings B and C (Figure 3-8), although pedestrian pathways through the dunes were weak points where erosion, landward flooding, and overwash were focused.

Figure 3-7:
Building A (location shown in Figure 3-6) lost doors and a window; interior repair work shown in inset (East Atlantic Beach, NY)

3.1.1.3 Barrier Island Breaches

Some barrier islands were breached by Hurricane Sandy, most notably, Mantoloking, NJ (Figure 3-9); Fire Island, NY; and Westhampton, NY. Almost all of the houses in and near the Mantoloking breach were heavily damaged or destroyed. One house in the center of the breach survived, presumably because of its pile foundation and elevation. The breach at Mantoloking, NJ, has been repaired by the New Jersey Department of Transportation.

Figure 3-8:
View east past Building C (location shown in Figure 3-6) toward Building B shows no evidence of Sandy flood damage or sand overwash (East Atlantic Beach, NY)

Two breaches occurred across the Fire Island National Seashore area near Smith Point and Old Inlet, NY, and one breach occurred at Westhampton Beach. One building near a breach survived Sandy but a subsequent storm knocked the building off its foundation. Two of the breaches (one at Westhampton Beach and another at Smith Point Beach) were repaired by the State and the U.S. Army Corps of Engineers, while one of the breaches at Fire Island remains open as of October 2013.

Flood Hazard Data: FIRM = Zone AE (5 feet)
ABFE = Zone A (8 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-9: Breach at barrier island, Mantoloking, NJ; note house that survived at the center of the breach
SOURCE: USFWS

3.1.1.4 Features and Structures That Focus Flow

Gaps in dunes, streets, and areas between buildings or other structures often channel floodwater flow. This process tends to be highly localized, and seemingly small obstructions or changes in elevation can facilitate flow channelization. Figure 3-10 shows an area approximately 0.8 mile north of the Mantoloking breach shown in Figure 3-9 that illustrates this effect. The MAT observed many significant flow channels in this area and four are discussed here (labeled channels A through D). Flow channel A was the largest and resulted in a house being washed into the bay (Figure 3-11). Flow channels B and C developed to the south and north of a house, and exited into the bay across a bulkhead that was at a lower elevation than neighboring bulkheads. The low bulkhead elevation apparently focused the flow coming across the island and between the houses, leading to scour around the shallow foundation of the house (Figure 3-12). Flow channel D developed where a bulkhead failed just north of a house that was undermined and collapsed (Figure 3-13). The house was on a shallow foundation, while its surviving neighbor to the north was on a piling and grade beam foundation.

3.1.1.5 Proximity to Erosion Control Structures

Many New Jersey and New York coastal communities were settled more than100 years ago. Shoreline erosion has been ongoing during much of this period, and the shorelines are highly armored with bulkheads, seawalls, rock revetments, groins, and breakwaters. Many beachfront areas have undergone periodic beach nourishment over the past several decades. In fact, Coney Island was the site of the first large-scale beach nourishment project in the United States in 1922–1923, when over 1 million cubic yards of sand was dredged from offshore and placed along the shoreline (Dornhelm 1995).

Figure 3-10:
Flow channels A–D (dashed lines) formed between buildings on the bayward side of the barrier island at Mantoloking, NJ, and washed sand into the bay at their ends
SOURCE: NASA

Flood Hazard Data: FIRM = Zone AE (5 feet)
ABFE = Zone V (10 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-11: House washed from the barrier island into the bay at the site of flow channel A (see Figure 3-10) (Mantoloking, NJ)

Flood Hazard Data: FIRM = Zone AE (5 feet)
ABFE = Zone V (10 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-12: Undermined house with damaged foundation between flow channels B and C (see Figure 3-10) (Mantoloking, NJ)

Flood Hazard Data: FIRM = Zone AE (5 feet)
ABFE = Zone V (10 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-13: Undermined house south of flow channel D (see Figure 3-10) (Mantoloking, NJ)

The convergence of old development and shoreline erosion means that buildings and infrastructure are often situated immediately landward of shore-parallel erosion control structures (seawalls, bulkheads, revetments). These structures may or may not be effective in protecting upland development during a severe coastal flood event, and the closer the development is to the structure, the greater the likelihood that flood or erosion damage will affect that development.[2] Even when erosion control structures remain intact, they can be overtopped by waves (and sometimes surge) if their elevation is low.

The MAT observed many instances of damage to buildings where erosion control structures were damaged or failed, and many instances of damage to buildings where intact erosion control structures were overtopped. Failed erosion control structures observed by the MAT included those with displaced vertical wall sections (Figure 3-14) and those where rocks from revetments were cast landward (Figure 3-15). The timber bulkhead in Figure 3-16 was overtopped, backfill was lost, and the adjacent house was damaged. The damaged houses shown in Figures 3-15 and 3-16 were both approximately

Figure 3-14:
Concrete seawall failed, resulting in damage to the house situated approximately 15 feet landward of the wall (Seagate, Coney Island, NY)

Flood Hazard Data: FIRM = Shaded Zone X
ABFE = Zone V (16 feet)
Sandy floodwater elevation = 13 feet NAVD88

Figure 3-15:
Rocks and rubble from a revetment were thrown and/or washed approximately 50 to 150 feet landward onto lawns and against houses at Manhattan Beach, Coney Island, NY

Flood Hazard Data: FIRM = Zone X
ABFE = Zone A (11 feet)
Sandy floodwater elevation = 11 feet NAVD88

2 NJ Coastal Zone management rule for Coastal High Hazard Areas at N.J.A.C. 7:7E-3.18(a) defines the "V zone" as that shown on the FIRM, plus areas within 25 feet of oceanfront erosion control structures. This provision was adopted based on post-storm damage surveys by the State that documented the impact of wave runup and overtopping of structures on landward development.

Flood Hazard Data: FIRM = Zone AO (flood depth 1 foot above ground surface)
ABFE = Zone A (7 feet)
Sandy floodwater elevation = 9 feet NAVD88

Figure 3-16: Timber bulkhead was overtopped, resulting in lost backfill and damage to the house situated approximately 15 feet landward of the bulkhead (Lavallette, NJ)

15 feet landward of vertical wall erosion control structures. The houses observed by the MAT that were within 20 feet of erosion control structures and exposed to ocean waves during Hurricane Sandy had almost always sustained significant flood and/or erosion damage.

3.1.1.6 Proximity to Flood-Borne Debris Sources

Flood-borne debris was plentiful during Sandy and generally consisted of pieces of destroyed buildings, floating (intact) homes, sections of boardwalks, vehicles, and small debris. The larger debris items caused structural damage in some cases. Two representative examples are provided here: a house that washed off its foundation and into an adjacent house in Lindenhurst, Long Island, NY, and a section of boardwalk in Ortley Beach, NJ, that became flood-borne debris.

The house that washed off its foundation was an older house on the south shore of Long Island, not well-connected to its foundation piers, that was exposed to storm surge and waves generated in Great South Bay (Figure 3-17). The house washed off its foundation and caused damage to the exterior walls of the neighboring house.

