Wyndham Partners
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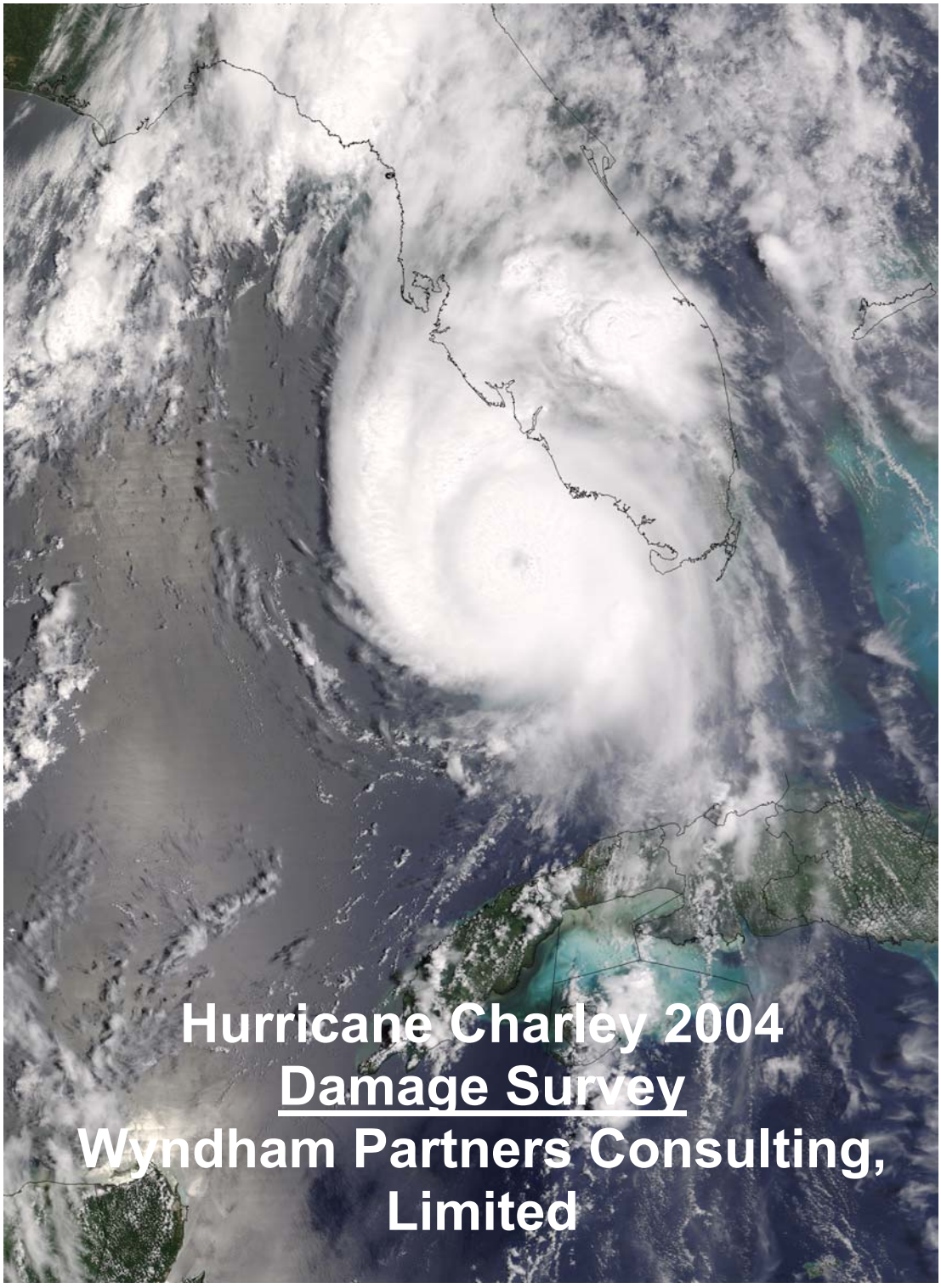

Hurricane Charley 2004
Damage Survey
Wyndham Partners Consulting, Limited

Executive Summary

Immediately after Hurricane Charley's landfall, representatives of Wyndham Partners Consulting, Limited (WPC) spent 3 days with the Institute for Business & Home Safety (IBHS) damage survey teams assessing the damage caused by Hurricane Charley. In our survey, we saw many examples of seemingly similar constructions experiencing the same local wind field but performing at two ends of the damage spectrum. We attribute this differential primarily to new Florida Building Code (since 2002) and the improvements they have brought to construction. Ultimately, the new code specifications were observed to perform as intended.

