Flood Resistant Construction

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Funded by:

The American Institute of Architects

Architects Foundation

Prepared by:

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Firm Description:

The Gulf Coast Community Design Studio (GCCDS) is a professional service and outreach program of Mississippi State University's College of Architecture, Art + Design. GCCDS was established in Biloxi, Mississippi in response to Hurricane Katrina to provide architectural design services, landscape and planning assistance, educational opportunities and research to organizations and communities along the Mississippi Gulf Coast. GCCDS works through close, pragmatic partnerships with local organizations and communities in and beyond the three Mississippi coastal counties, putting professional expertise to work in order to shape vibrant and resilient Gulf Coast communities.

Cover image taken by Daniel J. Martinez, US National Guard, 2017.

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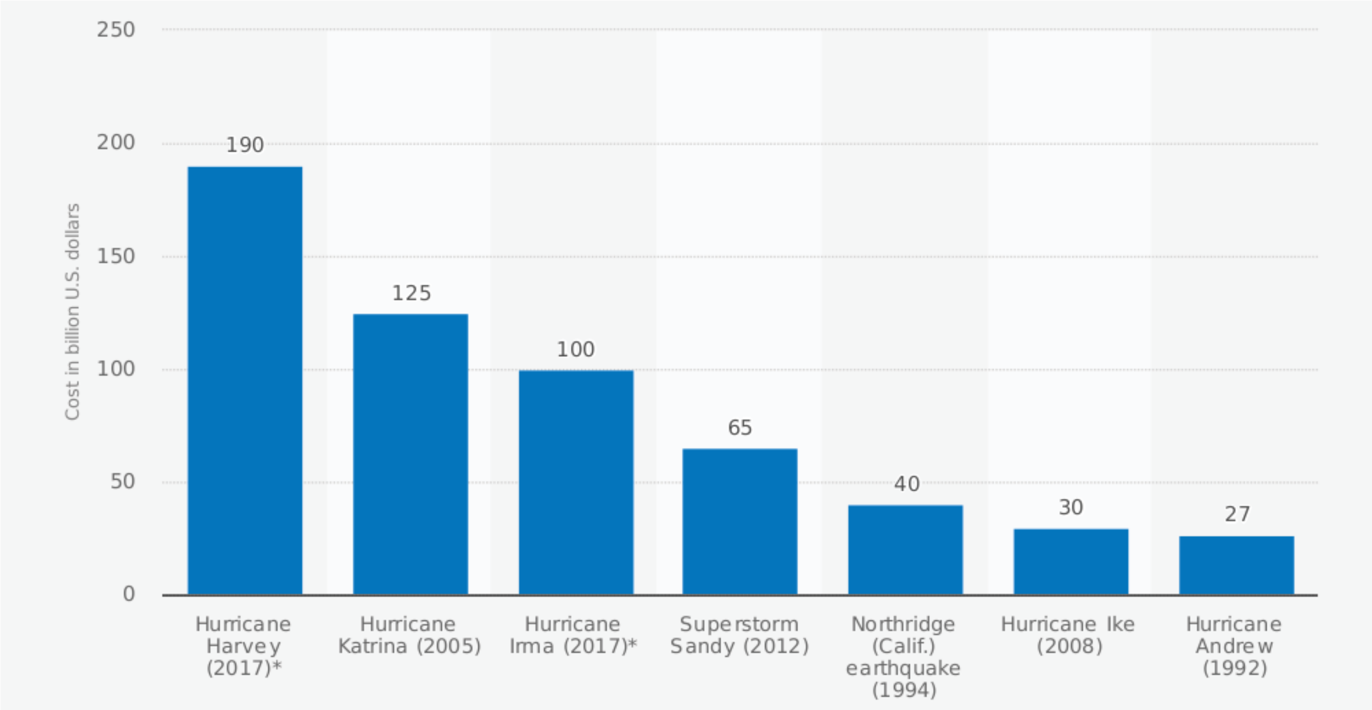
Introduction

The intense storms and flooding of 2017 engrained images of flooded suburban homes into many people's memories. Two of the four most expensive natural disasters in US history occurred in 2017—Hurricane Harvey and Hurricane Irma.[i] Hurricane Harvey first made landfall on August 25, 2017 and within its first twenty-four hours dumped two feet of water on Southeastern Texas. Over the next six days, Harvey made landfall two more times, stalling over the City of Houston and delivering 51 inches of rainfall in some areas. Core Logic's 2017 Natural Hazard Risk Summary & Analysis following Hurricane Harvey states:

Nearly 500,000 homes experienced some type of impact, and of those 500,000 homes, an estimated 90,000 incurred severe damage from flooding. Almost 200,000 more homes suffered extensive flooding that impaired immediate occupancy, and an additional 200,000 suffered short-term impaired functionality.[ii]



Most expensive natural disasters in the United States as of September 2017 (in billion U.S. dollars). *Image courtesy of USA Today; AccuWeather © Statista 2018.*

Hurricane Harvey's devastating impact on the residents of Houston and the surrounding communities began with the evacuation of many families during the storm; and displaced some families for months while repairs and renovations were carried out. The City of Houston estimated that approximately 37,000 families sought shelter in Red Cross and partner facilities following the storm.[iii] Given the impact of Hurricane Harvey, Houston's housing stock was ill-prepared to withstand Harvey's flooding even though advanced evacuation warning was issued two days before the storm's landfall. Evacuation ensures safety, but people they leave their homes with plans to return in a few days. We can say that hundreds of thousands of homes in Houston failed in their primary purpose– to provide shelter.

Scientific evidence supports the observation that flooding is increasing outside the boundaries of FEMA's Special Flood Hazard Areas. The trend of increased flooding outside of flood zones results from both landuse changes and climate changes. Areas that were natural are being developed with new roads and buildings impacting the natural drainage plain. And at the same time the frequency or strength of flood events is also increasing. The scientific basis of incrased flooding is not the purpose of this report, but suffice it to say that flooding in residential areas is a problem that will not go away anytime soon. As communities expand and development continues, flood-prone communities will continue to flood, and areas that have never experienced flooding might one day flood. The expanding impact of flooding is seen in events such as the flooding in Louisiana in 2016 where FEMA estimates that only 17% of the state's FEMA applicants for funding had flood insurance.[ii]

Regarding Hurricane Harvey, Core Logic's report goes on to say:

In the case of Hurricane Harvey, almost 75 percent of the flood damage was uninsured, the majority of which was residential properties. The properties at greatest risk of flood are generally located in Special Flood Hazard Areas (SFHAs) as identified by the Federal Emergency Management Agency (FEMA), but the severe flooding from these events extended far beyond those boundaries.[iv]

Regarding uninsured loss following Hurricane Irma:

Flood loss for residential properties from Hurricane Irma is estimated to be between $25 billion and $38 billion. This includes storm surge, inland flooding and flash flooding in Florida, Alabama, Georgia, North Carolina and South Carolina. Of this total, insured residential flood loss is estimated to be between $5 billion and $8 billion, and uninsured residential flood loss is estimated to be between $20 billion and $30 billion. This means an estimated 80 percent of flood damage to residential properties from Hurricane Irma is uninsured and, therefore, not covered by flood insurance.[iv]

Such statistics show the impact of floods occurring in areas previously considered low risk. Following the trend the Gulf Coast experiencd after Hurricane Katrina and parts of the North East experienced after Superstorm Sandy, areas mapped as high risk zones will continue to expand to include numerous homes that were once thought safe. The impact of expanded flood zones on our housing stock needs attention and creative solutions. It is clear that there are better ways to build to change construction methods and materials so that home could be better prepared to withstand the impact of a flood. In neighborhoods where a flood has already occurred, the established recommendations of elevating or relocating structures are cost prohibitive for most families. Therefore, there should be steps taken when renovating a home after a flood event that will help prevent the same level of damage from occurring again. Whether or not such improved methods should be required by code remains to be seen—perhaps just having best practices defined and accessible for homeowners, builders and volunteer organizations involved in disaster response is a good first step. This report looks at the need for practical applications for flood-resistant construction, and presents emerging studies that are currently being explored by design professionals across the country.

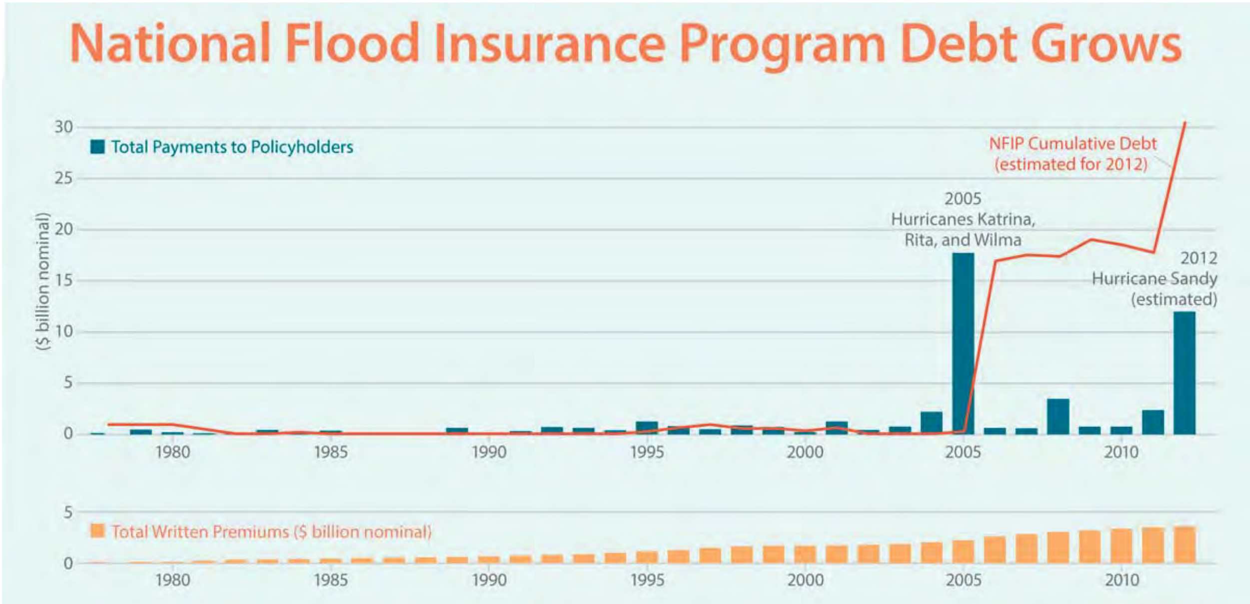
Water soaked debris is moved to the street curb for pickup following Hurricane Harvey. *Image courtesy of Charlie Riedel/AP.*

