Residential Construction

During field investigations, one focus of the MAT was on the performance of residential buildings, particularly those repaired or reconstructed after Hurricane Katrina.

Assessing the structural and building envelope performance of residential buildings was one of the MAT’s primary goals. In particular, buildings reconstructed after Hurricane Katrina that had experienced design flood conditions were of interest. The MAT used location-specific information that they gathered prior to and during the field investigations to identify which buildings were constructed post-Katrina. This prior knowledge of the hazard conditions that the buildings were exposed to during Hurricane Isaac was beneficial in the assessments.

Damage documented within this chapter was observed in the field or made available through information gathered from other public sources (local building departments, Substantial Damage inspection records, elevation certificates, etc.). Statements made herein are not intended to represent final judgments as to the cause of damage to individual buildings; the MAT recognizes that further investigation by others may refine or alter judgments made in this report. Nevertheless, general damage patterns and trends the MAT observed are the basis for the recommendations in this report for improving residential design and construction.
3.1 Residential Flood Damage

Isaac’s flood elevations did not exceed effective BFEs in most of the areas visited by the MAT. Consequently, severe flood damage to one- and two-family residential buildings was not common throughout the study area. Damage to residential buildings was primarily a result of inundation by storm surge. The exceptions to these observations were in LaPlace, a community along Lake Pontchartrain, and in several areas along the East Bank of the Mississippi River in Plaquemines Parish. In these areas, flood levels did exceed the effective BFEs, and the MAT observed evidence of damage caused by waves, velocity flow, and flood-borne debris.

Most traditional one- and two-family residential buildings in the affected area were built on shallow foundations, such as slabs, stem walls, crawlspace, or piers. In newly constructed buildings, pile or column foundations were more common. Masonry pier foundations were the most common foundations in areas designated Zone V and in Zone A near the shoreline, followed by timber pile foundations. When properly designed and constructed, all of these foundations were effective during Hurricane Isaac where waves and surge remained below the floor system. In areas that experienced damage, including LaPlace, Slidell, Mandeville, Orleans Parish, and Jefferson Parish, the damage was caused by slow rising water. Flood depths in residential buildings ranged from 2 to 4 feet above slab foundations. Typical damage to these buildings included interior finish, flooring, heating, ventilation, and air conditioning (HVAC); and contents damage. Very few homes on elevated foundations (piles/piers) in these areas visited by the MAT experienced flooding above the floor system; those that did experienced similar damage as homes on slab foundations. The one exception was buildings not properly anchored to piers that were displaced from their foundation.

The most extreme inundation was observed in Braithwaite along the East Bank in Plaquemines Parish, where floodwaters reached 8 to 10 feet above floor systems. In some areas along the East Bank, the MAT observed severe building damage in areas where levees were overtopped by rapidly rising, fast-moving water. This caused many buildings to be washed off their foundations.

At the Frenier Fishing Village, located east of LaPlace along the western shoreline of Lake Pontchartrain, some buildings were destroyed when surge and waves exceeded the floor elevation (see Figure 3-1). Age (ranged from 5 years to more than 30 years old) and elevation of construction were the primary damage indicators in this small community, with the older, non-elevated, pre-FIRM residences being destroyed and newer, elevated homes having less damage.

Most other areas visited by the MAT experienced damage caused by slow-rising water, where few indications of erosion and scour damage to foundations were observed. Typical flood damage in these areas is shown in Figures 3-2 through 3-4.

New construction and post-Katrina elevation projects consistently had minimal, if any, damage compared to adjacent non-elevated properties (see Figure 3-5). No flood damage was observed for the residential buildings the MAT visited that were constructed under the FEMA Hazard Mitigation Grant Program (HMGP) Pilot Mitigation Reconstruction Program.
Figure 3-1: Wave and surge damage to a residential building. The house is located in Zone V along Lake Pontchartrain's western shoreline (Saint John the Baptist Parish, LA).