This damage survey also supports the idea that construction detailing has a large impact on damage caused by hurricane force winds. For example, in commercial buildings, especially light metal buildings, significant failures of the metal wall sheathing may have contributed to loss of lateral support and, consequently, damage to the framing system. Well constructed reinforced concrete frames are also subject to severe roof damage, usually in instances where the leading edge of the standing seam metal roof allowed progressive peeling failure of the roofing system.

In downtown Punta Gorda and Arcadia, some older un-reinforced masonry structures collapsed – mostly from loss of lateral wall support due to severe damage to the roof diaphragm. Some "superior" commercial buildings also displayed EFIS delamination in areas where most other buildings performed well. Near the periphery of the wind field, where lower wind speeds were experienced, significant damage was observed to commercial signage, along with less severe damage to the leading edges of roofs and the initiation of roof membrane peeling failures.

In wood-frame and concrete block single-family homes, the damage progression was sometimes triggered by debris impacts from nearby buildings – especially the case with tile roofs. Tile attachment systems relying on non-mechanical methods were frequent offenders. Garage door failures were also common, and we found most construction did not employ the Dade County standard reinforced door. Sheathing attachment with staples was another contributor to the damage. Other details like sofits, gable-wall bracing, and shutter systems were all separately observed as major failure mechanisms. Even in downtown Punta Gorda, where residential buildings of all types were subjected to severe winds, examples of outstanding performance

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regardless of construction age were interleaved with many complete losses. Homes constructed under the new Florida Building Code generally performed well -- especially in areas were there was not significant debris generated by adjacent structures. With respect to mobile homes, it was clear that post-1994 construction performed appreciably better, relative to all other mobile home age groups. Similar to other residential structures, nearly all mobile homes lost screen porches, pool covers and carports. Also, we found that the use of tie-downs provided good roll-over protection, but in many cases the structure was still a total loss due to siding and roofing failures. Within the same mobile home park, a striking damage contrast could be seen between pre- and post-1994 mobile homes.

Damage Survey Findings

Members of the WPC team spent 3 days with the Institute for Business & Home Safety (IBHS) damage survey teams following Hurricane Charley's landfall. The research teams were led by Dr. Tim Reinhold (IBHS Vice President of Engineering) and other wind engineering experts from Clemson University, Florida International University (including Dr. Forrest Masters, Assistant Professor of Civil Engineering and Director of the Structural Mitigation Laboratory within the International Research Center), University of Florida and Florida Institute of Technology (including Dr. Kurt Gurley, Associate Professor of Civil Engineering, University of Florida, Gainesville). The objective of the teams was to research and to collect property damage information from several Florida cities damaged by Hurricane Charley. We visited homes and businesses affected by the storm, documenting damage and assessing what went wrong, as well as what withstood the wind. Initial observations were as follows:

Physical Damage Observations

We observed many light metal building failures. Many of the failures were related to building envelope performance; however, structural damage and collapse were also observed. The leading cause of envelope failure to metal sheathing was poor attachment methods (fastener type and spacing). When light metal frames collapsed, it was likely the result of reduced lateral support due to significant damage to wall and roof metal sheathing. Other collapses were due to poor basic structural design. In general, light metal structures have shown to be fairly vulnerable to wind damage in hurricane prone areas, and are susceptible to internal pressurization from large garage door failures.

The pictures below show a hybrid building construction with the lower 2/3 constructed from reinforced concrete block with light metal framing on the upper 1/3. The wall failure was likely the result of the roof framing lifting from the top wall plate, which caused the wall to lose its lateral support. According to eye witnesses, the roof began disengaging on the south east corner. As the opening grew, the wall likely lost lateral support at the top. This resulted in the wall framing being unable to sustain the lateral wind loads and progressive collapse began. There also appeared to be some inadequacy related to rebar anchorage within the wall structure, which may have exacerbated the severity of the collapse. This building was used as the Arcadia Community Center. It was 1.5 years old and used as a hurricane shelter during the storm. Some 1300 persons were inside the building as it began to collapse at the height of the storm.

The collapse of this light metal building was likely the result of lost lateral support from damage to the metal sheathing envelope. The building was used as a boat storage hangar and had a great deal of boat mass supported throughout the building height. Once the lateral support weakened, the frame was free to sway off center with the mass from the suspended boats sustaining the lateral motion until the structure collapsed. Content losses were likely in the millions. Also the lateral support was mostly provided by a concrete shear wall located at the left end of the building. The right portion of the building where the collapse initiated had much less lateral support.

