Performance of One- and Two-Family Dwellings

Mitigation Assessment Team Summary Report and Recommendations
Commonwealth of the Northern Mariana Islands
Super Typhoon Yutu

FEMA P-2178

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1. Executive Summary

In October of 2018, Super Typhoon Yutu broke several records by becoming the strongest typhoon ever recorded to impact the Commonwealth of the Northern Mariana Islands (CNMI). Yutu killed two people and injured 133 more, while also destroying homes and damaging infrastructure throughout the populated areas. Most damage to commercial and public buildings in southern Saipan had roof coverings blown off their roof decks; for residential buildings, the damage was more extensive, with roof coverings and roof decks being removed from roof frames or the loss of the entire roof structure. Many of these one- and two-family homes had light frame roof systems consisting of light gauge metal roof panels nailed to a non-engineered roof frame structure. When concrete homes constructed with concrete frames or masonry walls used this light roof system, the homes also were severely damaged. Many buildings that did not have extensive, visible exterior damage were observed to have experienced significant water intrusion, causing damage throughout the homes. Vegetation was uprooted and mixed with other wind-borne debris, such as doors and storm shutters, contributing to the wind damage. Saipan's and Tinian's critical infrastructure—including hospitals, schools, airports, power, water supply, and roadways—all suffered major damage. The damage caused by Typhoon Yutu is not unique, but rather something that the CNMI will likely face again in the future.

In November 2020, FEMA's Building Science Branch, in conjunction with FEMA Region 9 and supported by the Strategic Alliance for Risk Reduction (STARR II), provided specialized architectural and engineering expertise through the Mitigation Assessment Team (MAT) program to assess building performance; document observations, conclusions, and recommendations; develop customized Recovery Advisories and Fact Sheets; and provide tailored training and subject matter expertise. These products and trainings are meant to support the CNMI in ongoing recovery from Super Typhoon Yutu and in preparedness for and resiliency in the face of future similar storms.

The team worked with local agencies to assess damage to many types of buildings, including the hospital, police and fire stations, schools, government offices, and homes. The goal was to learn how buildings performed during the typhoon and why they withstood or did not withstand the strain caused by wind and flood hazards. Upon conclusion of the field investigation, specialists worked as a team to analyze the field data as well as other damage reports and studies conducted by government agencies or private firms. Finally, the team prepared conclusions and developed recommendations based on these findings. This information is presented in three targeted reports:

- Codes, Standards, and Permitting (FEMA P-2177)
- Performance of One- and Two-Family Dwellings (FEMA P-2178)
- Performance of Public Buildings and Critical Facilities (FEMA P-2179)

This report (FEMA P-2178) focuses on the performance of one- and two-family dwellings impacted by the event. The performance of these residential buildings varied depending on their design, construction type and quality, geographic location, maintenance history, and siting. Numerous homes sustained catastrophic structural damage from wind. Many other residential buildings performed adequately, but sustained damage to roof coverings, windows, and doors, allowing wind-driven rain to infiltrate the buildings and damage the contents. A consistent observation was that many home designs did not factor in the effects of wind speed-up due to the topography of the islands.

The recommendations resulting from building performance assessments help FEMA support long-term recovery efforts. FEMA coordinates with local agencies and organizations to assess the hazard-resistant provisions of building codes and standards, allowing these provisions to be enhanced and strengthened. In addition, recommendations support community development of long-term strategies to aid in reconstruction, reduce damage from hazard events, and improve community resilience.

The recommendations are provided to help the CNMI outline a path forward for reconstruction, building community resilience, and other relevant ongoing activities. These recommendations also can be used by the CNMI to help guide and better prepare communities, property owners, and other stakeholders for future storms. Table 1 briefly summarizes the detailed recommendations found in Section 4 of this document and recommends a leader to implement each suggested action.