Figure 3-2: Damage was observed in most at-grade slab foundation residences, while minimal damage was observed in adjacent elevated properties (Barataria, LA).
Figure 3-3: Typical flood depth of at-grade slab foundation residences; inset illustrates flood depth of 31 inches above the at-grade slab foundation (Slidell, LA).

Figure 3-4: The damage to some elevated Zone V residences was limited to the loss of stairs (Mandeville, LA).
3.2 Residential Wind Damage

Wind damage to one- and two-family residential buildings was minor. The most common damage observed was to exterior finishes (vinyl siding, soffit material, fascia, etc.) and included minor roof cover loss. Age of construction was a major contributing factor to the extent of wind damage. As expected, the building envelopes on older houses did not perform as well as those on new houses. The one exception to this observation was the widespread loss of underside paneling in relatively new elevated coastal construction (see Section 3.7). Typical residential wind damage is shown in Figures 3-6 and 3-7.

As anticipated, new residential buildings constructed under the FEMA Pilot Mitigation Reconstruction Program had no observed wind damage (see Figure 3-8); however, the number of properties built under this program was surprisingly low. In some cases, typically because of structural concerns, local communities were unable to complete a traditional elevation project because the structure would not be compliant with minimum standards of the 2003 I-Codes or other local codes and ordinances (because structural integrity may be questionable, the structure cannot be retrofitted to withstand current design wind speeds, etc.).
Figure 3-6: Loss of standard vinyl siding to recently elevated residential building; use and/or damage of high-wind siding was not observed by the MAT (Plaquemines Parish, LA).

Figure 3-7: Roof soffit and fascia damage to Exposure C residential building (Plaquemines Parish, LA).
3.3 Foundation Performance

The MAT observed a wide range of foundations in residential buildings. Foundation types included closed-style foundations like slab-on-grade, crawl space on perimeter foundation walls, and back filled stem walls, and open-style foundations like piers and piles. The MAT also observed several homes that were originally constructed with slab-on-grade foundations that had been elevated with their slabs intact. In those homes, the elevated slabs were typically supported on masonry or concrete piers.

Most non-elevated single-family or duplex residential buildings observed were constructed using a concrete slab-on-grade or masonry crawlspace foundation. Many of these buildings were pre-FIRM and experienced significant flood damage from inundation and the resulting hydrostatic and hydrodynamic forces. Side-by-side comparisons of non-elevated and elevated buildings in Slidell and Mandeville are shown in Figures 3-9 and 3-10. The elevated house had no observed damage, while the non-elevated house had interior finish, flooring, HVAC, plumbing, electrical, and contents damage caused by over 2 feet of flooding. The MAT consistently observed that the non-elevated houses experienced far greater flood damage than houses constructed on elevated foundations built to the ABFE or the preliminary FIRM developed after Hurricane Katrina. Flood depths in non-elevated houses in St. Tammany Parish were observed to be from 2 to 4 feet. However, in some locations of Plaquemines Parish, flood depths reached the rooftops of non-elevated homes. The deeper the flooding, the more damage the inundation caused; thus, the greatest damage was observed in Plaquemines Parish, especially along the East Bank of the Mississippi River.

Elevated foundations for existing single-family residential buildings were typically concrete or masonry piers supporting elevated slabs. Many of the home elevation projects were completed after Hurricane Katrina using FEMA Hazard Mitigation funds. Some elevated foundation projects involved detaching the home from its slab-on-grade foundation, elevating the walls, roof, and other
portions of the structure, and constructing a new elevated wood-framed first floor, while leaving the existing slab-on-grade in place. A few of the elevated houses the MAT observed were entirely new structures constructed on piers or piles as part of the Pilot Mitigation Reconstruction Program. Many elevated foundations were raised an entire story to comply with local freeboard requirements as well as to accommodate vehicle parking or storage underneath the building. Local building officials informed the MAT that they preferred reconstruction over other elevation techniques because it eliminated the uncertainty in the structural capacity of the existing slab and structure and allowed new housing to be constructed to current prescriptive codes and standards.