Needs Assessment

The high cost of repairs following a major flood event is a struggle for many families, even in the cases where homeowners have flood insurance. In an article in Insurance Journal from February 2018, the Texas Department of Insurance estimates the average claim for flood-affected residential properties at $80,000.[vi] Keep in mind this number is only related specifically to flood damage and any wind or storm damage would be an additional claim through homeowner's insurance, which usually has a separate deductible. FEMA estimates the average paid loss for structures (residential and commercial) following the August 2016 Louisiana flooding to be $90,548.[vii] Without insurance, unless a family is able to obtain governmental assistance they are left to their own means to pay for repairs.

In 1968 the federal government formed the National Flood Insurance Program (NFIP) to insure homeown¬ers and renters against loss due to flooding, a loss that exceeds the limits of risk that can be covered by private insurance. The NFIP is a pool of nearly 90 private insurance companies, administered by the Federal Emergency Management Agency (FEMA).[viii] To be eligible for flood insurance, a homeowner, landlord or renter must live in a community that has joined the NFIP. As an example, all jurisdictions on the Mississippi Gulf Coast are members of the NFIP.[ix] For a long time the program was fairly successful, receiving premiums from its customers at about the same rate as payouts were needed for flood damage. In more recent years, however, the NFIP has become more heavily indebted beginning with about 18 billion dollars in damages from Hurricane Katrina in 2005. A few years later Superstorm Sandy occurred, bringing the NFIP debt to an unprecedented level of cumulative debt, as seen in the graph below[x]. It is clear the NFIP is on an unsustainable path and reform is needed to address its growing debt. The chart on the next page depicts the emerging gap between the billions of dollars in flood damage and the total dollars received through premiums from policyholders. Keep in mind this chart was produced in 2013 and does not include the widespread damage caused by Hurricane Harvey and Irma in 2017.

NFIP rates are predicted to increase for all property owners, more dramatically for some, with ongoing NFIP reform. According to a 2014 US Government Accountability Office report, NFIP has accrued $24 billion in debt, highlighting increasing concerns about the NFIP burden on taxpayers. The Biggert-Waters Flood Insurance Reform Act of 2012 moves NFIP toward charging full-risk rates. The motivation behind NFIP reform is twofold: to reduce the subsidies that have historically kept NFIP rates below the actual risk rate; and to create an environment that will encourage increased private sector involvement



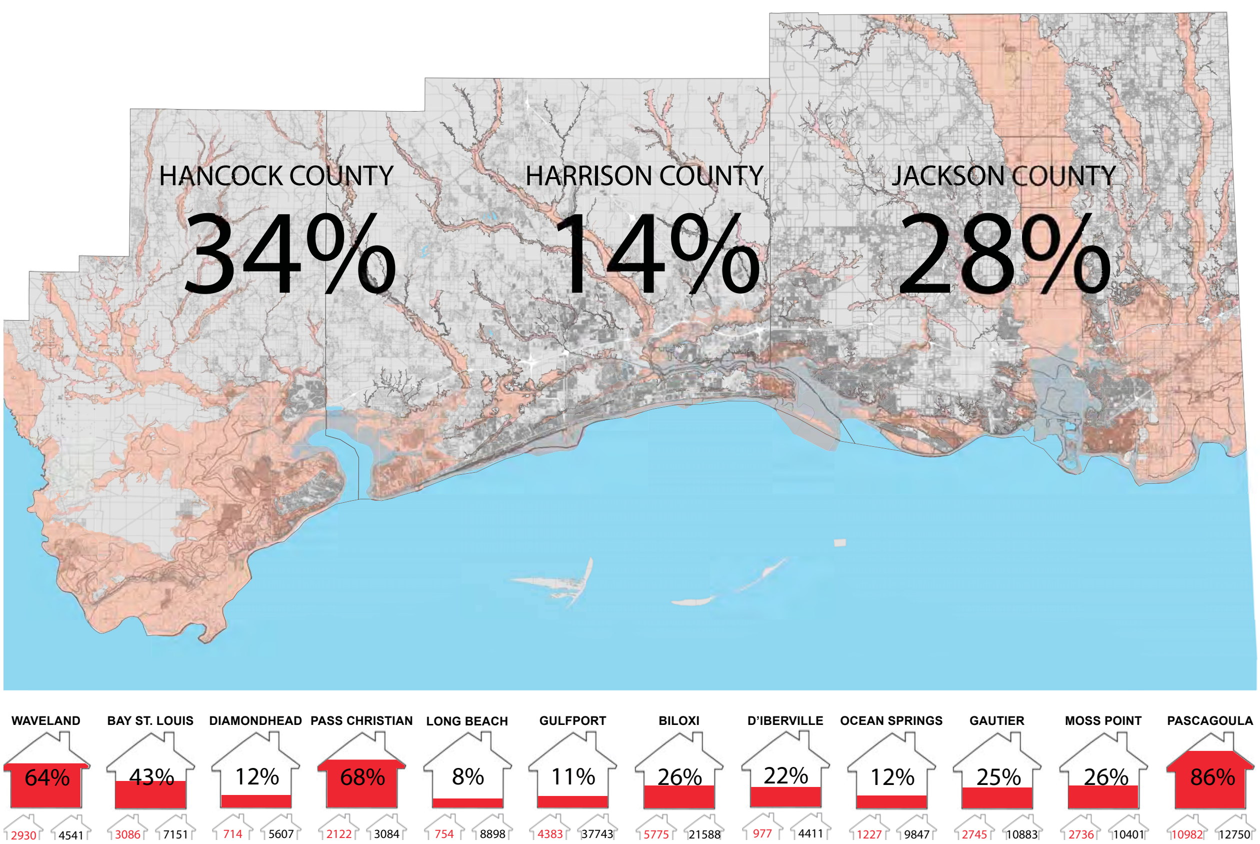
NFIP debt compared to premiums collected from policyholders over the years. *Image provided by Union of Concerned Scientists, 2013.*

in flood insurance. The 2014 Homeowner Flood Insurance Affordability Act modified some of the Biggert-Waters Act provisions to slow down the increase of most subsidized rates, moving toward full-risk rates at a pace of at least 5% and no more than 18% a year, but some high risk properties will continue to increase at the Biggert-Waters rate of 25% annually.[xi]

The move to phase out NFIP subsidies began at the same time the extent of flood zones outlined by FEMA's Flood Insurance Rate Maps drastically increased. After Hurricane Katrina the Base Flood Elevations on the Mississippi Gulf Coast increased on average six feet, extending the flood zones into established neighborhoods of houses that as a result do not meet the Base Flood Elevation requirements. These existing houses are now in a precarious situation. The property owners hear threats of ten-fold increases in insurance premiums for not meeting the FEMA requirements. The accepted long-term solutions in this situation is either to relocate out of the flood zone or raise the house on a new foundation to meet the Base Flood Elevation, neither of which are very encouraging options. Obviously there are numerous concerns when considering relocation such as the displacement of communities, disruption of life and financial burden to the governmental entity assisting in the matter and also to the people living in the precarious situation. The process of relocation is extremely complex and lengthy and so it is not the subject of this report; suffice to say, it is a solution that will certainly be considered by municipalities and state governments as the availability of funds arises, but in the short-term will only be able to assist a relatively small percentage of at-risk homes.

The other prospect to elevate a house in a high risk zone is also a daunting prospect for a homeowner. Depending upon the type of foundation and the BFE height, the cost to elevate an existing house to meet FEMA requirements is reported to average $74 a square foot, which for many houses on the Mississippi Gulf Coast, for example, can exceed the value of the house.[xii] For instance, at 2015 house prices, the market value of a modest house in a flood zone in East Biloxi is less than $50,000. If the house is on a conventional pier foundation, elevating the house is feasible but will likely cost about $40,000. Obviously, there is no way to recover such a cost in the sale of the house. When flood insurance premiums for a non-conforming house reach $10,000 and the difference between a house that meets FEMA requirement and one that doesn't might be $9,000, the payback for elevating a house appears to be less than five years. However, such calculations are deceiving because the homeowner probably cannot afford the high insurance cost in the first place and the reduced insurance of $1000 a year is probably close to what they are paying now with a subsidized premium. Therefore, the flood mitigation needs are overwhelming and need much work to find a path forward.