The second example, the boardwalk debris from Ortley Beach, NJ, is illustrated in Figure 3-18. The house shown in Figure 3-18, which had a wood column knocked out, was near a damaged boardwalk. Large debris noted by the MAT in the vicinity of the house included pieces of the boardwalk, asphalt pavement, and floating pieces of houses. Which particular piece of debris caused the column failure at the house is not known, but large debris similar to the boardwalk debris or another piece of large debris (which could have been asphalt pavement lifted by the flow, or a floating house or large section thereof) likely caused the damage.

Figure 3-17:
Bayfront house washed off its foundation and into its neighbor (Lindenhurst, NY)

Flood Hazard Data: FIRM = Zone VE (8 feet)
ABFE = Not available. ABFEs were not released for Suffolk County because the FIRMs are up to date.
Sandy floodwater elevation = 7 feet NAVD88

Flood Hazard Data: FIRM = Zone VE (10 feet)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 8 feet NAVD88

Figure 3-18:
Wood column knocked out, probably by floating debris, such as a section of boardwalk (shown in bottom inset). Top right inset shows the failed column and middle right inset shows the failed connection between the column and the column footing (Ortley Beach, NJ).

3.1.2 Elevation and Freeboard

Building floor elevation relative to the flood level was one of the principal determinants of flood damage. Houses whose lowest floors were below the flood level were inundated at best or heavily damaged or destroyed by waves and debris at worst.

Depending on location, Hurricane Sandy flood levels ranged from near the Effective BFE to several feet above the BFE. In the latter case, houses constructed with freeboard above the BFE had less flood damage to the building (refer to Section 1.4 for definition of freeboard). Figures 3-19 and 3-20 show a side-by-side example of two canal-front homes in Beach Haven West, NJ. The house on the left is a pre-FIRM house on a raised slab foundation. The Hurricane Sandy flood level was approximately 2 feet above the slab, and estimated to be less than 1 foot above the BFE. The house on the right was under construction at the time of Hurricane Sandy (only the foundation had been installed), but 2 feet of freeboard was included in the design, and the floor would have been at least 1 foot above the flood level.

Figures 3-21, 3-22, and 3-23 show houses across the street from each other in Beach Haven, NJ. Most of the oceanfront homes are elevated one story above grade on pile foundations (garage level is at grade) and the houses across the street are elevated approximately 2 feet above grade on a pile foundation.

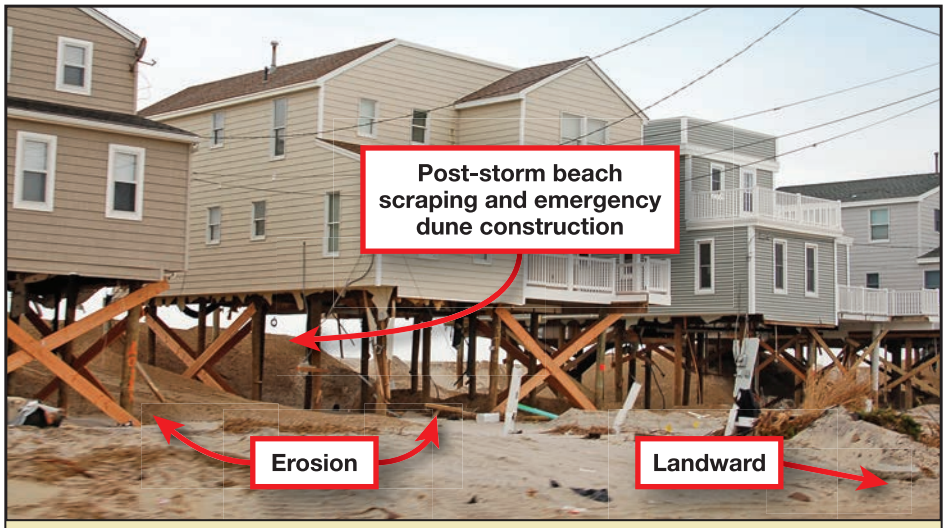
Flood Hazard Data: FIRM = Zone AE (8 feet)
ABFE = Zone V (10 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-19: Pre-FIRM house and adjacent elevated house under construction (Beach Haven West, NJ)

Figure 3-20:
Side-by-side view of houses shown in Figure 3-19;the Hurricane Sandy flood level was approximately 2 feet above the slab of the house on the left and below the floor level of the house under construction on the right (Beach Haven West, NJ)

When the dune was lost, as much as 5 feet of erosion occurred around the seaward pile foundations of the oceanfront homes (Figure 3-22). Much of that sand washed across the street and buried lots and roads. The house across the street washed off its foundation and into a neighboring home (Figure 3-23).

Figure 3-21:
Dune was lost and there was several feet of erosion around the pile foundations of oceanfront homes (see Figure 3-22) (Beach Haven, NJ). A lower elevation house across the street (circled) washed off its pile foundation and into a neighboring home (Figure 3-23).



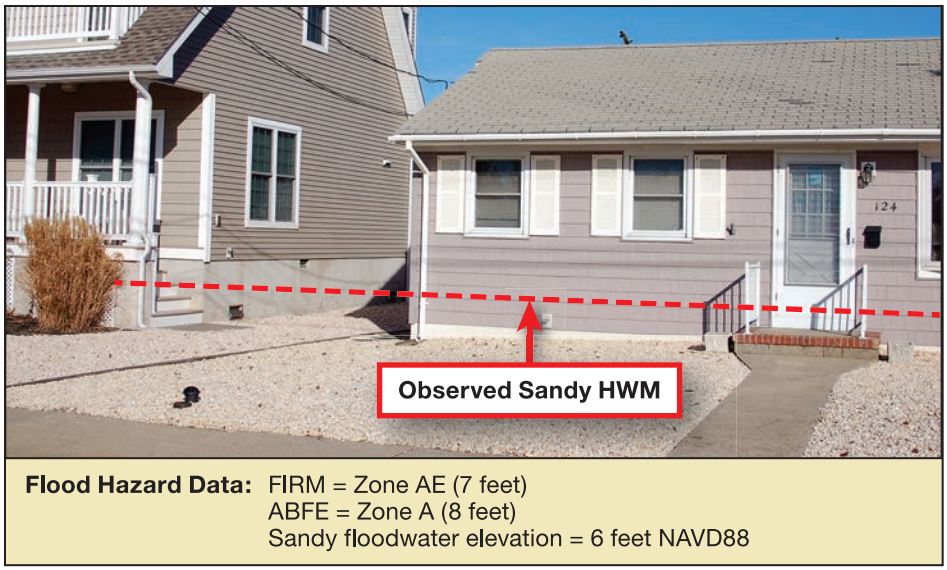
Flood Hazard Data: FIRM = Zone VE (10 feet)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 8 feet NAVD88

Figure 3-22: Dune next to these oceanfront houses was lost and an estimated 5 feet of erosion was observed under the seaward ends of the pile-supported buildings; cross-bracing for pile foundations shown in photograph was placed following the storm to prevent foundation collapses (Beach Haven, NJ)

Flood Hazard Data: FIRM = Zone AE (8 feet)
ABFE = Zone A (9 feet)
Sandy floodwater elevation = 8 feet NAVD88

Figure 3-23: House across the street from the pile-supported houses in Figure 3-22 was washed off its low pile foundation and shifted landward into a neighbor (Beach Haven West, NJ)

The final example of the value of freeboard is a house in Seaside Park, NJ. The house was elevated on a crawlspace foundation with 2 feet of freeboard (chosen by the owner). Hurricane Sandy floodwater entered the crawlspace via flood vents as expected, but the elevated house remained dry. The adjacent homes were not elevated, and floodwater inundated those homes above the floor (Figure 3-24).