Table 1: MAT Summary of Recommendations

#	Recommendation	Leader for Implementation
EXTERIOR WALLS AND ROOF STRUCTURE		
1a	Evaluate existing homes for wind vulnerabilities and retrofitting. Consider hiring design professionals to evaluate existing roof structures, to determine if roofs can carry at least 75% of the design load.	Homeowners
1b	Encourage residents to build in-residence storm shelters and identify their best available refuge area (BARA) before a storm.	Department of Public Works (DPW)
2	Use alternative materials, such as cold-formed metal framing (16 gauge) or wood treated to resist termite damage and decay.	Homeowners/Builders
3a	Limit extended open permit periods for staged or phased construction.	DPW
3b	Protect material during staged or phased construction. Where extended periods of time may lapse between phases for staged construction, provisions should be made for safeguarding the materials used in the construction so that they maintain their original strength (i.e., capping rebar).	DPW and Homeowners/Builders
4a	Require the use of structural roof deck below roof coverings (primarily below metal panel roof coverings), as directed by current building code.	DPW

#	Recommendation	Leader for Implementation
4b	Require larger framing members and smaller spacing to increase roofing strength and reliability.	DPW
4c	Require proper connectors between the roof framing and the walls. Homeowners and builders should connect wood structural members to the top of the walls, creating a continuous load path from the roof framing to the wall.	DPW and Homeowners/Builders
4d	Consider increasing the number of mechanical fasteners in connections, as required per the manufacturer's design.	DPW and Homeowners/Builders
ROOF COVERINGS		
5a	Avoid penetrating roof coverings with utility service masts, including on porches and overhangs.	Homeowners/Builders
5b	Apply corrosion-inhibiting coatings to metal roof panels that have had the zinc coating consumed.	Homeowners
WINDOWS, DOORS, AND OPENING PROTECTION		
6	Consider installing new windows and doors that are rated and labeled for wind pressures and debris-impact resistance when deficient windows and shutters are identified.	Homeowners
7a	Consider replacement of older glazed (glass) openings in existing buildings with new windows designed, tested, and labeled to resist water intrusion.	Homeowners
7b	Consider using water-damage-resistant materials to address water intrusion for interior spaces that have jalousie window systems.	Homeowners
7c	Check windows and doors regularly and ensure proper maintenance. Inspect weatherstripping and replace as necessary. Adjust and replace thresholds as needed.	Homeowners
8	Check shutters regularly and ensure they are properly maintained and serviced.	Homeowners

2. Acronyms and Abbreviations

ASCE	American Society of Civil Engineers
AWPA	American Wood Protection Association
BARA	Best Available Refuge Area
CMU	Concrete Masonry Unit
CNMI	Commonwealth of the Northern Mariana Islands
DPW	Department of Public Works
FEMA	Federal Emergency Management Agency
I-Codes	International Codes
IEBC	International Existing Building Code
IRC	International Residential Code
MAT	Mitigation Assessment Team
mph	Miles per hour
SEI	Structural Engineering Institute
STARR II	Strategic Alliance for Risk Reduction
USVI	U.S. Virgin Islands

3. Event Description and Purpose of Study

In October of 2018, Super Typhoon Yutu broke several records by becoming the strongest typhoon ever recorded to impact the Commonwealth of the Northern Mariana Islands (CNMI), the most powerful tropical cyclone of 2018 worldwide, and the strongest storm to hit the United States since 1935. For this commonwealth situated far from the continental U.S., evacuation is not a viable option. Help and supplies cannot reach the area for days following major storms. It is important to understand the event and the purpose of this study, as it serves to help the CNMI make sound decisions for disaster preparedness and recovery to best protect its citizens against future storms.