The number of homes located in flood-prone areas which are below Base Flood Elevation is generally not understood or quantified. In 2016, GCCDS embarked on a venture to conduct an analysis of the remaining vulnerability of populations living in Mississippi's coastal floodplain. The research focused on the high-risk flood zones within Hancock, Harrison and Jackson Counties and sought to identify (among other information) the number of homes on the Mississippi Gulf Coast susceptible to future flooding and therefore increasing flood insurance rates. It was quickly realized that none of the jurisdictions on the coast have a comprehensive inventory of what residential buildings are out-of-compliance in terms of



Map showing percentage of houses located in FEMA-designated flood zones across the Mississippi Gulf Coast.
Image provided by Gulf Coast Community Design Studio.

the post-Katrina FEMA Digital Flood Insurance Rate Map (DFIRM) and revised BFE's. Many jurisdictions have an intuitive understanding of where out-of-compliance homes are located, but not a systematic record of the number of homes and where they are concentrated. GCCDS began an analysis of the extent to which a jurisdiction's current housing stock was located in a high-risk flood zone. The map on the previous page represents the distribution of homes located within FEMA-designated flood zones across the Mississippi Gulf Coast. Hancock County has the highest percentage of residential buildings in the floodplain at 34%, followed by Jackson County at 28% and Harrison County at 14%. Each of the counties has one city, in particular, with a significantly higher percentage of homes in the floodplain. Pascagoula has the highest for Jackson County and the Mississippi coast overall at 86%, followed by Pass Christian at 68% in Harrison County, and Waveland at 64% in Hancock County.

Following Hurricane Katrina, when the FEMA flood zones were expanded, many residents found that their homes were now below the required BFE making them more susceptible to both flooding and increases in insurance premiums. Being below BFE also presents a barrier to resale and can prevent a homeowner from getting the necessary permits to complete significant renovations or repairs. Since none of the jurisdictions had a clear understanding of the extent of the problem, GCCDS staff began conducting a windshield survey of homes within high-risk flood zones. One of the first jurisdictions surveyed was the City of Diamondhead. With only 12% of homes located in high-risk flood zones this area provided a manageable area to test survey methods. Information about whether a home was slab-on-grade or built on piers was recorded, in addition to whether there was fill present and if the home was above or below BFE. The type of building foundation (slab-on-grade versus pier, for example) was noted because slab-on-grade homes cost significantly more to elevate than homes built on piers. This survey method proved to be too time consuming and resource intensive given the available funding, but was incredibly informative. A snapshot of the findings from the Diamondhead survey are in the figure below, showing that 79% of slab-on-grade homes within the survey area were found to be out of compliance with the current BFE. This is one such sample community that, if subjected to a damaging flood event, would suffer widespread economic and social impacts.

- 496 single-family homes are in high-risk flood zones (about 13% of residential)
- Overall, 55% not in compliance and 17% unverifiable
- 87% are slab on grade (34% with fill)
- 79% slab-on-grade not in compliance or unverifiable
- 11% are pier foundations
- 30% of homes with pier foundations are not in compliance or unverifiable

Snapshot of findings of homes out of compliance with BFE requirements within Diamondhead study area. *Data provided by Gulf Coast Community Design Studio.*

Retrofit Strategies

As explained above, FEMA's Flood Insurance Rate Maps change (typically expanding flood zones) as risk from flooding increases. What is more, FEMA flood zones do not ensure safety from flooding as seen by increased flooding outside of FEMA flood zones, as well as flooding within flood zones that exceeds the Base Flood Elevation. Therefore, buildings cannot rely solely on meeting FEMA requirements, but should be built to be more flood-hardy in places that are flood prone.

This study explores improvements to the construction of houses to make them more flood-hardy with the proposition that better building materials and methods will reduce the damage to a house if it floods. The suggested application of such flood-hardy or flood-resistant construction is broad. In new construction out of flood zones but in flood prone areas, flood hardy construction is a straight-forward improvement to make a house more resilient. In new construction such as a rebuilt house to replace a destroyed house after a disaster, such improved construction would be added resilience to a house that would be built to meet the FEMA Base Flood Elevation. In this case, such flood-hardy construction can be seen like the concept of "freeboard" which is beyond any FEMA requirement and imposed by the local municipality. Finally, in the increasingly common case of a house that is flooded in or out of a flood zone, retrofitting the house with flood resistant materials is a practical approach that is not intended to be seen as a way to meet FEMA requirements, but as a way to simply reduce loss in the event of another flood.

The following sections provide a more detailed context to the proposed flood-hardy construction approach. The most common mitigation suggestions from FEMA are elevating a structure to or above the base-flood elevation, moving the structure to a site out of a flood zone, or demolishing the structure to build a new house on the site. A less common approach included in FEMA publication is floodproofing. FEMA makes a somewhat confusing distinction between "wet flood-proofing" and "dry floodproofing."

In short, "wet floodproofing" is the term FEMA uses to describe construction that can be flooded and still meet FEMA requirements. FEMA specifies the allowed uses, the construction materials and methods required to minimize damage in the event of a flood. "Dry floodproofing" is in fact construction that keeps water from coming into the building.

Both wet flood-proofing and dry floodproofing are described below to provide the context for the primary subject of this study, which is not flood-proofing of any sort, but construction that minimizes the loss in the event of a flood.

FEMA-Applied Mitigation Approaches:

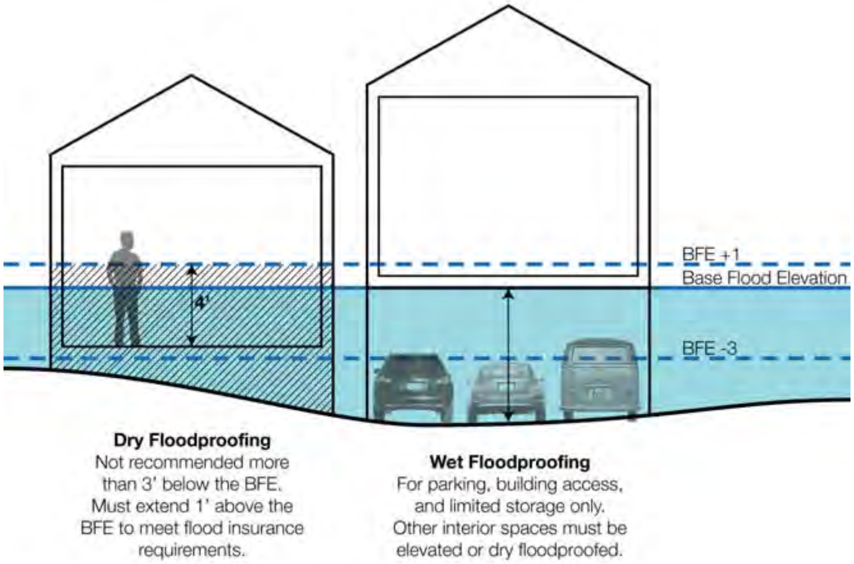
FEMA's publication *Homeowner's Guide to Retrofitting* covers several approaches to flood mitigation including elevation, relocation and demolition. The strategies of relocation and elevation are oftentimes prohibitively expensive for homeowners without financial assistance. These mitigation approaches are also limited by the home's foundation type and structural system; for instance, a slab-on-grade brick home is difficult to elevate or relocate. Some homeowners may opt to demolish a home after a flood event and rebuild an elevated structure. This option is somewhat straightforward from a practical standpoint because it means the home is beyond salvageable and the homeowner has insurance or other funds to enable them to build another home. All three of these strategies (relocation, elevation and demolition) are generally well understood in flood-prone regions and are employed by people who have the financial means.

This report will not focus on the options of elevating or relocating; rather, we will focus on the options of flood-proof and flood resistant construction. Flood-proof and flood resistant construction is a more relevant strategy pertaining mostly to the materials and methods of construction and are, therefore, a focus for the architect and building construction specialists.

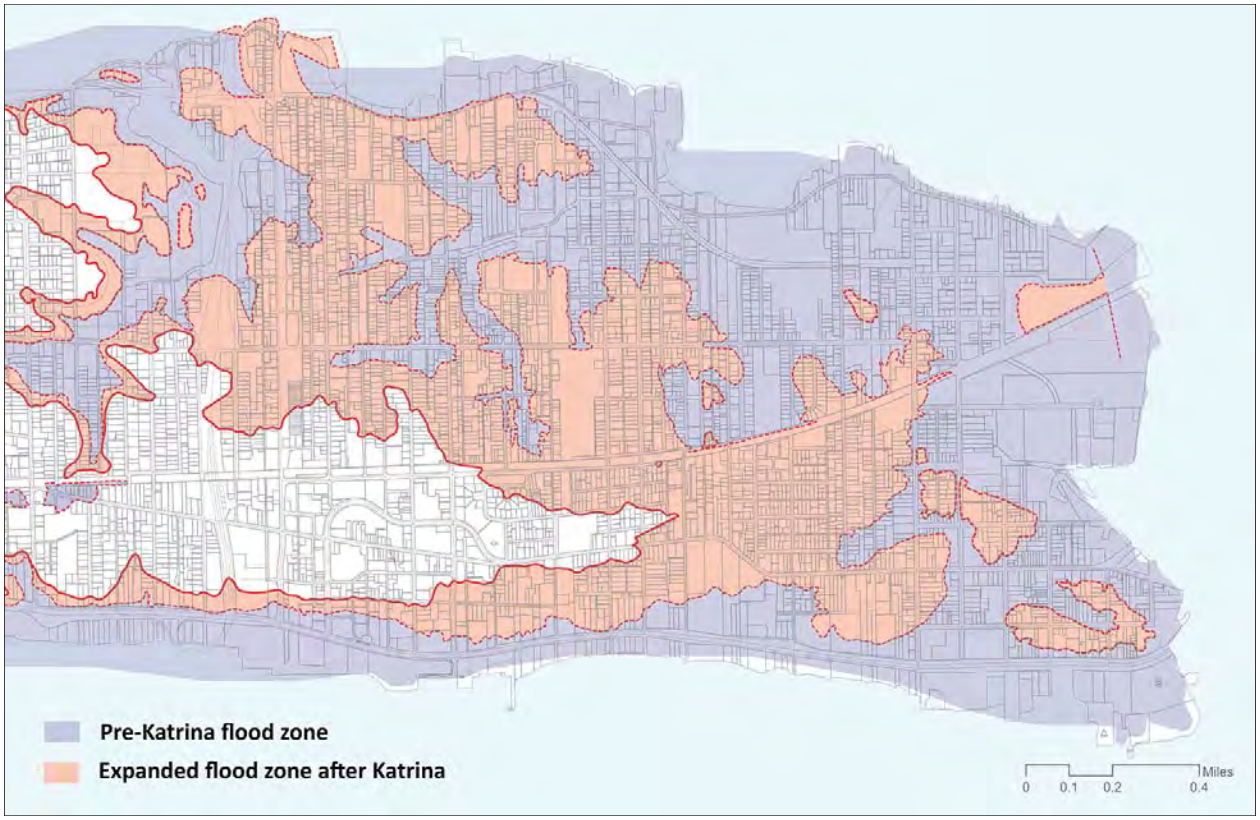
It should be noted that floodproofing is much easier to implement in new construction than in retrofit. Floodproofing during new construction allows different types of materials to be specified from the beginning of the construction process and implemented seamlessly within many typical building practices. The use of floodproofing methods is increasing in new construction projects, especially in commercial structures where the additional costs associated with floodproofing receive higher pay-back over time through reduction in flood insurance. At this time, floodproofing in residential structures does not offer the same financial incentives in the form of insurance discounts as in commercial construction because FEMA does not allow residential