Flood Hazard Data: FIRM = Zone AE (7 feet)
ABFE = Zone A (8 feet)
Sandy floodwater elevation = 6 feet NAVD88

Figure 3-24:
The house on the left was constructed with 2 feet of freeboard and remained dry during Hurricane Sandy; the house on the right was flooded above the floor level (Seaside Park, NJ)

3.1.3 Foundation Performance

The MAT observed a variety of foundation types, from wood to masonry to concrete, and with varying embedment depths, from shallow to deep. As expected, older, shallow foundations were observed to fail more frequently from erosion and local scour, regardless of the foundation material used. Deep foundations performed better in situations where erosion and scour occurred. Open foundations, such as piles or columns, performed better than solid wall foundations where waves or water moved at apparently high velocities.

The MAT also observed something not usually seen in post-storm inspections: reuse of old foundations for elevating old buildings or constructing new buildings. In some cases, the old foundations appeared largely unchanged, while in others, the new foundation elements were placed on top of or adjacent to old elements. As-built drawings and calculations were not available, so the degree of attention to design of these foundations is unknown, but the use and modification of pre-existing foundations appear to have led to additional load-path continuity problems.

Shallow versus Deep Foundations. Figures 3-25, 3-26, and 3-27 show the effect of foundation type on building performance in the area near the main breach at Mantoloking, NJ. Figure 3-25 shows the locations of two houses: House A, approximately 500 feet south of the main breach, and House B, approximately 500 feet north of the main breach. The MAT observed secondary flow channels near each of the houses, and flow depths above ground elevations near the houses were probably shallow (in the range of 2 to 3 feet), but flow velocities were probably quite high (several nearby homes in the area were swept off their foundations). Figure 3-26 looks north (toward the breach) past House A; House A was on a shallow masonry foundation and tipped into the secondary channel that formed on the north side of the house. House B shown in Figure 3-27 was constructed on a pile foundation with concrete grade beams. Although some of the columns supporting the deck on House B failed, the main foundation of the house remained in place despite scour around the foundation.

Figure 3-25:
Locations of two houses, House A (see Figure 3-26) and House B (see Figure 3-27), near the main breach at Mantoloking, NJ
SOURCE: NOAA

Flood Hazard Data: FIRM = Zone AE (5 feet)
ABFE = Zone V (10 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-26:
View looking north past House A toward the main breach, Mantoloking, NJ, shows the house tipped into the secondary scour channel that formed on the north side of the house. The area around the east and north sides of the house had been backfilled by the time photograph was taken.

Figure 3-27:
House B was under construction at the time of Hurricane Sandy; although the porch on the southeast corner collapsed into the secondary channel that formed on this side of the house, the main house survived because of its deep foundation. Inset shows grade beam supported by pilings (Mantoloking, NJ).

Many other shallow-versus-deep comparisons were evident in the Mantoloking area, where the Sandy damage was some of the worst seen by the MAT. In the area between the Mantoloking main breach and 1 mile to the north, there were approximately 55 oceanfront homes before Hurricane Sandy. After Hurricane Sandy, more than half were destroyed or had been heavily damaged by erosion. Almost all of the surviving houses—and few of the collapsed houses—were built on pile foundations. Figures 3-28 and 3-29 show pre- and post-Hurricane Sandy photographs of two adjacent oceanfront homes just north of Lyman Avenue (0.8 mile north of the main breach). House A was on a shallow foundation, and House B was on a pile foundation; House A was destroyed, but House B survived.

Figure 3-30 shows a house in a hard-hit neighborhood on the east side of Union Beach, NJ. The house was approximately 400 feet from Raritan Bay. The one-story house looked no more than a few years old and was elevated on a masonry wall foundation. The wall failed, and the house washed off the foundation (the order is uncertain).

Figure 3-31 shows a third-row house (approximately 300 feet from the Raritan Bay shoreline) in the Tottenville neighborhood of southwest Staten Island, NY. The habitable space is elevated over a garage. The garage walls are composed of a short masonry or concrete wall ("knee" wall) that extends approximately 4 feet above grade, and a wood-frame cripple wall atop the knee wall. The MAT observed many buildings with similar construction in this neighborhood. In many cases, the surge washed through the cripple wall section.

Flood Hazard Data: FIRM = Zone VE (12 feet)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-28:
Pre-Hurricane Sandy photograph showing the area near House A and House B, approximately 0.8 mile north of the main breach at Mantoloking, NJ
SOURCE: USGS

Figure 3-29:
View looking across the former location of House A toward House B; inset shows remnant of a shallow footing for masonry pier at House A (Mantoloking, NJ)

Flood Hazard Data: FIRM = Zone AE (11 feet)
ABFE = Zone A (14 feet)
Sandy floodwater elevation = 13 feet NAVD88

Figure 3-30:
House washed off its masonry wall foundation, which collapsed (Union Beach, NJ)

Flood Hazard Data: FIRM = Zone VE (11 feet)
ABFE = Zone V (16 feet)
Sandy floodwater elevation = 13 feet NAVD88

Figure 3-31:
House elevated on a concrete or masonry knee wall and a wood-frame cripple wall was damaged when storm surge washed through the cripple wall section (side wall of house faced the bay) (Staten Island, NY)

Combinations of Foundation Systems. The MAT observed several instances where combinations of foundation systems were used under a single building, possibly a result of reusing old foundations when buildings were repaired, rebuilt, expanded, or elevated. The ages of the buildings are unknown, but many are apparently pre-FIRM buildings that have been modified over the years. Although the reasons for the foundation configurations are unknown, these foundations—and/or the connections to them—often failed to withstand the loads and conditions to which they were subject. Buildings were damaged in some cases and collapsed in others. The MAT observed several examples of these combined foundation systems over a short stretch of beach in Normandy Beach, NJ.

One example is an oceanfront house, constructed behind a dune, with a combination of masonry walls and timber piles used to support the house. The dune eroded, and the foundation elements were exposed to surge and waves. Figure 3-32 shows that the shore-parallel masonry wall collapsed, and the red circles show the failed connections between the timber piles and floor beam.

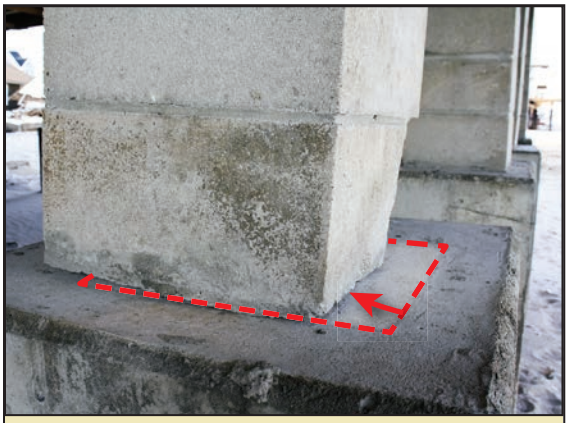
The second example is another oceanfront house in Normandy Beach elevated over a garage set into the back of the dune. The house was mostly supported by a deep, open foundation. The landward portion of the house was supported by piles with a concrete grade beam, steel pipe columns, and masonry (garage) walls above. The seaward portion of the house was supported by timber piles with concrete pile caps and masonry columns above the caps (Figure 3-33). The pile caps varied in depth from approximately 1 foot to 5 feet. The MAT observed movement of some of the masonry columns (Figure 3-34), indicating a lack of ties between the columns and pile caps or insufficient ties between the two.