3.1. Event Description

Super Typhoon Yutu began as a tropical depression in the Pacific Ocean and grew rapidly in a short period of time, producing 90 mile-per-hour (mph) winds on October 23, 2018, that doubled the next day to 180 mph (Figure 1). On October 25, 2018, Yutu made landfall in the CNMI, with maximum sustained winds of 180 mph and torrential rainfall, according to the U.S. Navy Joint Typhoon Warning Center.[1]

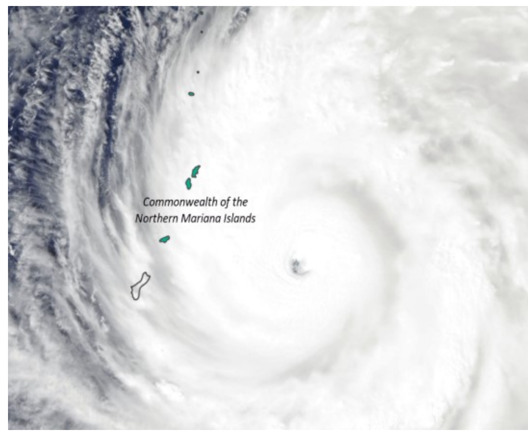

Figure 1: Super Typhoon Yutu crossed over CNMI in October 2018. [Image credit: NASA]

Yutu killed two people and injured 133 more, while also destroying homes and infrastructure throughout the populated areas. Most commercial and public buildings in southern Saipan had roof coverings blown off their roof decks. For residential buildings, the damage was more extensive, with roof coverings and roof decks being removed from roof frames or the loss of the entire roof structure. Multi-story concrete and steel frame buildings generally performed better, though some of these buildings experienced heavy roof covering and cladding (wall, door, and window) damage, though only a few of them were destroyed. Many buildings that did not have extensive, visible exterior damage were observed to have experienced significant water intrusion, causing damage throughout building interiors. Vegetation was uprooted and mixed with other wind-borne debris, such as doors and storm shutters, contributing to the wind damage. Saipan's and Tinian's critical infrastructure—including hospitals, schools, airports, power, water supply, and roadways—all suffered damage.

[1] Wind speed reference data obtained from https://weather.com/storms/typhoon/news/2018-10-28-super-typhoon-yutu-philippines-china-saipan

3.2. Purpose of the Study

In 2020, FEMA's Building Science Branch, in conjunction with FEMA Region 9 and supported by the Strategic Alliance for Risk Reduction (STARR II), was asked to engage the Mitigation Assessment Team (MAT) to study building performance in support of long-term recovery efforts in the CNMI. Though the MAT typically deploys immediately following a major disaster, providing support even two years after Super Typhoon Yutu can help steer long-term recovery and resilience efforts for these high-risk islands.

In November 2020, the MAT deployed to Saipan and Tinian to assess building performance; develop customized Recovery Advisories and Fact Sheets; provide tailored training and subject matter expertise; and document observations, conclusions, and recommendations. The team worked with local agencies to assess damage to many types of buildings, including the hospital, police and fire stations, schools, government offices, and homes. The goal was to learn how buildings performed during the typhoon and why they withstood, or did not withstand, the strain caused by wind and flood hazards. Upon conclusion of the field investigation, specialists worked as a team to analyze the field data, as well as other damage reports and studies conducted by government agencies or private firms. Finally, the team prepared conclusions and developed recommendations based on these findings.

Many residential homes had suffered tremendous damage from recent typhoons Soudelor in 2015 and Yutu in 2018. Wind damage from the typhoons was experienced in homes that were both formally permitted and constructed and homes that were informally constructed (i.e., were not permitted, designed, or constructed per the building code). Guidance and recommendations in a study such as this one can aid homeowners in their efforts to recover well, rebuilding to mitigate future damage and losses. Many common damage themes were observed. Identifying these weaknesses and effective mitigation to address flood and wind vulnerabilities can help focus recovery efforts to areas of most benefit.

The recommendations resulting from this building performance assessment help FEMA coordinate with agencies and organizations in the territory and at the local level to assess the hazard-resistant provisions of building codes and standards. In addition, recommendations support community development of long-term strategies to reduce future damage and impacts from hazard events and improve community resilience.

The recommendations are provided to help the CNMI outline a path forward for reconstruction, building community resilience, and other relevant ongoing activities. These recommendations also can be used by the CNMI to help guide and better prepare communities, property owners, and other stakeholders for future storms and encourage them to take action with specificity, where possible.