Report covers for various FEMA publications regarding floodproofing and risk reduction. *Images courtesy of FEMA.*

Right: Comparison of dry and wet floodproofing techniques. *Image provided by Gulf Coast Community Design Studio, 2010.*



construction to be built below the base-flood elevation, which is the primary reason flood proof construction is not used for housing. Furthermore, advanced methods of floodproofing such as the methods discussed in the following pages generally require the oversight of an architect or engineer, which may not be involved in more standard home construction.



Flood Insurance Rate Map in East Biloxi before and after Hurricane Katrina. *Image provided by Gulf Coast Community Design Studio, 2009.*

Wet Floodproofing:

The intention of wet floodproofing is to allow floodwaters inside the structure while limiting damage to systems and equipment. Its application is generally limited to unoccupied areas of a structure such as basements, crawlspaces, garages and storage areas. Electrical or mechanical equipment can be raised or relocated to areas above an understood elevation point so floodwaters can enter the building and significant damage will be limited or easily repaired. Unlike dry floodproofing, wet floodproofing equalizes the hydrostatic pressure on the walls of the building, so severe structural damage is limited in that way, although damages from floodborne debris or high velocity wave action are still concerns. The equalization of hydrostatic pressure is provided by flood vents in the building's exterior wall which remain open at all times or open with a floatation device or other mechanism in the event of a flood. FEMA provides numerous requirements as to the size, functionality, placement and number of these vents in their Technical Bulletin *Openings in Foundation Walls and Walls of Enclosures*.[xiii] While this requirement is fairly straightforward in new construction projects, it becomes somewhat complex and disruptive in a retrofit situation. As in dry floodproofing, it is recommended that a design professional evaluate the foundation wall or exterior wall the flood vents are to be placed in, especially in areas prone to riverine flooding where the wall may be susceptible to higher velocity flood waters. If the area is below grade, pumps may be required to pump out floodwater after an event.

Flood openings in foundation walls are required for wet floodproofing to allow the free movement of water in and out of a structure. *Image provided by FEMA.*

The obvious downside to a retrofit by means of wet floodproofing is that the enclosure which receives the flood vents is essentially sacrificed to floodwaters in the event of a flood. This is why this strategy only works in conjunction with relocating or elevating more expensive and necessary equipment above the BFE and out of harm's way (such as water heaters, heating and cooling equipment and appliances). Because of the ever-present threat of a flood occurring, these resulting spaces' only practical uses are storage, access or parking. In extreme cases, when a house is located below BFE and elevation is impractical, homeowners may opt to completely abandon the ground floor of the house and renovate or construct a second story of the house in which to live. In this instance, flood vents would be installed toward the bottom of the exterior walls of the home and the ground floor would be used for parking, access and storage.

Because the lower levels of the walls and especially floors are still susceptible to flood waters, only materials resistant to floodwaters should be used in this type of retrofit. FEMA has published a list of flood-damage resistant materials recommended for these types of applications, such as pressure treated plywood, concrete or cement board. These materials are able to remain wet for a period of time, be cleaned and still have structural integrity to remain in place. This topic will be explored further in later sections in this report. As with dry floodproofing, FEMA does not consider the strategy of wet floodproofing to be an acceptable retrofit if your home has been flooded and is considered Substantially Damaged or Substantially Improved (meaning, damaged beyond 50% of the structure's value). Therefore, wet floodproofing is most practical for new construction.

Two workers are elevating condenser units on a platform above the Base Flood Elevation. *Image courtesy of FEMA.*

Dry Floodproofing:

Dry floodproofing is accomplished by installing watertight materials around the perimeter of a structure to prevent floodwaters from entering the building. This is done by using waterproof coatings and membranes around foundation materials and the lower portion of the exterior walls to prevent water from flowing through. Along with this, shields are installed at the exterior doors and windows which are put into place by the homeowner in the event of a storm. Dry floodproofing can be a problematic retrofit strategy because the structure will be subjected to various forces that it was not originally designed to withstand and it may fail. One such force is the hydrostatic pressure exerted by the weight of the floodwaters pressing against the outside of the house. Because of this, dry floodproofing is usually suggested only to a height of about three feet and even then, advice should be sought from an engineer. Another force the structure may not be able to withstand is the buoyancy force of the water from underneath, which may cause foundation damage or settling issues over time. A problem may also arise if windborne or water-carried debris were to strike the structure during a storm and puncture the structure or cause further damage. Finally, a potential issue arises if floodwaters overtop the level of floodproofing, enabling the floodwater to rush in and possibly cause severe structural damage.

A waterproofing membrane is installed below grade to prohibit the flow of water into basement areas. *Image courtesy of Foundation King.*

Right: Flood barrier gates installed at doorways before a flood event is a form of dry floodproofing. *Image courtesy of New York City Planning Department.*

The various sealants, gaskets and shields employed in dry floodproofing will require human intervention in terms of maintenance and installing shields into place at doors and windows upon hearing warnings of an approaching storm. Recognizing all the risks as stated above, a homeowner may be able to install some dry floodproofing measures in their home as a means of protecting certain areas or levels of the home but as each home and its construction methods will be different, careful consideration and perhaps professional help may be needed to determine the best applications. In any case, the applications for installing dry floodproofing measures are limited and must be determined on a case-by-case basis, suggesting that the cost of the work may outweigh the financial paybacks of the retrofit. Some success has been seen in dry floodproofing in new construction where its application is more easily incorporated into the initial detailing and specification of materials. As previously mentioned, commercial structures may be more appropriate for dry floodproofing because of high retrofit costs, and they also may be able to better capture insurance discounts than residential buildings. Furthermore, the inherent value of protecting a commercial building is significant in that the loss of its contents would be of great detriment to a business and the employability of its staff.

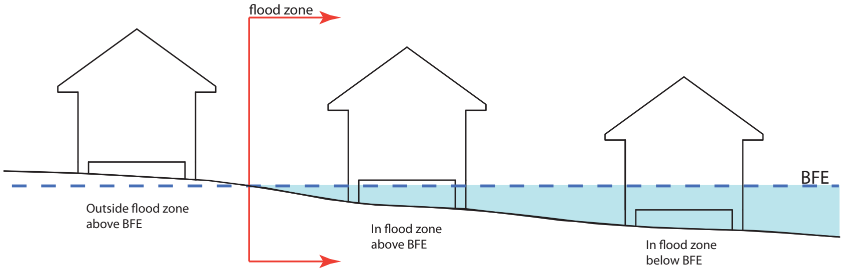
Another practical application of dry floodproofing is for historic structures. Careful design and would be needed in order to assure the building could withstand external forces from flooding, but a historic structure could be protected from a flood event up to the level of its floodproofing. Furthermore, many sealants, gaskets and paints could be applied in ways that would protect the building while maintaining its original exterior appearance and any historic designations. We can see that many buildings could benefit from dry floodproofing, however its practical application in standard, residential buildings is limited.

Flood Resistant Construction

Flood resistant or flood hardy construction is different from dry and wet floodproofing and is the primary focus of exploration in this report. It is not a strategy that has been recognized by FEMA or flood insurance providers, but has been gaining some attention as a noteworthy retrofit option in recent years. For the purpose of this report, the authors define flood resistant construction as the use of materials and methods that are able to withstand being subjected to floodwaters for a period of time (say 8 hours), and are capable of returning to their nearly original state after being cleaned, allowing time to dry and undergoing minimal construction work. This has been seen many times following flood events where houses with flooring made of concrete or ceramic tile, for example, are much easier to dry, clean and restore to their pre-storm condition than a carpeted floor.