Flood Hazard Data: FIRM = Zone AO (flood depth 2 feet above ground surface)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-32: View of seaward side of the house shows combination foundation of masonry walls and timber piles; red circles indicate failed connections (Normandy Beach, NJ)

Flood Hazard Data: FIRM = Zone VE (10 feet)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-33: Seaward side of house supported by an open foundation (Normandy Beach, NJ)



Flood Hazard Data:
FIRM = Zone VE (10 feet)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-34: Movement of masonry columns where they join the pile caps (Normandy Beach, NJ)

The third example is an oceanfront house in Normandy Beach, NJ, that was elevated on a combination of timber piles, with wood beams and steel beams above. A timber bulkhead with a masonry wall above was attached to the perimeter piles (Figures 3-35 and 3-36). The seaward wall was pushed in, probably by waves and surge, and caused the failure of several timber piles and beams.

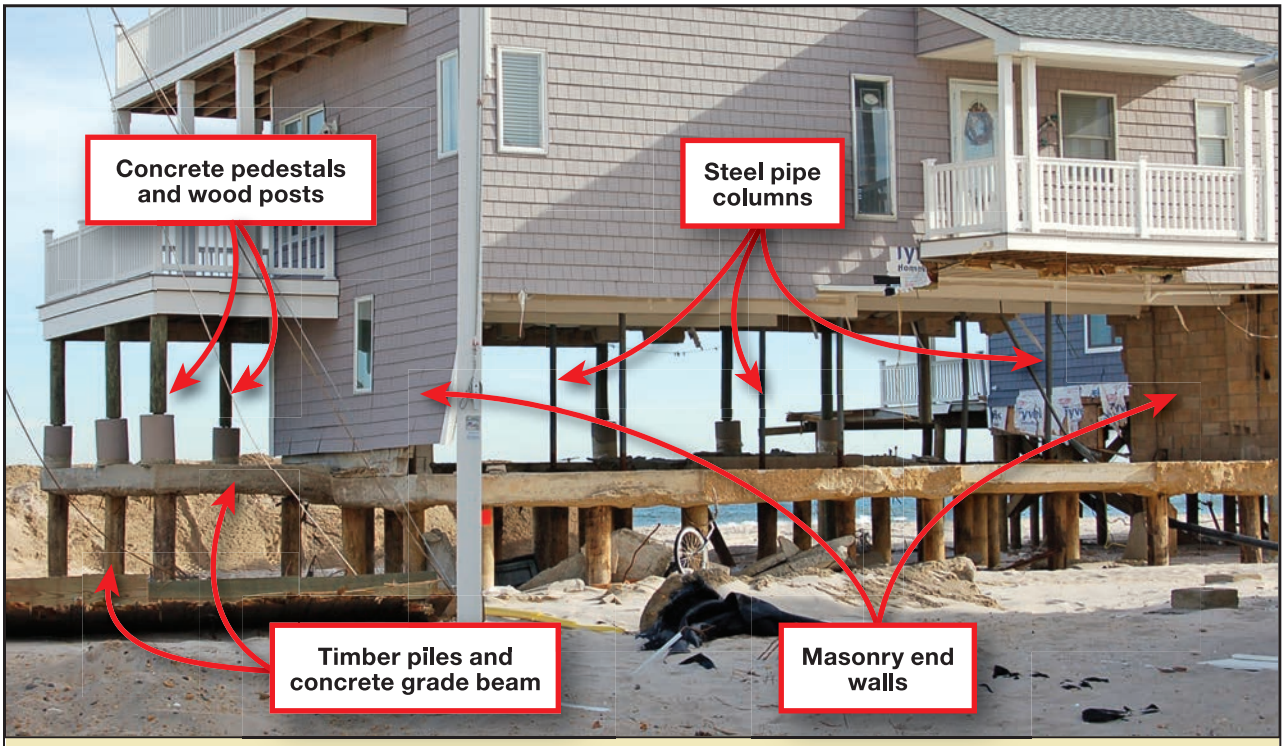
Flood Hazard Data: FIRM = Zone AO (flood depth 2 feet above ground surface)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-35:
Elevated house supported by timber piles with a perimeter timber and masonry wall attached (Normandy Beach, NJ)

Flood Hazard Data: FIRM = Zone AO (flood depth 2 feet above ground surface)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 7 feet NAVD88

Figure 3-36:
Seaward piles and beams failed, probably when the seaward wall was pushed in by surge and waves (Normandy Beach, NJ)

The final example is a two-story residential building elevated above ground-level parking in Lavallette, NJ (Figure 3-37). The foundation of the elevated building is a combination of concrete grade beams atop timber piles, with three types of vertical structural elements above the grade beam: cast concrete pedestals with wood posts supporting elevated decks; masonry walls supporting the ends of the building; and steel pipe columns supporting the interior of the building. The timber piles and grade beams were exposed by approximately 5 feet of erosion. The masonry end walls were damaged (Figure 3-38), and one of the concrete pedestals was dislodged (Figure 3-39). Load path continuity from the foundation piles to the concrete pedestals to wood posts was compromised, and the masonry end walls were clearly inadequate for the flood loads encountered during Hurricane Sandy.



Flood Hazard Data: FIRM = Shaded Zone X
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 9 feet NAVD88

Figure 3-37: Looking seaward through the parking level of a building elevated on multiple types of foundation elements (Lavallette, NJ)

Figure 3-38:
Damaged masonry end wall (north wall) of the building shown in Figure 3-37 (Lavallette, NJ)

Figure 3-39:
Failed concrete pedestal on the seaward side of the building shown in Figure 3-37 (Lavallette, NJ)

3.1.4 Connections between Foundation and Building

In many instances, the MAT observed insufficient connections between foundations and the buildings above. Although the load path to resist uplift and shear was not visible for every structure observed, the framing inspections revealed that, in most cases, the primary connection between the building and the foundation was accomplished through straps connecting the floor joists to the foundation beams. Load paths using hold-down anchors at the corners of shear walls were rarely observed. In most cases, the strapping used did not appear to be designed for both shear and uplift, and the straps were either insufficiently sized or there were not enough connectors. In several cases, the MAT observed significant corrosion of the connectors, which severely compromised the overall load path of the building. Foundation elements in several cases were not tested during Hurricane Sandy because there was an insufficient load path associated with the foundation-to-building connection. Poor load path connections in many of the buildings observed by the MAT allowed the buildings to become disconnected from their foundation. When struck by flood forces, these houses either moved entirely off their foundation, destroying the buildings, or allowed them to float off their foundation. Although some foundation failures were observed in situations where the building loads were not transferred to the foundation, most of the piles and beams remained in place even after being exposed to storm surge, and even when the surge overtopped the foundation elements.