Figure 3-9: Neighboring residential buildings; the elevated residence had no observed damage, while the non-elevated home had significant interior damage caused by more than 2 feet of flooding (red arrow indicates flood depth) (Slidell, LA).

Figure 3-10: House elevated as part of the HMGP Pilot Mitigation Reconstruction Program (Mandeville, LA).
Elevated Slab Concerns

The MAT observed many residential buildings where the existing slab had been elevated in place. The process to elevate a structure with a slab-on-grade foundation begins with excavating around the existing foundation to allow a network of lifting beams to be placed underneath the existing slab. Once the beams are in place, the home is lifted on the network of beams using hydraulic jacks. As with traditional elevation projects, there is a risk for cracking due to differential lifting, as shown in Figure 3-11. The elevated home is then supported on temporary timber cribbing or shoring until the permanent elevated foundation is completed. Figure 3-12 shows a home supported on timber cribbing. Permanent elevated foundations typically consist of reinforced concrete or masonry piers. Once the permanent foundations are in place and have been connected with the slab, the cribbing and other temporary supports are removed.

Figure 3-11: Slab-on-grade elevation with structural cracks due to differential lifting (Slidell, LA).

Figure 3-12: Slab-on-grade elevation in progress (Slidell, LA).
The MITIGATION ASSESSMENT TEAM observed several slab-on-grade elevations with the following features:

- Vertical supports consisting of square masonry or concrete piers or 3-inch pipe columns that supported the elevated slabs. Pier and column spacing varied greatly. Most spans were approximately 6 feet; some exceeded 12 feet. In some cases the permanent supporting foundations were constructed using mini-piers. These mini-piers consisted of concrete blocks connected to one another with a series of threaded steel dowel rods, cable, or other material running through a hole in the center of each block.

- A decorative perimeter wall finish was placed around the base of the elevated houses to provide an attractive covering for the uneven appearance of the raised grade slab.

Local building officials who the MITIGATION ASSSESSMENT TEAM interviewed in both Slidell and Mandeville on October 8 and 9, 2012, expressed concerns about slab-on-grade foundation elevation projects. Although neither of the building officials had documented any foundation failures, one official had received numerous reports of buildings in the community with structural cracks associated with this technique, and both expressed concerns about the lack of data provided by owners’ representatives on the existing slab (i.e., concrete thickness, steel reinforcement) and the pier-to-slab connections.

The MITIGATION ASSSESSMENT TEAM’s field observations of completed and ongoing slab elevation projects confirmed the observations of local building officials and revealed the following concerns:

- **Insufficient slab reinforcement/thickness:** Elevated concrete slabs were often found to be of minimal thickness with limited wire mesh steel reinforcement and/or insufficient concrete cover of the wire mesh, as shown in Figure 3-13. This was also observed in ongoing residential building slab elevation projects with attached garages.
Lack of pier-to-slab connections: Different types of elevated foundation-to-floor framing connections were observed, including bolted connections for pile foundations and grouted connections for pier foundations. However, elevated slabs were often observed to have no visible connection to their piers. Where connections were observed, they appeared to be structurally insufficient, as shown in Figure 3-14.

Figure 3-14: Structurally insufficient connection to pier. This house had a total of 7 such connections out of 17 piers supporting the structure (Mandeville, LA).

3.4 Utilities

The most prevalent damage to elevated residential buildings observed by the MAT was flood damage to electrical service components (see Figure 3-15). The NEC and local utility company requirements control where electrical service components can be located. The NEC requirements primarily focus on safe clearances around energized lines and safe working space; utility company requirements incorporate access requirements based on local conditions so they can control, maintain, and repair the equipment. Utility companies commonly require the center of electrical meters to be placed 4 to 6 feet above the finished grade to allow access for recording electrical usage as well as disconnecting or removing the electrical meters if they need to discontinue electric service to a home. Utility repairs to individual residences are typically some of the last repairs to be made, which impedes recovery and extends power outages, especially if the equipment is beyond repair and needs to be replaced.