Many materials typically employed in the construction of houses are inherently susceptible to water damage, and so when a flood event occurs, these types of materials will naturally be the first removed from the building—sheetrock, fiberglass insulation and carpet are among these. However, developments in construction technologies and materials is ever-evolving, especially considering new advancements toward energy efficiency and indoor air quality in buildings. Construction practices and material properties aimed to reduce dust and mold within buildings is a rapidly growing segment of the market, as consumers are recognizing the effects of "unhealthy buildings" on asthma and allergy sufferers. It stands to reason that these same materials which are designed and installed to withstand the moisture needed to produce mold may have applications that are also suitable to withstand the effects of flooding. Newer and emerging construction products such as closed cell spray foam insulation are deemed to have waterproofing properties as well as their originally intended purpose of providing insulation, and perhaps is a better material to use while repairing a flood-damaged home after a storm event. In later sections of this report, we will look at recommendations such as these which are emerging in the fields of building science and construction, and determine additional work that is needed to more completely develop a set of recommendations that can be deployed following a flood event.

Right: Homes within or outside of flood zones, above or below BFE can benefit from employing flood resistant construction. *Image courtesy of Gulf Coast Community Design Studio.*



Available Guidance

FEMA:

FEMA released a guide in 2014 entitled *Homeowner's Guide to Retrofitting: Six Ways to Protect your Home from Flooding*, a non-technical publication to guide homeowners toward the best ways to protect their homes. It covers retrofit options from relocation, elevation and demolition to wet and dry floodproofing, along with some information on barrier systems. Lastly, the guide gives guidance on deciding which technique is best for your home, considering its level of risk to hazards, construction type and finish floor elevation. Some basic information regarding community rating systems, working with local code officials, contractors and design professionals as well as finding financial resources to help pay for retrofits is also included, to help homeowners navigate the sometime overwhelming process of home renovations. The guide includes the relative costs of the various retrofit techniques and lists wet floodproofing as the least expensive approach, followed by dry floodproofing.

NFIP regulations require that any non-residential areas below BFE are constructed with flood damage-resistant building materials. For example, this would occur in storage sheds or utility areas located at ground level under a structure with a raised floor system. While the structure and its materials are not able to be included in a claim following a flood (even if they are flood damage-resistant materials), any appliances located under BFE such as hot water heaters or furnaces are insured. The NFIP defines flood damage-resistant material as "any building product [material, component or system] capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage." Cosmetic fixes are to be expected which include cleaning, sanding, refinishing and painting.

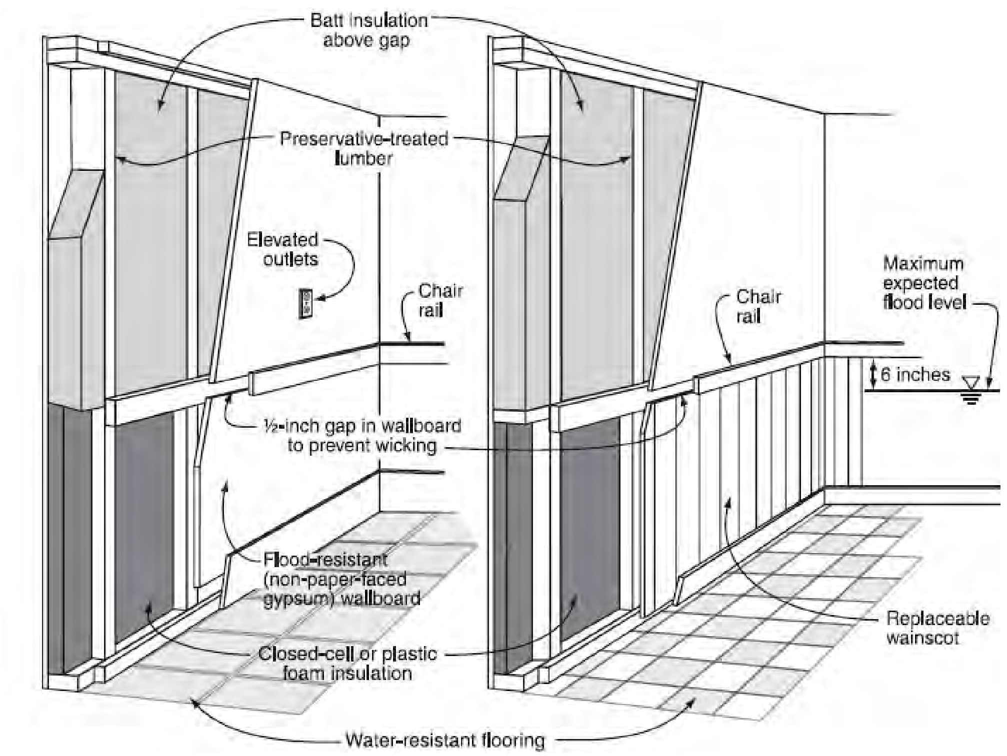
FEMA has defined five levels of flood resistance and states that Classes 4 and 5 are acceptable in areas under BFE. A full list of recommended materials can be seen in FEMA's *Technical Bulletin 2* entitled *Flood Damage-Resistant Materials Requirements*.

The diagram on the opposite page illustrates some suggested retrofitting of interior walls in a pre-FIRM building. However, please note that the techniques illustrated cannot be used to bring a substantially damaged or substantially improved building into compliance with the NFIP. For additional information on wet floodproofing, see *Technical Bulletin 7, Wet Floodproofing Requirements*. In the *Wet Floodproofing Requirements* bulletin, FEMA also gives guidance on designing or elevating electrical, heating, ventilation and plumbing components to protect them from potential flooding. This may include using special waterproof outlets and light fixtures under the BFE level which help prevent damage during a storm

5	Highly resistant to floodwater damage, including damage caused by moving water. These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants. Materials in this class are permitted for partially enclosed or outside uses with essentially unmitigated flood exposure.
4	Resistant to floodwater damage from wetting and drying, but less durable when exposed to moving water. These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants. Materials in this class may be exposed to and/or submerged in floodwaters in interior spaces and do not require special waterproofing protection.

Excerpt from FEMA's classification of flood-damage-resistant materials showing the characteristics of acceptable materials. *Information courtesy of FEMA, table provided by Gulf Coast Community Design Studio.*

event and help speed up the recovery process afterward. Furthermore, fully enclosed areas below BFE must be outfitted with flood ventilation openings which allow the free movement of water into and out of the structure which helps to prevent hydrostatic pressure buildup. Minimum area of openings is required based on the square footage of the enclosure, and flood vents must be located within a foot of grade level.



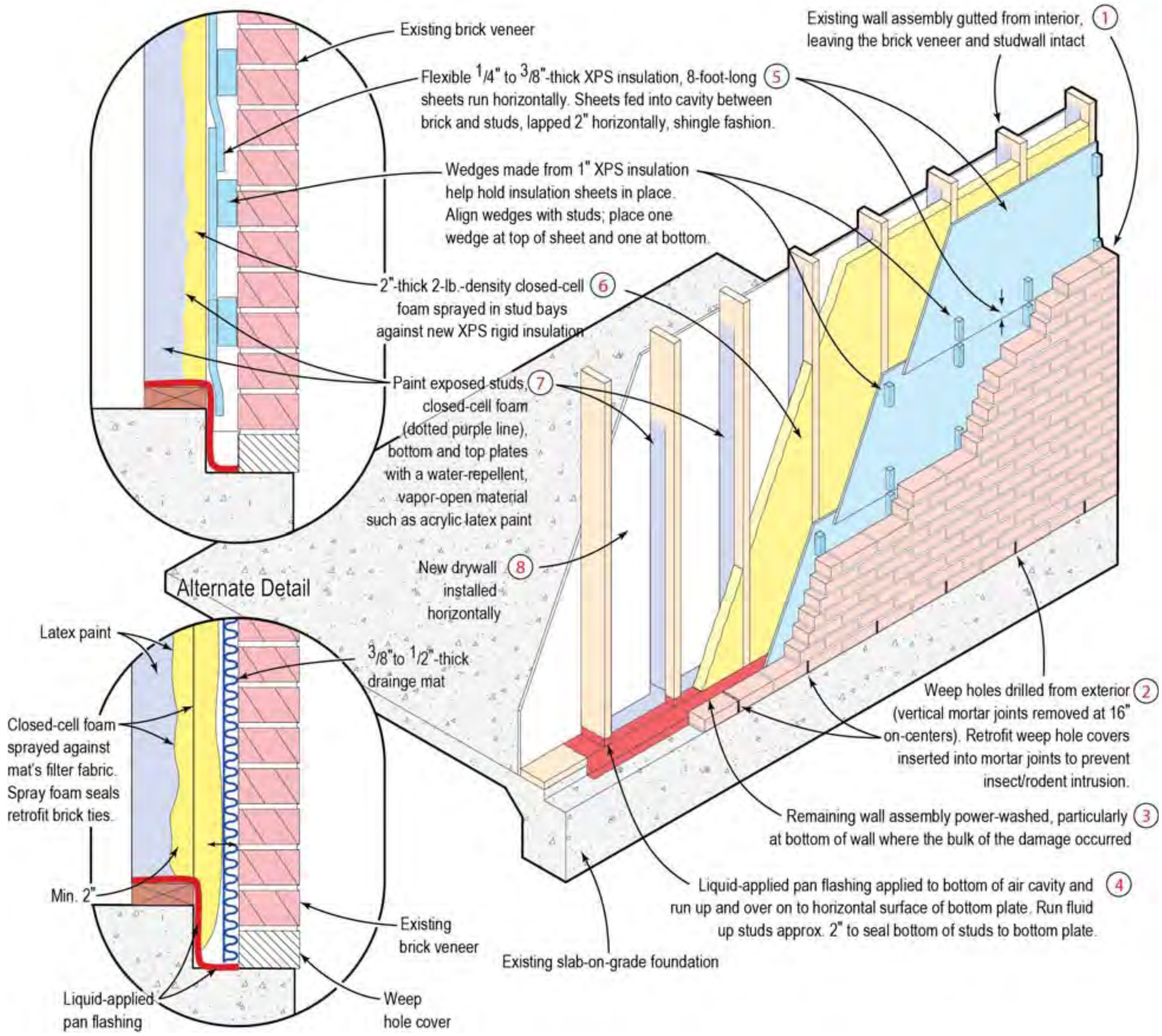
Partial wet floodproofing techniques employing flood damage-resistant materials for finished wall construction. *Image courtesy of FEMA.*