The MAT observed numerous instances where the connections between the foundation and the building failed. The following examples are representative of the types of failures observed.

Seaside Heights, NJ – Connector Length

Figure 3-40 shows houses from the beachside community of Seaside Heights, NJ. Two houses, labeled House A and House B, were subjected to similar flood forces with different outcomes. The houses were at approximately the same elevation and similarly protected from storm surge by another row of houses along the shoreline. House A completely slid off its foundation and was resting against another house farther inland, while House B remained in place.

The foundation for House A consisted of timber piles with wood beams, on top of which the wood-frame house was attached. The house was attached to the foundation using small clips typically used to connect rafters to top plates and used only three nails at each end to make the connection. That MAT observed that many of the connections at House A appeared to have either sheared, or the nails withdrew from the floor joists they were attached to as the connector rotated (Figure 3-41). The failure of the connections allowed the house to slide off its foundation.

Although directly across the street from House A, House B remained in place. House B sustained some damage, but remained on top of its foundation. Although House A was framed with dimensional lumber floor joists rather than the engineered floor joists used for House B, the primary observed difference between the two houses with respect to the load path was the length of the load path connectors between the foundation beam and the floor framing. The load path connectors at House B were significantly longer than those across the street at House A (Figure 3-42). The House B connectors extended more than half the depth of the floor joists and more than half the depth of the foundation beam. Although the House B straps did not have the proper total number of nails in many of the connectors observed, the additional length of the connector improved the load distribution along the beam and floor joist. Neither House A nor House B appeared to have visible corrosion on the straps.

Flood Hazard Data: FIRM = Zone VE (10 feet)
ABFE = Zone V (14 feet)
Sandy floodwater elevation = 8 feet NAVD88

Figure 3-40:
Two houses (labeled A and B) near Harding Avenue in Seaside Heights, NJ, that experienced similar exposure to storm surge with different results

Figure 3-41:
In House A, a series of connectors failed due to withdrawal when the building was subjected to uplift and shear (Seaside Heights, NJ)

Figure 3-42:
In House B, a series of longer strap connectors (inside red circle) between the beam and floor joist maintained connection during Hurricane Sandy (Seaside Heights, NJ)

Beach Haven, NJ – Connector Length

Figure 3-43 shows a foundation beam that split because of a compromised load path connection. The connectors were too short, and the alignment of the connectors, combined with the uplift loads associated with high winds and flood levels exceeding the floor system, caused the foundation beam to split. Connector straps along one side of the beam were nailed into only the upper third of the beam depth, resulting in the nails splitting the grain of the wood; the beam split and failed, allowing the house to float back into an adjacent house. Although assessing whether the uplift on the house would have exceeded the capacity of the connectors would be difficult, the beam would probably not have split with longer load path connector straps.

Figure 3-43:
Beam failed due to a series of short connectors installed near the top of the beam, allowing it to split along the grain (Beach Haven, NJ)

Flood Hazard Data: FIRM = Zone AE (8 feet)
ABFE = Zone A (9 feet)
Sandy floodwater elevation = 8 feet NAVD88

Driftwood Beach Club, Sea Bright, NJ – Corroded Connectors

Many homes on Harding Avenue in the Driftwood Beach Club community of Sea Bright, NJ, experienced uplift from flood loads, with some contribution from wind loads. Wave loads likely knocked out windows, doors, and walls along the front (ocean side) of the buildings, and then, as flood heights increased, the buildings slid landward off their foundations until large sections of the foundations detached from the back. An inspection of remaining foundation systems of buildings on Harding Avenue revealed several instances of corroded connectors that no longer provided uplift or shear resistance for the foundation; an example is shown in Figure 3-44. Some of the remaining connectors observed in the nearby community of Seaside Heights exhibited similar failures where connectors had twisted, causing withdrawal of the nails.

Staten Island, NY – Older Homes

The MAT observed numerous houses constructed in low marshy areas on Staten Island, primarily between 1920 and 1960, with either minimal or no foundation-to-building connections. Several houses floated off their foundation during the storm event. The condition of many of the foundations

indicates that the crawlspaces flooded, and the buoyant forces lifted the houses off their foundations. Masonry foundations in this area are common, and the connections to houses were either highly corroded bolts or, in some cases, wooden sill plates embedded into mortar (Figure 3-45).

Flood Hazard Data: FIRM = Zone AE (9 feet)
ABFE = Zone A (8 feet)
Sandy floodwater elevation = 10 feet NAVD88

Figure 3-44:
Corroded connectors (red circle) between the foundation beam and floor joists did not provide uplift and shear resistance to withstand flood loads (Sea Bright, NJ)

Flood Hazard Data:
FIRM = Zone AE (10 feet)
ABFE = Zone V (16 feet)
Sandy floodwater elevation = 13 feet NAVD88

Figure 3-45:
A foundation with corroded connection bolts (shown in red circles); the house was lifted off the foundation because of an insufficient number of connectors (Staten Island, NY)

Fire Island, NY – Compromised Connectors

Houses along the beachfront on Fire Island were situated directly behind the dune system before Hurricane Sandy struck. Many of these houses had foundation-to-building connections, but the connectors were corroded either completely or to a degree that uplift and shear resistance would have been compromised. In some cases, the connectors had been replaced, and in others, the houses lacked a continuous load path. Figure 3-46 is an aerial photograph showing two homes, labeled House A and House B, before and after Hurricane Sandy. Figure 3-47 shows a close-up of these same two houses. House A did not have a continuous load path, and the house slid off its wooden pile foundation onto the sand (Figure 3-48). Although much of the damage observed to House A was likely from floodwater that exceeded the elevation of the house, the house next door (House B), which was similar in construction, remained in place. The MAT observed that House B had more load path connectors still intact after the storm event.

Flood Hazard Data: FIRM = Zone VE (16 feet)
ABFE = Not available. ABFEs were not released for Suffolk County because the FIRMs are up to date.
Sandy floodwater elevation = 14 feet NAVD88

Figure 3-46: Pre- and post-Hurricane Sandy aerial photographs of two Fire Island, NY, houses visited by the MAT; floodwater rose to 14 feet at this location

SOURCE: USGS

Figure 3-47: House A was unable to maintain a continuous load path because of significant corrosion of the connections between the foundation beams and floor joists (see Figure 3-48). House B had some corroded connections, but several had been replaced, and the continuous load paths were sufficient to enable relatively good performance (Fire Island, NY).

Figure 3-48:
In House A (shown on Figure 3-47), the corroded foundation beam-to-floor joist connections failed to maintain a continuous load path (Fire Island, NY)

3.1.5 Basements and Subgrade Areas

Though rarely observed by the MAT in the coastal areas of New Jersey, basements and below-grade garages are common in the New York City metropolitan area. Structurally, the basements and subgrade areas of the low-rise buildings the MAT evaluated performed well. Buildings that were constructed primarily for residential use, such as multi-family dwellings, sustained damage consistent with single-family construction. Most of the damage observed by the MAT was to interior finishes and contents. Few major structural issues related to basements and subgrade areas were encountered in the areas the MAT inspected.