The likelihood of experiencing a storm of the magnitude of Super Typhoon Yutu in the CNMI has always existed and the threat remains still. Storms like Typhoon Soudelor and Super Typhoon Yutu have served as demonstrations of the need to take the proper steps to be prepared when the next disaster occurs.

4. Observations, Conclusions, and Recommendations

The MAT visited the CNMI in November 2020 and made numerous observations related to residential building practices. Residential building performance varied greatly across the CNMI, with some houses experiencing significant structural damage while others had only minor damage to the structure or building envelope. Homes showed wide-ranging differences in performance that can be attributed to variations in local wind speeds, types of construction materials, quality of construction, and maintenance history.

The conclusions and recommendations presented in this summary report are based on the MAT's observations in the areas studied; evaluations of relevant codes, standards, and regulations; and meetings with Territory and local officials and other interested parties. They are intended to assist the CNMI, communities, businesses, and individuals in the reconstruction process and to help reduce future damage and impacts from storms, and specifically storms that are considered design level wind events such as Super Typhoon Yutu.

The recommendations are presented as guidance to the Territory and those who are involved with the design, construction, and maintenance of the built environment, specifically one- and two-family dwellings, across the islands. The government of the CNMI and the entities involved in reconstruction and mitigation efforts will need to consider these recommendations in conjunction with their existing priorities and resources when determining how they can or will be implemented.

4.1. Structural Walls and Roof Framing

Structural walls in one- and two-family dwellings in the CNMI were built from concrete masonry units (CMUs), wood-framed load-bearing walls, and concrete frames with infill. The most common wall systems were CMU and concrete frame with CMU infill. The concrete and CMU wall systems showed good performance, while buildings with wood-framed walls performed much worse.

The roof structural systems for these residential homes typically were wood framed or cast-in-place concrete roof systems. The wood-framed systems used roof trusses or were common framed lumber roofs. Most residential wood-framed roof systems did not use wood decking atop the framing and beneath the metal roof panels (coverings). The lack of roof decking within the roof structure contributed to poor roof performance in areas that received high winds. Roof coverings typically were metal panels of differing shapes or profiles. The metal panels and 2-inch x 4-inch nailers typically were nailed into place instead of screwed, and many of the beams/joists had weak connections to the bearing walls. This is illustrated in CNMI MAT Recovery Advisory 1—*Code-Based Wind-Resistant Roofing for Homes: Reducing Wind Damage in the CNMI*. The roof systems typically did not incorporate underlayment or secondary roof membranes. The concrete roof systems usually were thin slabs that occasionally incorporated concrete beams beneath (or integrated with) the slabs.

4.1.1. OBSERVATIONS

The MAT observed a wide variation in construction quality of residential homes. The CMU appeared to have non-uniform quality and dimensions. Additionally, CMU work frequently had non-uniform joint spacing and occasionally no joint spacing. It was not obvious whether CMU wall reinforcement was used, either as an in-fill or as a structural wall.

Staged or phased construction allows homeowners to use the home while they plan for future expansion. Many times, these future additions are built on top of the initial home construction with provisions made to grow vertically through the use of exposed rebar splices. “Hope sticks” or reinforcement extended above current construction in anticipation of future construction was some indication of reinforcement use (Figure 2). This practice, however, can lead to deterioration of the existing concrete caused by corrosion of the exposed reinforcement, which then will allow water and corrosion to move into the base structure.

Figure 2: Red arrows indicate “Hope sticks” extending out from base home construction. These unprotected reinforcing bars will lead to damage of the base structure as they experience harmful corrosion.

There were widespread failures of wood-framed roof systems during Super Typhoon Yutu. Typical failures were caused by metal roof panels blowing off the underlying nailers or the nailers separating from the beams and joists. Many traditional homes with corrugated metal roofs lost large sections of the roof. For some houses, entire assemblies—roof structure and covering—were missing, indicating that the high wind speeds separated the roofs at their connections to the walls. This suggests that connections between the roof panels and/or decking and the rafters were stronger than the connection between the rafters and the walls (Figure 3). The connection from the roof structure to the top of the wall is a critical connection in the load path and was observed to be poorly addressed in most homes with wood-framed roof systems.