Building Science Corporation:

Building Science Corporation is a well-known building science consultation practice out of Westford, Massachusetts. Founding principal Joe Lstiburek has been a notable thought leader in the building science industry over the years, releasing numerous *Insights* articles regarding building science hot topics, and has weighed in on his recommendations for retrofitting flooded houses. In his article, *Rebuilding Houston: Wash and Wear Buildings*, Lstiburek gives his recommendations for addressing one of the most challenging flood retrofit conditions—that of a slab-on-grade brick veneer home. After complete removal of any water permeable products such as exterior sheathing and drywall, the brick ties are cut and removed. New weep holes can be cut into the brick from the exterior and then time is allowed for the assembly to dry. His strategy begins with a new fluid-applied flashing on the bottom plate of the exterior walls. Extruded polystyrene sheets (also called XPS) are installed in one of two ways—either in pieces between each stud bay, or in three-foot tall sections slipped in behind the brick in shingle fashion. The polystyrene sheets may need to be temporarily secured along the edges until the final step which is two inches of closed cell polyurethane spray foam insulation. The closed cell insulation is important because it creates a vapor barrier and is resistant to wetting, while also adding structural stability to the wall. The structural component is especially important since the exterior sheathing was removed in previous steps. The final step before drywall can be installed is spraying acrylic latex paint from the interior of the structure onto the entire wall assembly (studs, top and bottom plates, and insulation) which creates a barrier for the wall that is easily cleanable when the next flood comes.

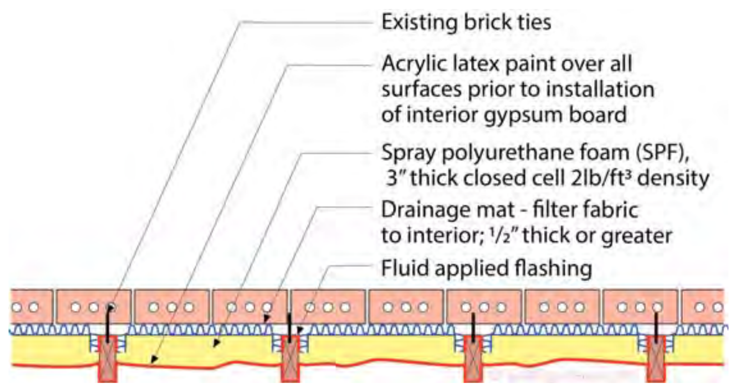
While this approach produces an airtight wall assembly that has many benefits, there are also a few difficulties and drawbacks in its design. Firstly, installing the polystyrene sheathing between the brick veneer and the studs is an extremely difficult if not impossible task to accomplish. Even with new developments in fan-folded polystyrene sheathing, the worker could better handle the sheathing, but maneuverability would still be difficult within the stud bays. Secondly, the brick ties would need to be cut from the back of the studs which at first seems to be an acceptable short-term solution; however, if the building was inspected by a building code inspector, he or she would expect to see brick ties installed to protect the integrity of the building. There are retrofit brick ties which could be utilized by puncturing the polystyrene sheathing, but installation would again be difficult and would damage the watertight barrier that was so carefully installed. However, if this approach was implemented successfully, the wall assembly would have a complete exterior sheathing layer which has valuable energy efficiency benefits since thermal bridging is greatly reduced. Furthermore, a solid, continuous drainage plane behind the brick veneer would create an impermeable, durable air and water barrier.

An alternative approach involves a drainage mat filter fabric applied directly to the backside of the brick, which is installed in lieu of the extruded polystyrene sheets. A drainage mat is a high impact polystyrene fabric-like material commonly



Above: Drawings showing a strategy to retrofit a flood tolerant wall system from a slab-on-grade brick veneer wall. *Image courtesy of Building Science Corporation.*

Right: Alternative retrofit strategy showing a drainage mat directly applied to the brick in lieu of polystyrene sheets. *Image courtesy of Building Science Corporation.*



used in rainscreen applications to provide an semi-structured air drainage gap behind siding. The thinking is this alternative is more user-friendly and workable to be able to push the material in and around framing members. The guide even provides recommendations in the case that a drainage mat is unable to fit behind framing members, in which case the mat could be folded around the studs and attached that way, as shown in the image on the previous page.

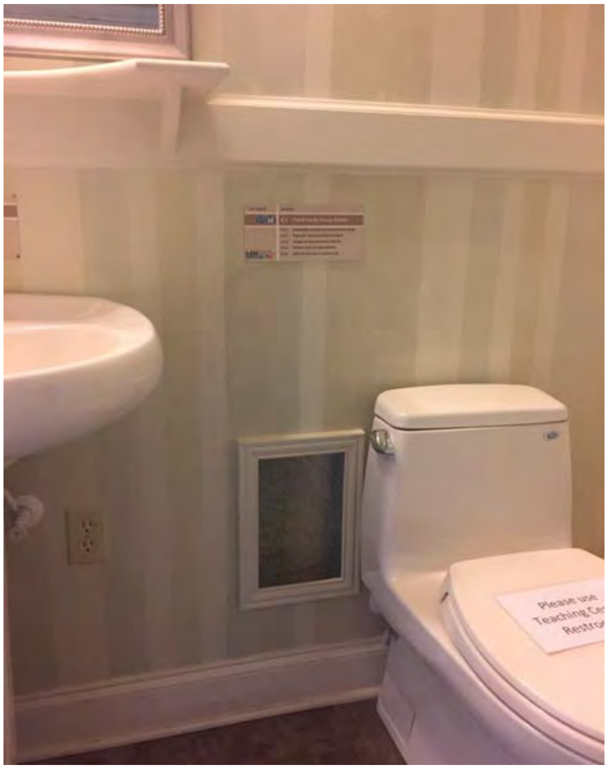
The article makes mention of the importance in correctly flashing and reinstalling windows and doors in order for the new drainage planes and flashing to perform properly. This is clearly one of the more challenging intersections to work on, as the space is small and difficult to maneuver within, especially if the worker needs to access the backside of the stud cavity. While installing the drainage mat (as seen above) is an easier approach to implement than sliding polystyrene sheathing behind the studs, this approach does not waterproof or protect the backside of the studs, leaving them susceptible to water damage over time. It is unknown if this water damage would become a serious issue over time, or if it would be mediated by the movement of air within the air gap. It is also possible that mold may grow within the air gap since the space will be damp, and whether the mold would be able to spread to the interior of the home if the interior materials were not properly sealed from the exterior. However, quality installation of the drainage mat and closed cell spray foam insulation should remedy that threat.

The article also goes into some depth describing Lstiburek's recommended construction details in the case of new construction in a flood-prone area. He strongly urges an elevated platform with the entire first floor constructed from concrete masonry units; however, realizing this approach is beyond the budget of most middle-income homeowners, he gives in to a much less ambitious approach. He gives recommendations for a slab-on-grade brick house with expanded polystyrene sheathing in the walls held in place with closed cell spray foam insulation. This approach will be discussed in more detail in the following section about Louisiana State University's LaHouse project in Louisiana, where Lstiburek collaborated with local leaders to help design the "flood-hardy" wall assemblies for the demonstration house.

Louisiana State University and the LaHouse:

The Louisiana House – Home & Landscape Resource Center is a public- private partnership, built in Baton Rouge, Louisiana, with monetary gifts and donated materials. At the time the house was initially conceived, it was designed to exhibit multiple products mainly concerning the energy efficient, healthy and "green" market of home construction. However, when Hurricane Katrina struck, the house was mid-construction and was left that way for two years in order to display some of its flood resistant features to visitors looking for best practice recommendations. Its flood and wind resistance features meet or exceed the criteria of the Fortified for Safer Living program of the Institute for Business and Home Safety (IBHS), with a portion of the building built to a Design Flood Elevation (DFE) of BFE+3. The teaching center which is dry floodproofed. Use of flood-resistant materials and methods in some places further protects the structure should flooding exceed BFE+3.

The strategies employed within the LaHouse are similar to those recommended by Building Science Corporation, with a few additions. Their approach protects the home should a major flood event infiltrate the home above the height of BFE, and so the wall is constructed so the lower half can be removed and the upper half of the wall can remain as is. Wainscoting is installed on the lower half, with a chair rail around the perimeter of the room which provides a covering that can be removed in the event of a storm. In the LaHouse, the wainscoting is pressure-treated plywood which has been painted and striped to match the upper half of the wall, so it is hardly noticeable to the undiscerned eye. Like Building Science Corporation's strategy, the LaHouse also uses closed cell foam insulation below flood level while still employing low-cost batt insulation on the upper half of the wall. A gap between the wainscoting and the floor, as well as another gap at the upper sheathing, prevents wicking up to the non-flood resistant half of the wall. The LSU guidance goes a step further and also provides recommendations for elevating utilities as able including electrical outlets and switches, washers and dryers and air conditioning. A brochure available online gives homeowner-friendly recommendations as far as building platforms to elevate the washer and dryer and building a storage shed above flood elevation level which can store appliances and valuables in the case of a flood. It also



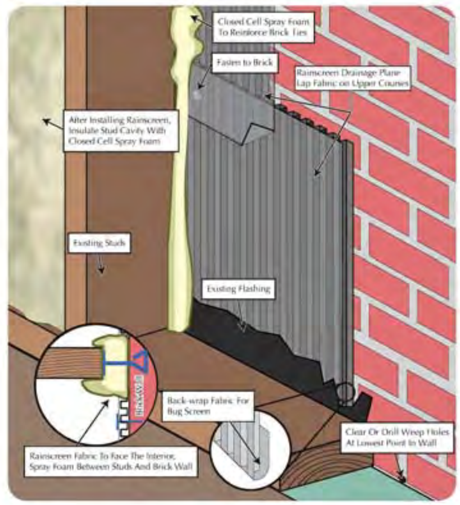
View of the plywood wainscoting in the LaHouse bathroom which has been painted to match the upper portion of the wall which is sheathed in drywall. *Image courtesy of Gulf Coast Community Design Studio.*

makes mention to have sewage backflow valves installed in the home's main sewage line which helps prevent sewage from back flowing into the home which occurs in rare cases when floodwater overwhelms the City sewer lines.