The MAT observed many instances of driveways that sloped down toward a garage, often as much as 4 feet below grade. In most cases, houses had one-car garages and below-grade basement areas that housed MEP systems. These spaces are usually pumped out during normal rain events using a standard residential sump pump. However, during Hurricane Sandy, water from either the rain event or storm surge overwhelmed these sump pumps. Some of the sump pumps may have been rendered inoperable due to a loss of power or an extended outage whose duration exceeded the battery capacity of sump pumps with small backup power supplies. In most cases observed by the MAT, the water exceeded the curb and sidewalk elevation and filled the below-grade garage and basement area to the outside flood elevation. In most of these instances the main house did not sustain flood damage, but equipment and contents in the garage and basement were destroyed.

The following examples are representative of the types of damage observed by the MAT in low-rise residential buildings.

Manhattan Beach, NY – Storm Surge and Sand Damage

Although the flooding of garages in Manhattan Beach, NY, was due in most cases to high flood levels in the streets, houses along the shoreline were inundated directly by storm surge. Floodwater appeared to reach the garage height in many of the houses the MAT visited. Figure 3-49 depicts a typical below-grade garage in the New York City area. Houses subject to such flooding were not only subjected to floodwater but also to sand conveyed by the surge. Many of the sand-damaged properties may have otherwise been resistant to floodwater alone but required sand removal to restore the property to its pre-storm condition.

Figure 3-49:
A below-grade garage typical in the New York City area that was inundated by storm surge (Manhattan Beach, NY)

Flood Hazard Data: FIRM = Shaded Zone X
ABFE = Zone A (11 feet)
Sandy floodwater elevation = 11 feet NAVD88

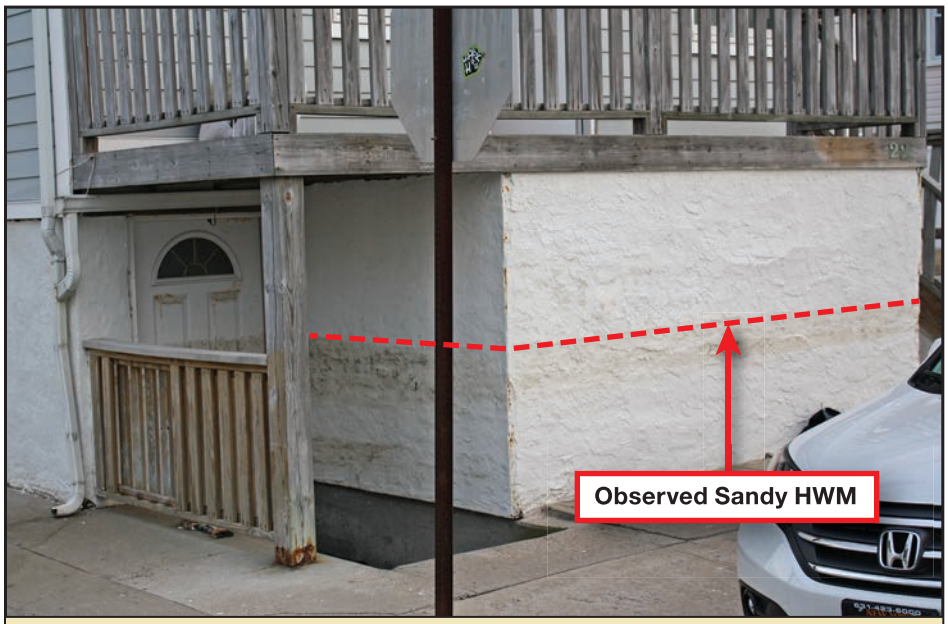
Long Beach, NY – Basement Apartments

There were numerous basement apartments where the MAT observed marks made by sand deposited approximately 2½ to 3 feet above grade. Based on the height of the HWMs above the doors and on exterior walls, the floodwater reached a height of 5 to 6 feet inside the basements (Figure 3-50). Although the flooding may not have caused enough damage for it to be determined as Substantial Damage to the structure, the damage to the finished area and contents in basement apartments was significant.

Long Branch, NJ – Use of Lowest Level for Parking

The condominium shown in Figures 3-51 and 3-52 appropriately used the lowest level as a parking garage. Although storm surge penetrated the beachside face of the building, breaching windows and doors, it did only minimal damage inside the building. Gypsum wrapping over structural

steel beams was damaged, but the beams themselves were not damaged. Lines along the exterior concrete masonry unit (CMU) walls of the structure indicated that a significant amount of sand was deposited inside the building, but it had been cleared before the MAT arrived.



Flood Hazard Data: FIRM = Zone AE (14 feet)
ABFE = Not available. ABFEs were not released for Nassau County because the FIRMs are up to date.
Sandy floodwater elevation = 14 feet NAVD88

Figure 3-50: Example of a basement apartment flooded by storm surge (Long Beach, NY)

Flood Hazard Data: FIRM = Zone X
ABFE = Zone AE (9 feet)
Sandy floodwater elevation = 12 feet NAVD88

Figure 3-51: Exterior view of an at-grade parking area for a condominium (Long Branch, NJ)

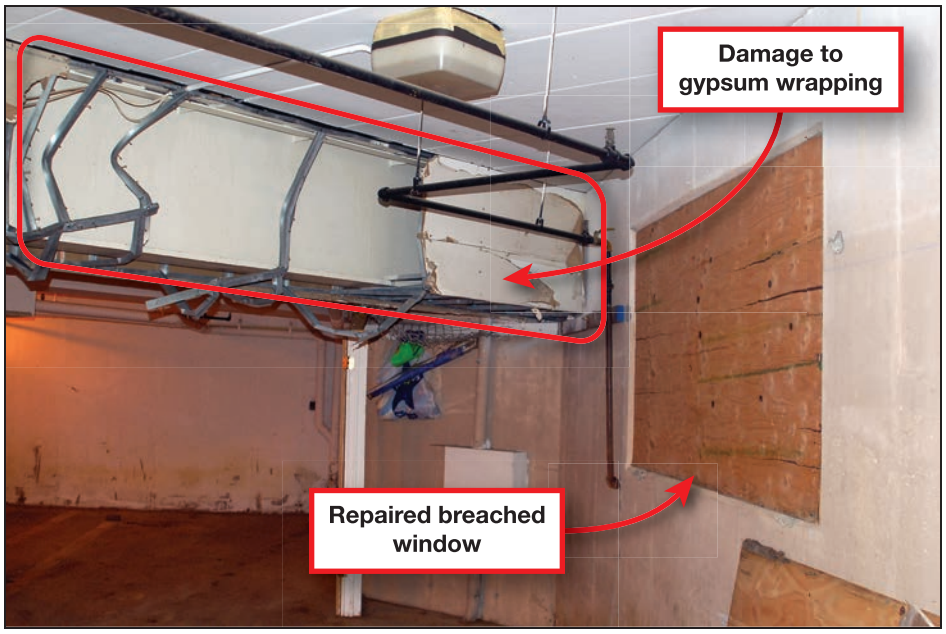


Figure 3-52:
Interior view of the at-grade parking area showing signs of storm surge and sand damage; note damage to the gypsum wrapping over the structural beam (red circle) (Long Branch, NJ)

3.1.6 Mechanical, Electrical, and Plumbing Systems

In many homes, the MEP systems are located on the lowest level of the building. These spaces were often below the BFE and subjected to significant flooding during Hurricane Sandy. Furnaces, boilers, water heaters, electrical panels, and other equipment were damaged beyond repair in many of the buildings the MAT visited. The systems were located in below-grade garages or basements, or utility rooms in at-grade floors that were inundated by floodwater or displaced sand. Other houses were flooded to an elevation above the height of the electric meter. Even when the main portion of the house was not damaged by floodwater, the owners were still displaced because of loss of power. In other cases, equipment such as air-conditioning units was elevated on exterior platforms, but was damaged by flood-borne debris dislodging support piles for the elevated platforms.