When allowed by the local utility company, placing all electrical equipment above the flood level prevents floodwater from damaging it. The MAT observed several residences where components were elevated and accessible by stairs, walkways, or decks. These elevated structures typically supported condensers and other mechanical equipment (e.g., generators). When the equipment was properly elevated above potential flood levels, the damage to it was minimal.
Proper elevation of equipment involves installing it above design flood levels and maintaining access for utility workers and first responders. Figure 3-16 shows an example of elevated electrical service components.

When conditions or local utility company requirements limit elevation of electrical meters and they must be situated below design flood levels, it is critical not to attach utilities to breakaway walls or other building components not designed to resist flood loads. Figure 3-17 shows an example of a home where the utilities are attached to foundation piers. See the *Minimizing Flood Damage to Electrical Service Components* Recovery Advisory in Appendix D for more details on recommended practices for utility placement.

A service drop is an overhead electrical line running from a utility pole to a home. Traditionally, the lines enter residential buildings through a weatherhead that penetrates the roof (see Figure 3-18). The MAT observed service drops along rooftops and along the sides of the houses. At times, vertical clearance requirements constrain the service drop location to rooftops, but in most circumstances there is some flexibility in where the connection is installed. When the service drop was attached to the roof, the MAT observed some instances where a utility pole collapsed or wind-borne debris struck it, causing the weatherhead to shift in a way that tore the roof and allowed water to penetrate. This was less likely when the service drop was installed on the side of the house. Overhead clearance requirements or the locations of the utility pole and the electrical meter may dictate whether a weatherhead is attached to the roof or the side of the house.
Figure 3-16: Residential building with electric meter installed adjacent to side entrance (Mandeville, LA).

Figure 3-17: Electric meter attached to foundation pier (Plaquemines Parish, LA).
3.5 Stairs

The MAT observed a variety of exterior stairway configurations on elevated residential buildings in St. Tammany and Plaquemines Parishes. Stairway materials ranged from wood to masonry and wrought iron. In many neighborhoods, exterior stairs on residential buildings were curved or segmented in multiple directions as shown in Figure 3-19. This is often done for aesthetic reasons, to reduce the visual impact of the elevation on the structure.

Figure 3-18: Post-Katrina residential reconstruction with service drop attached to the side of house (Slidell, LA).

Figure 3-19: Curved and split stair configurations for elevated residential buildings (Mandeville, LA).
The MAT observed damage to these exterior stairways, most frequently along Lakeshore Drive in Mandeville, as shown in Figure 3-20. Many of the homes with stairway damage had long runs of wooden stairs with solid risers oriented perpendicular to the direction of the flow of floodwater and no intermediate landings. Stairs of this type suffered the most severe damage or complete loss.

![Figure 3-20: Front and side view of stair damage to elevated waterfront residential building due to closed riser, inadequate foot anchoring, and insufficient connection with the building frame (Mandeville, LA).](image)

### 3.6 Enclosed Areas

The NFIP defines an *enclosure* as the portion of an elevated building below the lowest elevated floor that is either partially or fully enclosed by rigid walls. This area is to be used solely for parking, storage, and building access. The *lowest floor* is defined as the lowest floor of the lowest enclosed area (including the basement). The area within an enclosure is not considered the lowest floor provided that it is built in compliance with the applicable non-elevation design requirements of 44 CFR §60.3.

The MAT observed a variety of enclosed areas below elevated buildings, including several partially enclosed areas (see Figure 3-21), some fully enclosed areas, and a small number of above-grade enclosed areas (see Figure 3-22).