On the LaHouse website, further recommendations for retrofitting a brick veneer wall can be accessed in the Frequently Asked Questions (FAQ) section. The recommendations provide a thorough set of instructions for homeowners to reference after a flood event, covering topics from how to clean and treat any mold found within houses to how to solve cupping in wood floors. The recommendations provide brief descriptions of three retrofit options for brick veneer wall assemblies which are outlined below:

Brick Veneer Rainscreen Retrofit

Closed cell spray foam is sprayed behind each stud, providing reinforcement to the brick ties and also protecting the backside of the wooden studs. A rainscreen drainage plane fabric is then installed between each stud which provides an air gap behind the brick veneer and also a substrate for which to apply closed cell spray foam throughout the stud cavity. This option is probably the most practically-applied retrofit option of the three listed, as it would be the easiest to implement in the field and would provide protection to the studs.



Rendering showing rainscreen fabric installed in contact with closed cell spray foam insulation to create a watertight wall. *Image courtesy of LaHouse website.*

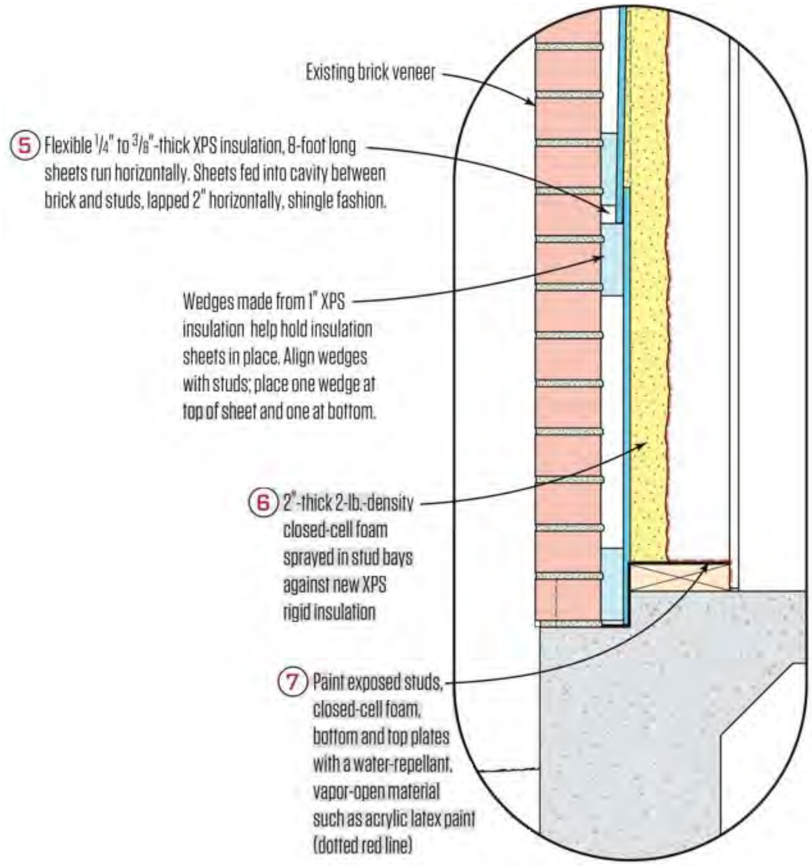
Cavity-Applied XPS Sheathing

XPS sheathing would be custom cut and installed toward the rear of each stud bay, caulking each board in place to ensure an airtight assembly. This option is probably the lowest cost and easiest application of the three methods recommended by LaHouse as it allows the homeowner to install low-cost insulation such as fiberglass batt insulation. However, it leaves the backside of the wooden studs exposed within the air gap. This could be addressed by painting or applying liquid-applied flashing, the website suggests. This option would also allow the brick ties to remain in place.

Application of XPS sheathing installed in each stud bay as backer for insulation. *Image courtesy of LaHouse website.*

XPS Sheathing with Closed Cell Spray Foam

After preparing the interior of the wall cavity, the brick ties would be cut in order to install polystyrene sheets within the wall assembly. This is the recommendation originally provided by Building Science Corporation, and as mentioned earlier would be difficult to install in the field. The large sheets of XPS sheathing would need to be slipped in between the brick veneer and studs, ensuring that a tight, waterproof substrate could be achieved.



Drawing showing the application of XPS insulation applied to a brick veneer wall in a flood tolerant retrofit. *Image courtesy of Building Science Corporation.*

While LaHouse staff and their collaborators have given a great deal of thought in order to arrive at these three recommendations, they do not have the capacity to conduct any applied research to evaluate the success of each wall assembly. Claudette Reichel, the Director of LaHouse Resource Center has provided a great deal of thought leadership and outreach within Louisiana, as the LaHouse facility is used to train design and construction professionals and students. When asked, Ms. Reichel knows of projects within her region that have applied some of the recommendations as described above, but she has not had the resources to monitor the success or durability of any of the retrofits. It was clear to the authors of this report upon visiting the LaHouse and meeting Ms. Reichel, that very valuable knowledge has been cultivated there over the years and should be considered an under-utilized resource for more distant parts of the region. An applied research study of the LaHouse recommendations would help determine which practices are best applied, and resources could be developed to better develop best practices and educate homeowners and contractors in disaster-prone regions.

Emerging Products:

While conducting research for this report, some products were discovered which are marketed specifically for post-flood event retrofits. Noting that none of these products have been utilized or tested by the authors of this report, we thought it noteworthy to include them as they demonstrate a market shift toward addressing retrofitting in flood-prone areas. Not only does their existence validate the need for development of these types of specialized products, their material properties acknowledge that flooding is likely to occur again in these retrofitted homes.

One such product is Masonry Technology Incorporated's (MTI) retrofit brick ties. MTI's website states that these ties were originally developed for flooded homes where it became necessary during retrofitting to cut the original brick ties, as presented in the recommendations earlier in this report. These brick ties are anchored from the interior of the wall, attaching into the stud while the other end is embedded into the brick with epoxy.

Retrofit brick ties provide a means of anchoring brick veneer to the interior stud framing during renovation. *Image courtesy of Masonry Technology Incorporated.*

Keene's Driwall™ Hydric Buffer Mat (HBM) is designed to eliminate moisture vapor during the rehabilitation of homes with brick construction. It is a three-dimensional mat that is a heat-laminated, breathable fabric which is impenetrable to water vapor in masonry walls. It is typically installed within each stud bay from the interior, where the mats are cut to snuggly fit and then are spray-foamed into place with closed cell spray foam insulation. The mat is 0.75 inches thick and helps provides a drainage plane within the wall while helping to seal the interior of the house. Its intention is to ward off any mold, mildew or bacteria that may have been introduced while providing a vapor barrier to aid in the energy efficiency of the retrofitted building envelope.

Keene's Driwall™ HBM drainage mat is used to provide an impenetrable layer in masonry walls. *Image courtesy of Keene Building Products.*

As briefly mentioned above, some developments have been made in regards to polystyrene sheathing insulation, or XPS sheathing. This sheathing is a widely-used insulative board which is commonly installed on the exterior of wall assemblies, particularly in northern climates. When installed under siding it provides a continuous, durable and airtight water barrier which also reduces thermal bridging across the studs, greatly reducing energy loss from within the building. It is normally delivered in four by eight-foot panels so it is somewhat cumbersome to move through door openings and in tighter areas; however, new advancements are helping to make it a more workable product by providing it in a fan-folded form so that it can be worked into smaller compartments and then unfolded along its length. While there is some challenge involved with ensuring the drainage plane is continuous and well-sealed in its entirety, particularly around openings, this product is a promising development toward workability in retrofit situations.

Right: Fan-folded polystyrene foam board insulation provides a vapor and air barrier that is more manageable to use in retrofit situations. *Image courtesy of Lowe's.*

Insurance and Policy Outlook

While construction practices have been adapted over the years and the building product industry has begun to develop new products to aid in retrofits following flood events, the insurance industry has been slow to develop new practices in dealing with flood mitigation. As mentioned earlier, even many of the buildings employing FEMA-approved strategies such as dry and wet floodproofing measures are not able capitalize on insurance discounts for the reduced risk of these structures. At the time this report was written, commercial structures are the only structures able to receive reductions in insurance premiums by floodproofing.

The insurance industry, including the NFIP, would need to completely evolve in order to begin incorporating a procedure aimed at adopting premium discounts for homes that have been retrofitted with flood-damage resistant materials. It stands to reason that if the materials in a home (or commercial structure for that matter) were resistant to flood waters such that they were able to be cleaned, dried and remain in place for continued use, the building would require less work and therefore less of an insurance payout to allow continued operation. In other words, because the building was constructed with materials resistant to damage from flood waters, its actual risk would be lessened. Ideally, this reduction in risk would equate to a discount in the building's annual insurance premiums, but a great deal of work would need to be done before this could happen.