Damage to MEP systems in other low-rise buildings was consistent with that observed in single-family residential construction. In many locations, the similarities with single-family dwelling damage were particularly apparent for small multi-family dwellings with four and five apartments (Figure 3-53). These units often had basement apartments that were significantly damaged. Even occupants in units well above the reach of floodwater were displaced because of the lack of electricity and other services. Other buildings, such as some low-rise condominiums, appeared to have had their services restored before the MAT arrived (Figure 3-54), and the remaining damage was primarily to the lowest levels.

The following examples are representative of the types of damage observed in low-rise residential buildings.

Figure 3-53:
Damaged electrical meters at a multi-family dwelling (Far Rockaway, NY)

Figure 3-54:
A new transformer beside a low-rise apartment building replaced one that was damaged by storm surge (Far Rockaway, NY)

Beach Haven, NJ – Damage to At-Grade Equipment

The MAT observed numerous houses with MEP equipment in at-grade enclosures (Figures 3-55 and 3-56). These systems either were directly damaged by floodwater or sand was deposited inside the equipment. Although floodwater did not appear to have caused significant damage to the homes, the lack of power or air circulation from the inoperative heating, ventilation, and air conditioning (HVAC) system may have resulted in mold damage from even minimal water intrusion.

Flood Hazard Data: FIRM = Zone VE (11 feet)
ABFE = Zone V
Sandy floodwater elevation = 8 feet NAVD88

Figure 3-55: Electrical panels and water heaters installed in the lowest level of this beachfront house were damaged during Hurricane Sandy (red circles) (Beach Haven, NJ)

Figure 3-56: Water heater and furnace system installed in an at-grade enclosure underneath a beachfront house were damaged by floodwater (Beach Haven, NJ)

3.2 Performance Relative to Wind

Although Hurricane Sandy was primarily a flood event, the MAT observed some wind damage to low-rise buildings. Based on the MAT review of the wind data, the wind speeds during Hurricane Sandy did not exceed the ASCE 7 design wind speeds (approximately 100-120 mph) in any location across the affected area (Figure 3-57). In New Jersey, where Hurricane Sandy made landfall, maximum sustained wind speeds of approximately 80 mph or less were measured (NHC 2013b),

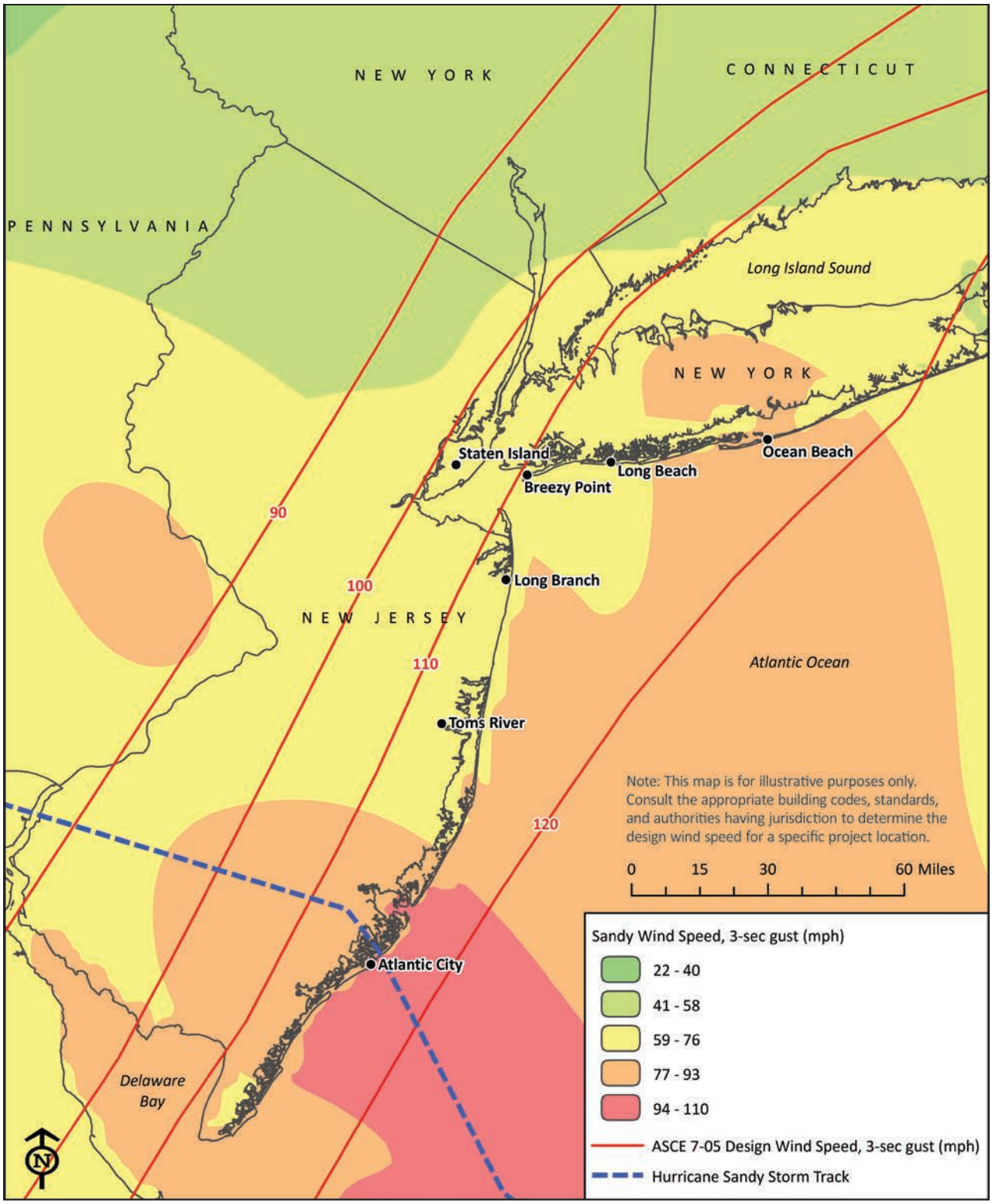


Figure 3-57: Wind speed data gathered by NOAA for Hurricane Sandy adjusted to the 3-second gust and compared with ASCE 7-05 design wind speeds.

SOURCE: ASCE 7 WIND SPEED INFORMATION USED WITH PERMISSION FROM ASCE

which is at the low end of the wind range for a Category 1 hurricane. The minimum sustained wind speed for a hurricane is 74 mph. For more information, refer to the Saffir-Simpson Hurricane Wind Scale shown in Appendix B.