Figure 3: Building with entire roof blown off.

CMU homes did sustain some wall damage, often at the top of the wall near damaged rooflines. In many cases, CMUs were pulled off with the roof structure. Adequate wall reinforcement in the horizontal and vertical direction was not evident, and the lack of reinforcement likely contributed to the wall-to-roof connection failures when subjected to the winds from Yutu (Figure 4).

Figure 4: Home with concrete frame with CMU in-fill wall construction. The CMUs have variable joint spacing down to no joint spacing. Rafter connectors are informal and spaced far apart. The back-right wall of the house (in red box) has been blown off with the roof and is separated from the home.

Some homes had little to no structural damage, while others experienced near complete destruction. While some of this difference in performance may be due to the variable wind field from Super Typhoon Yutu, much of it is attributable to the structural elements and details used in home construction. The most-heavily damaged buildings lacked a continuous load path from the roof to the foundation. Buildings that had breaks or weak load paths performed poorly under high winds (Figure 5 and Figure 6). Failures of wall-to-roof connections allowed many roofs to separate completely from the dwelling walls below. Many wood-framed homes had inconsistent framing layout, dimensions, and spacing, which makes dependable continuous load paths difficult to establish.

Since many homes have weak, inconsistent, or unknown structural features, it is beneficial to identify the best place to seek safety in a home. Some places are better than others in storms and provide an improved margin of survivability. These spaces are known as Best Available Refuge Areas (BARA).

Figure 5: Wood-framed roof-to-beam construction. Connection is an informal method that is not an engineered solution.

Figure 6: Wood-framed home that suffered near complete damage.

In addition to the issues noted above, many metal roofs did not have the required structural roof deck or diaphragm under the metal panels needed to resist and transfer the lateral loads to the walls. Often the rafter-to-wall connection was inadequate to resist the intense uplift loads from the high winds.

Wood roof framing was subject to decay and damage from environmental factors, especially termites (Figure 7). The MAT observed many instances where termite damage had compromised already marginal framing. The further weakened structural members then were stressed by Yutu to the point of complete failure. Extensive termite damage and decay of roof structural members—rafters, purlins, nailers, top plates—further compromised the continuous load path for wind loads.

Figure 7: Roof framing showing lack of structural roof deck under corrugated metal roof, rafters spaced too far apart, informal connectors from rafters to walls, and extensive termite damage to most roof structural members.

4.1.2. CONCLUSIONS AND RECOMMENDATIONS

Conclusion 1

Key wind vulnerabilities remain in many undamaged homes. The MAT observed several homes that experienced little to no structural damage from Yutu, yet they remain vulnerable to the effects of high winds. These homes may not have experienced the highest winds because of their locations on the islands; however, typhoons could impact the homes in the future. In many cases, the connections between the structural wall and roof systems are a substantial weakness in the links in the load path and are vulnerable to failure. Proper structural connections between the roof and walls are critical to the performance of the home.

Recommendation 1a:

Homeowners should evaluate existing homes for wind vulnerabilities and retrofitting as necessary. Consider hiring design professionals to evaluate the existing roof structure to determine if it can carry at least 75 percent of the design load (per the 2018 International Existing Building Code [IEBC]). If it cannot, perform wind retrofits using design guidance found in FEMA P-804, *Wind Retrofit Guide for Residential Buildings* (FEMA 2010). Additional information can be found in the FEMA Recovery Advisories for the U.S. Virgin Islands (USVI), which were published after Hurricanes Maria and Irma hit in 2017. Specifically, refer to Recovery Advisory 3, *Installation of Corrugated Metal Roof Systems* noted in the references in Section 5 of this report.

Recommendation 1b:

The Department of Public Works (DPW) should encourage residents to build in-residence storm shelters and safe rooms and identify their Best Available Refuge Area (BARA) before a storm. Owners of existing homes can benefit from creation of refuge spaces in their homes, as well. Guidance for residential safe rooms can be found in the publication FEMA P-320, *Taking Shelter from the Storm,* which provides design guidance and information on making a safe room in an existing home.