Determining a building's risk and thus insurance premium is generally a non-invasive visit to the building where the insurance agent records data about the exterior finishes such as roofing material, roof pitch and other surface-level details. It is not practical to think that an insurance agent could one day visit a finished building and record enough information to determine if the structure would be able to successfully weather a flood event. As discussed earlier, even the structural capacity of the building would need to be evaluated by a design professional to evaluate its potential to withstand wave action or high-velocity impact. Furthermore, each material within the foundation and wall assemblies would need to be specified and constructed so as to withstand wetting, drying and refinishing. An inspection would need to be done mid-construction or mid-retrofit to ensure the correct kinds of materials were installed in the building, and that they were installed properly. This is obviously not a process or skillset the current insurance industry would be comfortable to take on.

However, the insurance industry has the same risk reduction goals as the consumer, and has taken an active role in creating ways to reduce risk, contrary to the belief of many consumers. The most apparent aspect of the insurance industry's active participation in risk reduction is the creation and growth of the Insurance Institute for Building and Home Safety (IBHS). IBHS is an independent research and education organization that is funded by the insurance industry whose purpose is to determine the most effective strategies for fortifying homes, businesses, and communities against future natural disasters, most notably high wind hazard. By conduct-ing simulated wind and storm events in their state-of-the-art research facility, IBHS is able to test full-scale houses to see the effects a given storm will have on the structure. In 2010, IBHS created the FORTIFIED Home™ program, a three-tiered set of standards identifying construction features that will protect an existing home from an identified disaster. The tiers, labeled Bronze, Silver and Gold, are cumulative and for the Hurricane program target typically weak areas in home

FORTIFIED Home™ Standards produced by the Insurance Institute for Business & Home Safety. *Image courtesy of IBHS.*

construction: the roof covering, window and door openings, and structural framing, respectively. A third-party evaluator performs an initial assessment and inspects the home again after the retrofits have been implemented. If implemented correctly, the homeowner will be issued a FORTIFIED certificate.

A key change began to happen following the creation of the FORTIFIED program in that policy mandated that insurance carriers begin offering wind insurance discounts to buildings with a certificate. For example, in Mississippi this policy change occurred in 2012 and only required carriers to offer discounts but did not assign a percentage value of discount. As carriers have learned more about the FORTIFIED program, this discount amount has slowly crept upwards and consumers are being educated on the importance of shopping around for the best insurance rates. In other words, the insurance carriers must compete to offer the lowest premiums for their customers. This has allowed us to reach a point where wind mitigation is a worthwhile investment for a homeowner, where he or she will be able to receive a fair payback through reduced insurance premiums following an investment in roof retrofit work.

Beyond the benefit of achieving reduced insurance premiums, the FORTIFIED program has brought about other, more altruistic benefits. Professional development and outreach has expanded tremendously since its implementation, offering continuing education opportunities for design professionals and contractors to learn best practices in wind mitigation. Some contractors are beginning to see the financial and marketing benefits of carrying a FORTIFIED-Wise designation, indicating they have the knowledge and experience to construct a home to withstand hurricane force winds. Homeowners are beginning to recognize and even request that their new home carry the FORTIFIED designation, or to consider retrofitting their roof to meet the requirements. In extreme instances, in places like Baldwin County, Alabama, the local municipality has gone a step further by writing a supplemental building code which includes provisions from the FORTIFIED program, in essence strengthening the municipality's building stock and lowering insurance premiums for many residents.

The payback equation for flood mitigation work does not yet work for a homeowner like it does for wind mitigation, but there are still many benefits to its implementation. The most obvious benefit is the decreased loss of property which brings numerous advantages. Any property damage that is lessened decreases the cost to repair the damage and shortens the amount of time a family is displaced after a major flood event. This in turn allows people to return to work more quickly after a storm, earn money and continue contributing to their local economy. The billions of pounds of debris pushed to the curb of many neighborhoods after a flood would be lessened, as would the impact on local landfills. The burden to the NFIP would be decreased as homeowners become armed with a strategy to implement changes within their homes and lessen the loss experienced after a flood event.

Politically, the 2017 storms Harvey and Irma were a strong motivator to address the growing need for flood mitigation guidance. Republican Congressman Sean Patrick Duffy of Wisconsin and Democratic Congressman Earl Blumenauer of Oregon are members of the House Financial Services Subcommittee on Housing and Insurance and are spearheading policy changes to the NFIP. In an article they wrote for the *Omaha World-Herald*, they say this:

> ***We've concluded that the way the federal government handles disasters is itself a disaster. Drastic reform of the National Flood Insurance Program is long overdue. The program now subsidizes insurance for millionaires, puts low-income families in harm's way and keeps people trapped in vulnerable homes by masking the true risk of flooding. The president and Congress have just extended the program for three months, creating a perfect opportunity for Congress to enact bipartisan reforms.*** [xviii]

They believe that the national government has for too long fostered the ability for people to live in coastal areas by subsidizing their flood insurance rates through the NFIP and thereby disguising the amount of risk their home faces. As a first step they called for the FEMA flood maps to be updated to better depict the number of homes at risk from flooding. Eventually, they would like to see flood insurance premiums more toward actuarially sound rates so homeowners would be

House in Pearlington, Mississippi, that was elevated following Hurricane Katrina. *Image courtesy of Gulf Coast Community Design Studio.*

somewhat motivated to move away from flood prone areas or retrofit their homes to better prepare them for floods. More specifically, in their article published in the Omaha World-Herald, they call for:

> ***Strong flood-proofing standards are needed to see that repeatedly flooded properties are reinforced or elevated. In many cases, flooded homes should be relocated, allowing floodplains to return to their natural state.***

The Congressmen are sensitive to the financial burdens this may cause, particularly on low and moderate-income families, and realize certain measures will need to be taken to help these families, although those measures seem undefined for now. However, they say that major policy reform is mandatory at this point, as the NFIP program was indebted more than $24 billion at the time the above-mentioned article was written (September 2017), and it collects $3.5 billion a year for a program which costs $5 billion to run annually.

In November 2017, Blumenauer and Duffy helped pass the 21st Century Flood Reform Act in the House of Representatives, which extends the NFIP funding through 2022. Along with extending the program, the bill includes several items aimed to facilitate the transition toward some of the mandates of the Biggert-Waters Act of 2012. Included in that bill were provisions to:

- Protect policyholders from unreasonable premium rate hikes
- Encourage more private flood insurers to enter the market
- Improve flood mapping
- Reduce costs for repetitive loss properties
- Require FEMA to share historic flood loss data with private insurers

The bill will be revised in the months before it heads to the Senate (that date unknown).

Research has found that $1 billion was included in the bill's budget which is designated to "help homeowners flood-proof their homes" but specific measures for this initiative were not found.[xix] In order to implement widespread floodproofing or hardening measures, it seems as though more research is needed in order to evaluate best practice measures that have been proposed by the construction industry, and determine if these retrofits are in fact beneficial and economical over the long term.

Conclusion

Changing construction practices is a long-term effort, but it is possible. The effort starts with questions and experiments to begin to demonstrate the value of change. Changing the way houses are built and retrofitted in flood-prone areas has obvious benefits. Reducing losses after a flood will save costs, reduce waste and speed up the process of people getting back into their houses. All of these benefits are obvious. However, the challenge to changing construction practices is not simply a building technology problem; it is also an industry, insurance and financing problem. A good analogy to the challenge of improving flood resilience is the long term changes in construction practices that significantly reduced losses due to building fires. There was a time in history when a fire was seen as a catastrophic hazard. A fire generally destroyed the entire building and often spread to destroy neighboring buildings as well. Today, building fires sometimes make the news and can be tragic. However, most potential building fires either do not even get started or are controlled and contained to significantly reduce losses. This change is significant and came about because the insurance industry led an effort to create building codes and building material testing and standards with the American Society for Testing and Materials (ASTM). It is easy to imagine the same path forward for flood resistant construction. ASTM could test various assemblies and create standards for flood resistance. The building code could require flood resistant materials and assemblies in the same way it requires fire resistant

Houses in Biloxi, Mississippi, that are in flood zones and under Base Flood Elevation. *Image courtesy of Gulf Coast Community Design Studio.*

materials and assemblies. Such building industry changes would be part of the insurance industry's effort to reduce losses.

Why have such changes in construction practices to make buildings more flood resistance not happened? The main reason is because flood insurance does not work like fire insurance. The National Flood Insurance Program was created to help people who otherwise would suffer an even greater loss. NFIP has been a blessing for hundreds of thousands of people. However, as discussed above, the NFIP is not working to solve the long-term problem of reducing flood losses. It is obvious that changes are needed in the way flood insurance works to create the industry incentives to make buildings more flood resistant. It is not surprising that the main political concern with the NFIP is the fact that it is in an impossibly deep financial hole due to unprecedented years of flood losses. We hope that in the efforts to address the fiscal problem of NFIP, the insurance industry will take a lead to address a longer-term goal of creating an insurance environment that will result in the same sort of improvements which were achieved with fire hazards.

In the meantime, making progress will depend upon experiments and demonstrations to show better ways to build. Following the example of FORTIFIED Homes, these demonstration projects will likely start with grant funded non-profit organizations, and will eventually move to the private market when the insurance industry creates the right incentives to benefit all involved. We at the Gulf Coast Community Design Studio are certainly aware of the need as we work and live in communities which suffered after Hurricane Katrina, and continue to struggle with high insurance cost and the uncertainly of living in flood-prone areas. We are committed to do future work to move this long-term effort along and look forward to creating partnerships with other organizations to work together to make changes that will make houses and communities more flood resilient.

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