Few buildings sustained wind damage, and much of the damage observed was confined to the building envelope. Where envelope damage was observed, it was typically on older buildings that had multiple layers of exterior cladding that were not appropriately attached to each other or to the building framing. Some roof losses were observed on tall buildings with sloped roofs and a few one- to two-story buildings; however, this type of damage was not frequently observed. Broken glazing was observed, but it was mostly confined to lower floors, and much of it was from flood-borne debris, not wind.

3.2.1 Main Wind Force Resisting System

Although the MAT observed no wind-related damage to the main wind force resisting system (MWFRS) of buildings, exposed building framing was inspected where present. In many cases, the buildings had no clear load paths or the load paths appeared insufficient based on wind speeds used in modern codes and standards for their location. However, because the wind speeds experienced during Hurricane Sandy were below the design wind speed for houses constructed under the building codes, the load paths present in these buildings—typically consisting of either nailed-only connections or undersized metal connectors—were mostly not tested by this wind event. If a design wind event had occurred, many additional structural failures would be expected.

Seaside Heights, NJ

Figure 3-58 shows a two-story house that was one of the few buildings observed to sustain wind damage. The fascia on the seaward side of the building appeared to be nailed to short sections of dimensional lumber, which were spaced similarly to the roof rafters and held in alignment with sections of oriented strand board running parallel to the ridge line. It was difficult to determine how this architectural extension to the roof system was attached to the roof framing, but it appeared that the entire extension section rolled up onto the roof system because of the small overlap of the roof sheathing section onto the main roof trusses. The loss of roof sheathing opened up the building to wind-driven rain and potentially internal pressurization. The lack of other damage to the siding, trim, and windows suggests that wind speeds were well below the design wind speed.

Although damage to the components and cladding of some buildings was observed, the damage was likely caused by incomplete load paths, which could result in additional loads on the MWFRS than were accounted for in the building design.

Figure 3-58:
Failure of a roof rafter fascia due to wind loads; loss of the fascia allowed water to enter the building (Seaside Heights, NJ)

3.2.2 Building Envelope Damage

Damage to building envelopes (components and cladding) was more common than to the MWFRS. This was particularly true for older structures. Many older structures with multiple layers of siding added during various remodeling efforts were observed. Consequently, the fasteners for the outermost layer of siding typically had insufficient embedment into an appropriate solid material, such as wood studs. Although vinyl siding nailed into older wood siding was observed, it probably did not meet the manufacturer's installation recommendations for attachment.

The building envelope damage was primarily to older buildings as noted below.

- + Loss of inadequately attached siding or windows that may not have been properly anchored to the building framing (Figure 3-59).

Figure 3-59: Commercial building on Staten Island, NY, with siding loss due to wind damage

- + Several older buildings that had multiple layers of exterior cladding and insulation. These buildings lost significant areas of the cladding material because the fastener length was insufficient or fasteners were attached to older cladding that had decayed (Figure 3-60).

- + Minimal loss of roof covering; roof damage observed was typically associated with older roof systems (Figure 3-61).

There were a few instances where siding material was lost from some newer construction (Figure 3-62). The nature of the siding loss indicated that the siding may not have been a high-wind vinyl siding capable of withstanding wind in an Exposure Category C as defined in ASCE 7-05.

Figure 3-60:
A multi-family low-rise building in Belmar, NJ, was damaged by wind; note multiple layers of siding

Figure 3-61:
Shingle loss on a beachfront restaurant; note that surrounding roofs do not appear to be damaged (Belmar, NJ)

Issues such as insufficient fastener length, overdriving or underdriving of fasteners, or improper fastener spacing all contributed to premature siding failure.

The following examples are representative of the types of wind damage observed in low-rise residential buildings.

Figure 3-62:
Vinyl siding on this recently constructed multi-family dwelling was damaged by wind during Hurricane Sandy (Union Beach, NJ)

S. Bay Avenue in Beach Haven, NJ – Multiple Sheathing Layers

Numerous houses along S. Bay Avenue in Beach Haven sustained various degrees of envelope damage. Many houses had four or more layers attached to the exterior sheathing. These consisted of several layers of siding, felt, and exterior insulation (Figure 3-63). Whether the additional layers of vinyl siding were purely aesthetic upgrades or intended to replace existing siding in disrepair was unclear. The poor or decayed condition of the original exterior siding, insulation, felt, and sheathing appeared to allow windblown rain to penetrate the building envelope once these layers were pulled off the building.

Figure 3-63:
Damaged siding on house with felt, exterior insulation, and two layers of exterior siding (red arrows show various layers) (Beach Haven, NJ)

Fane Court in Gerritsen Beach, NY – Improperly Fastened Siding

The MAT observed damaged siding on several older homes in Gerritsen Beach, several of which had vinyl siding installed over older materials. In many cases, insulation was added to the original siding and the vinyl siding was attached to the outside of the insulation. Fasteners were presumably not long enough to resist the wind loads.

In one case, insulation was attached to the outside of brick veneer (Figure 3-64). The insulation and vinyl siding were not installed with a symmetrical nail pattern, and not enough fasteners were used. In fact, large sections of insulation did not appear to have any fasteners. The vinyl siding was attached with fasteners that were likely not long enough to pass through the insulation and penetrate the brick veneer. Much of the loss of siding was on an open wall area where the vinyl was not restrained by fascia or window trim.

Figure 3-64: Damage to exterior siding with newer vinyl siding installed over insulation and brick veneer (Gerritsen Beach, NY)

Staten Island, NY – Wind-Borne Debris

Several beachfront houses experienced roof and window damage during the storm. Whether this damage was from wind-borne debris or just wind pressures is unclear. Damage to gutters suggests that some of the damage may have been the result of wind-borne debris. Houses, such as the one shown in Figure 3-65, had window damage that started at lower level windows, which was probably caused by floodwater and flood-borne debris rather than wind. The windows that spanned the full height of the building up to the roof covering and skylights were more likely damaged by wind-borne debris, since the elevation exceeded storm surge heights. Anchorage systems or attachment points for shutters were not visible on the houses the MAT visited.

Figure 3-65: Beachfront house with damaged windows, skylights, gutters, and siding (Staten Island, NY)

3.3 Mold

Mold contamination is always a potential issue after a major flooding event. Mold is an issue for all of building types observed by the MAT, but particularly damaging to the one- and two-story residential buildings. Many residents were not able to immediately return to their homes to remove and replace flooded materials. Although there was little evidence of mold contamination during field investigations, the thousands of buildings with at-grade or below-grade living areas that were inundated by floodwater had finishes that needed to be cleaned after Hurricane Sandy or replaced following contact with potentially contaminated floodwater and to prevent the occurrence of mold.

Even though homeowners may have cleaned or replaced materials that were below the flood level, the materials above the flood level may have remained intact for a long time after the flooding. These materials may harbor mold or other contaminants. The low temperature and humidity after Hurricane Sandy gave property owners time to dry out their homes; the climate was especially helpful in homes without power because the interior of the home was kept cool and in a condition not conducive to mold growth. However, mold would have become more obvious in areas that were not properly cleaned or on finishes that were not replaced as house interiors became warmer after power, and thus heat, was restored, and during the warmer months in the spring and summer of 2013.