Best Available Refuge Areas

Homes with unknown structural capacities or known vulnerabilities will benefit from identifying the safest location in the home to take cover during storms. These spaces are known as Best Available Refuge Areas (BARA). FEMA P-320 and P-361 provide information on storm shelters.

Conclusion 2

Wood structural members as main structural elements need better attention in design and installation. Wood material choices for type, size, and spacing also need careful consideration by the design professional. Use of the American Wood Protection Association (AWPA) Use Category system to best identify the proper wood preservative and protection treatment will help improve wood durability.

Recommendation 2:

Homeowners and builders should use alternative materials, such as cold-formed metal framing (16 gauge) or wood members treated to resist termite damage and organic decay.

Conclusion 3

Staged or phased construction where the base building is occupied for a period of time before future additions are constructed can lead to less-than-ideal practices. Staged and phased construction is not addressed with specific time durations within the International Residential Code (IRC®). Best practices for staged construction use embedded bar splices or mechanical bar splices to avoid exposed and deteriorating reinforcement. Staged construction performance varied, and often led to degraded building materials and poor building performance.

Recommendation 3a:

DPW should institute time limits on permits for staged or phased construction that is left incomplete (i.e., rebar extended through roof sections for future second stories, partially completed additions, etc.).

Recommendation 3b:

Homeowners and builders should protect material during staged construction. Where extended periods of time exist for staged construction, provisions should be made for safeguarding the materials used in the construction of the home so that they maintain their original strength (i.e., capping rebar).

Conclusion 4

Roof panels (coverings) often lacked structural roof decks beneath them. Structural roof framing members alone cannot carry wind loads set forth in the current International Codes (I-Codes). The size of the roof framing members generally is too small and spacing of the members is too large The absence of a structural deck below the roof panels, the absence of any secondary roof element below the roof panel to remain in place if the roof covering was blown off, and the lack of adequate anchorage for the roof panels led to reduced stability of the roof structure and full exposure of the building interior and its contents when the metal roof panels failed.

Recommendation 4a:

DPW should require the use of structural roof decks below roof coverings (primarily below metal panel roof coverings), as directed by current building code requirements. Wood decking and connections to framing should be calculated, designed, and installed to resist the appropriate wind loads for the location, including exposure and topographic effects. Screws of proper size and spacing should be calculated, designed, and used in the roof framing.

Recommendation 4b:

DPW should require larger framing members and smaller spacing to increase roofing strength and reliability. Wind loads for CNMI, which are comparable to other island territories, typically require that roof structural members cannot be spaced more than 2 feet on center to carry the forces acting on the roofs. Homeowners and builders should increase the number of wood structural members providing support to the roof decking and roof covering.

Recommendation 4c:

DPW should require proper connectors between the roof framing and the walls. Professional design of the connectors is recommended. Homeowners and builders should connect wood structural members to the top of the walls, creating a continuous load path from the roof framing to the wall. Homeowners will need to retrofit the connections to framing already in place. Metal bars and straps bent over wood roof framing members at the top of the wall are not code-compliant connections. CNMI Recovery Advisory 1, *Code-Based Wind-Resistant Roofing for Homes: Reducing Wind Damage in the CNMI,* includes guidance for these connections.

Recommendation 4d:

Due to the extreme loads and the common failure point of the connections from the wall to roof and in roof framing, homeowners and builders should consider increasing the number of mechanical fasteners in connections, as allowed per the manufacturer’s design. The number of metal connectors also should be increased. If common framed systems are used, the homeowners should consider screws in lieu of nails in wood-to-wood connections. Homeowners should consider doubling the metal connectors in critical locations such as the roof-to-wall connection and the ridge board connection in common framed roofs.

4.2. Roof Coverings

As is common to all buildings, roofs are the primary systems for keeping wind, rain, and wind-borne debris from entering the home. The failure of roof systems can lead to significant water intrusion and damage to interior finishes and contents. The proper design, installation, and maintenance of roof systems serve a key role in keeping the building occupants, components, and contents protected during storms.