All enclosures below the BFE must be made of flood damage-resistant materials; in Zone A they must also have openings that allow floodwater levels inside and outside to rise simultaneously to equalize the hydrostatic pressure. Often, homeowners finish these areas as additional living space, which is in violation of the NFIP. The MAT observed damage to enclosures that were not constructed with flood damage-resistant materials (see Figure 3-23).
Figure 3-21: Residential building under construction with a partially enclosed area—front closed/rear open with effective BFE of A13 (EL12), Katrina ABFE of Zone AE (EL13), and preliminary FIRM of Zone VE (EL14) (Madisonville, LA).

Figure 3-22: Example of above-grade enclosure below elevated residence (Plaquemines Parish, LA).
For enclosures below elevated homes in Zone V, rigid walls are not permitted. Enclosures in these areas must use breakaway wall construction, which is designed to fail under flood-loading conditions. Areas used for building access, storage, and vehicle parking in Zone V are required to be open or enclosed with lattice or breakaway walls. In addition, the MAT observed above-grade enclosures at a few sites. The primary issue with above-grade enclosures is that they may not be intended to fail under flood-loading conditions and, thus, may cause additional loading to foundation elements or cause damage to spread upward. The ramps into these above-grade enclosures can also become flood-borne debris and potentially impact the foundation and/or surrounding buildings. Any damage to enclosures below the lowest floor must not result in damage to the foundation, the utility connections, or the elevated portion of the building. For homeowners in Zone V, having breakaway enclosure walls below an elevated building will result in somewhat higher flood insurance premiums than having a completely open foundation.

### 3.7 Underside of Elevated Buildings

The MAT observed hurricane wind damage to paneling and sheathing on the underside of several elevated homes in Plaquemines Parish. Paneling torn completely away became a source of wind-borne debris with the potential to damage neighboring buildings, and the loss of this layer of protection allowed water infiltration. Figure 3-24 shows an example of a residential building that experienced a loss of sheathing underneath the elevated first floor.
Although the wind loads underneath a building are significantly less than those on the roof system, the potential loads imposed on the sheathing system should be calculated to determine the fastener size and spacing required to adequately attach the material. The MAT team observed that, in many instances, vinyl paneling material used to cover the underside of elevated buildings frequently tore at the connection point or failed because fasteners pulled out. Less damage was observed at elevated buildings where the covering material was wood that was properly fastened to the framing above. The use of wood or more rigid materials may not eliminate all damage during high-wind events, but it will minimize the damage. See the *Minimizing Wind and Water Intrusion by Covering the Underside of Elevated Buildings* Recovery Advisory in Appendix D for more details on recommended practices.

### 3.8 Fire-Resistant Materials

The MAT observed several elevated structures with combustible materials or vehicles stored under the elevated portion of the home. In many cases, the underside of the elevated structure did not have a fire-resistant floor assembly. The residential structures observed by the MAT often had plywood sheathing or a wood finish material over standard wood floor joists or the lowest horizontal structural member, as seen in Figure 3-25. Using standard exterior grade plywood sheathing alone or wood finish material, such as wainscoting, is dangerous if the area underneath the elevated building requires a fire-resistant floor system. If the area underneath an elevated building is used for parking or storing even small quantities of fuel or other potentially combustible materials, most building codes require partitioning these areas from living spaces. For structures with elevated concrete slabs, the MAT observed several instances of conduits, plumbing, or other penetrations through the concrete slab without a compliant fire stop system, solid fire blocking, or a fire barrier.
Such conduits, as shown in Figure 3-26, would allow fire beneath the slab to enter the structure. The elevated structure should be constructed in accordance with the IRC or IBC. The 2012 IRC Table R302.6 requires not less than 5/8-inch Type X gypsum board or equivalent for habitable rooms above a garage. See the *Minimizing Wind and Water Intrusion by Covering the Underside of Elevated Buildings* Recovery Advisory in Appendix D for more detail on fire-resistant assemblies in elevated structures.