4.2.1. OBSERVATIONS

A variety of roof coverings were observed by the MAT, including various types of metal panels, clay tiles, and membrane over concrete roofs. The most common roofs were metal panels over wood framing. Gutters at the roof were uncommon, with most homes not incorporating facia and trim boards to support the gutters. Roof system failures resulted in significant damage to the houses and the contents.

There were several instances where electrical service masts penetrated the roof, creating potential problems for the roof (Figure 8). The weather seal at this interface between the electrical mast and the roof was difficult to maintain. This junction between the mast and the roof also provided a point of initiation for roof failure when electrical lines became overstressed from wind and debris impact and loaded the roofing. Additionally, when trees and power poles fell, they pulled the mast, which damaged the roof.

Figure 8: Left—Electric service mast going through roof; Right—Electric service on separate pedestal.

Numerous metal panel roofs were only lightly secured and did not use adequate numbers and types of fasteners. While some roofs remained in place during the storm, several roofs experienced partial or complete blow-off. Many metal roof panels were attached to wood purlins with nails, which provided inadequate wind uplift resistance (Figure 9). Screws provide a better alternative to nails when securing metal roof panels to the roof structure since it is much more difficult for high winds to pull screws loose.

Figure 9: Roof panel blew off purlin nailers.

Maintenance of roof systems often was lacking, resulting in lost roofing and severe damage. Galvanized metal roof panels consume the zinc protective layer throughout their life. When the zinc layer is gone, corrosion of the base metal begins. Metal roofs can be recoated with special metallic paints to extend their life many decades. Loss of the initial zinc layer and lack of recoating with protective paint allowed corrosion to become established on the roof panels. Consumed and corroded metal roof panels failed and allowed water intrusion (Figure 10). Many roofs failed due to corroded and missing fasteners.

Figure 10: Corroded roof panel with zinc galvanizing consumed.

4.2.2. CONCLUSIONS AND RECOMMENDATIONS

Conclusion 5

Where service masts penetrated the existing roofs, localized roof failure and water intrusion damage often occurred. Because many roofs have overhangs or porches, when the power feed is extended up from the wall (where the meter is located), the mast typically is extended up through the roof covering.

Recommendation 5a:

Homeowners and builders should avoid penetrating roof coverings with utility service masts, including porches and overhangs. New construction and most major renovations are required to install new meter pedestals at homes for power and utility connections. Where existing homes are being repaired or renovated, installation of a new meter pedestal will prevent the need to penetrate the roof with a utility service mast.

Recommendation 5b:

Homeowners should apply corrosion-inhibiting coatings to metal roof panels that have had the zinc coating consumed. Application of special metalized paints can extend the life of metal roof panels by inhibiting corrosion.

4.3. Windows, Doors, and Opening Protection

Windows, doors, and openings in walls frequently were the source of building performance problems and failures during Yutu. Openings must be able to withstand both the pressure from the wind and the impact from wind-borne debris. The wind load and impact resistance of doors and windows is a primary concern for building owners. The common approach to managing these two different damage factors is to have pressure-rated windows to withstand the wind forces and also to have protective shutters to handle the impact from debris and missiles. Proper design, testing, installation, and maintenance of these building envelope openings is vital to overall building performance.

4.3.1. OBSERVATIONS

Houses in the CNMI have many window types, including glass jalousie, casement, and sliding pane glass windows. Accordion shutters are the primary tools used to protect the various openings. Numerous windows and shutters suffered damage from wind-borne debris. Water seeped around and through jalousie windows and door gaps, causing minor interior water damage, including damage to some contents (Figure 11). The use of concrete walls and floors limited the impact of water intrusion as these materials are water resistant.

Figure 11: Home with jalousie windows.

The windows and doors generally did not have labeling to assist in identification of the window design characteristics. No windows or shutters observed had branding or testing labels to indicate the performance ratings for pressure and impact for the product. Although not labeled, some commonly used windows that are manufactured in the CNMI appeared to perform satisfactorily for wind pressure.

The MAT also observed shutters on doors and windows that remained attached to the structure and appeared to have provided adequate protection. An accordion shutter that is commonly used in the islands and is manufactured in the CNMI performed well and withstood impacts from wind-borne debris. Some shutters were damaged while still protecting the glazing or doors behind them. The accordion shutters used a folding panel arrangement permanently mounted in place with the tracks and hardware (Figure 12). This prevented loss of the hardware, but it lacked the ability to close from the inside.

Figure 12: Home with accordion shutter door protection (shutter not deployed in this photo).

Some of the accordion shutters had a handle-style twist lock closing mechanism (Figure 13) that, when deployed, created a single point of connection that became inoperable after being struck and broken by debris impact. Shutters in several applications were not operable due to debris, corrosion, and roller or track damage. Shutters typically were not cleaned or maintained.

Figure 13: Residential window with typical accordion shutter with handle-style lock located in the center of the shutter.

4.3.2. CONCLUSIONS AND RECOMMENDATIONS

Conclusion 6

Windows (glazed openings) and doors on most existing buildings are vulnerable to damage and failure from wind pressure and wind-borne debris. When these glazed openings fail, the building is exposed to additional internal wind pressure and the building interior also becomes exposed to the wind and rain associated with the event.

> ***Recommendation 6:***
>
> Homeowners should identify deficient windows and doors and consider installing new code-compliant windows and doors that are rated and labeled for wind pressures and debris-impact resistance. If the windows and doors are only rated (and labeled) for wind pressure resistance, they should be protected from wind-borne debris impact with code-compliant shutters.

Conclusion 7

Water intrusion through and around existing windows (glazed openings), panel jalousie systems, and doors was common during Yutu. Door/window weatherstripping often is past its life expectancy, not functioning, or missing.

Recommendation 7a:

Homeowners should consider replacement of older glazed (glass) openings in existing buildings with new windows designed and tested to resist water intrusion. To address water intrusion issues around glazed openings on existing buildings, replace and re-flash existing windows with windows designed and labeled to meet the pressure testing requirements set forth in the American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) E1105, Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference (ASCE/SEI E1105 2015). Where conditioned space exists behind the glazed window system, consider use of impact-resistant glazing or glazed openings that are protected with impact-resistant (opening protection) systems such as shutters.

Opening protection systems that protect from wind and wind-borne debris are not rated to reduce water intrusion at the windows and openings they protect.

Recommendation 7b:

Homeowners should consider using water-damage-resistant materials to address water intrusion for interior spaces that have jalousie window systems. Designers and contractors should consider using materials that are resistant to damage from wind-driven rain within the occupied space where jalousie windows are used. Although these systems provide some shading, privacy, and minimal non-rated impact resistance, they typically are not sealed systems and enable significant amounts of wind-driven rain to enter the building's interior spaces, with associated potential damage. See FEMA Technical Bulletin 2, Flood Damage-Resistant Material Requirements (2008). (https://www.fema.gov/media-library/assets/documents/2655).

Recommendation 7c:

Homeowners should check doors and windows regularly and ensure proper maintenance. Inspect door and window weatherstripping annually and replace as necessary. Adjust and replace thresholds as needed.

Conclusion 8

Many shutters were not operating properly due to debris, rust, or roller damage. Many residential uses of shutters with handle-type closing mechanisms and single-point connections were broken by wind-borne debris and became inoperable after the storm event.

Recommendation 8:

Homeowners should check shutters regularly and ensure they are properly maintained and serviced. Annual maintenance for shutters will include cleaning, lubrication, and repairs. Homeowners should wash and clean the shutters to remove accumulated dirt or materials from the surfaces. The tracks that rollers move in should be cleared of grit and debris that will prevent movement of the rollers. The rollers, hinges, and joints need to be lubricated to assure they are free to move and are not corrosion bound. Lastly, any components that are found to be broken, damaged, or compromised should be replaced or repaired.

5. References

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