The following failure mode is more typical of light metal building damage. Notice the high corner suction zone damage on the left hand picture. It also shows where roof sheathing began to peel away. It is clear that the mechanical attachment methods used were not sufficient for these high suction zones. The right hand picture shows damage to the leeward wall where negative pressures pulled metal sheathing away from the structure. We can also see that severe damage was sustained to the standing seam metal roof (daylight can be seen through the roof). Although this building was under construction, the area shown in the photograph was reportedly completed before the storm.

Homes built under the new Florida Building Code generally withstood the storm better than neighboring homes built prior to the new standards. However, the fact that strong winds persisted across the state underscores the need for maintaining strong code requirements throughout the interior of the state.

Pre-1994 Construction

2003 Construction
with opening protection

These homes are within 200 Yards of each other and experienced the same wind field but performed substantially different based on construction practices.

2003 Construction

Prior to 1994

New manufactured homes built to the most recent standards also held up better than older homes. However, add-on structures like carports, laundry rooms, or porches often failed causing damage. Mobile Homes post-1994 performed significantly better than older units. This was observed in several different parks on Pine Island, in Punta Gorda and northwest of Punta Gorda. Generally, tie downs on most mobile homes mitigated foundation sliding and/or rollover, but significant roof and siding failures were observed to pre-1994 homes. In most cases even when the actual structure was left intact, awnings, screened rooms and various mechanical equipment (e.g., A/C condenser unit) were damaged.

2003 Model: Construction and tie down much superior at 4 foot spacing. The three homes surrounding this newer construction were totaled by the same wind field. This type of damage gradient conditional to year of construction was observed repeatedly.

2003 Construction: Side and back views of the same house.

Typical mobile home damage field – The surviving unit is later construction.

We found that large and poorly detailed vinyl sofits were significant contributors to progressive roof failures and internal wall/ceiling damage.

A fairly common progressive failure was due to internal pressurization from positive pressure acting on sofits.

In this case the pressurization on the windward sofit led to a massive progressive failure of leeward sheathing and gable end (no bracing).

Outside windward sofit caused the interior tongue and grove cedar finish to fail from positive pressure.

In this case roof sheathing attachment was sufficient to resist additional positive load but the interior ceiling failed. Interior damage was mitigated only because no gypsum board was used on ceiling finish.

We also found that large and poorly detailed roof overhangs were significant contributors to progressive roof failures and internal wall/ceiling damage. Large unprotected picture windows that were vulnerable to wind loads were another contributor to progressive failures.

Progressive sheathing failure induced by failure of large overhang.

Large unprotected picture window failed in positive pressure and resulted in massive damage to this home. These types of architectural features are typically installed by local carpenters and may not meet code wind loads.

Non hurricane rated garage doors continue to be a leading cause of progressive failure to both residential and commercial buildings. The majority of garage doors in which we observed failures did not appear to be hurricane rated.

Non hurricane rated garage doors fail under relatively small loads and will typically lead to more significant progressive failures. In this case the exterior side walls were blown out. Note the walls are flood break away walls but failed from wind loads. This scenario was repeatedly observed.

Commercial non-reinforced garage door failures also are common and lead to significant progressive failures.

This building survived internal pressurization resulting from the garage door failing. The skin used in these non hurricane rated doors are vulnerable to wind borne debris impacts.

Poor roof edge design continues to contribute to massive peeling failures of single ply and standing seam metal roofs. Current code wind loads are not conservative and exacerbate commercial roof failures. It is estimated that 70-80% of all flat roof peeling failures are initiated at the roof leading edge. Once the roof is compromised, contents are likely to be damaged with business interruption losses likely to follow. A 20% loss to the roof envelope can easily bring content losses towards 50% and initiate BI loss on commercial risks.

Leading edge failures lead to progressive peeling of the roof membrane.

The following is an example where roof tie downs could have been applied during construction to help reduce damage. This example shows a course of construction where the roof system was not tied down immediately following assembly. The damage consisted of the entire roof assembly sliding off the wall top plate and was dramatic. This building was under construction and the roof rafters had not been strapped to the top wall plate prior to the storm.

This roof was not secured to the wall top plate. The surrounding structures did not suffer any damage under identical wind field conditions.

Gable end failures were also common where the gable end was not adequately supported. Gable end failures also occur when the sheathing is lost and lateral support removed.

High suction zones occur near gable ends. These loads likely cause significant sheathing loss.

In this case sheathing loss ultimately led to the gable end failing in positive pressure from reduced lateral support.

Many sheathing failures were related to staples as the attachment method. The sheathing thickness in these instances was typically 3/8.

Staple attachment – Simply a disaster waiting to happen.

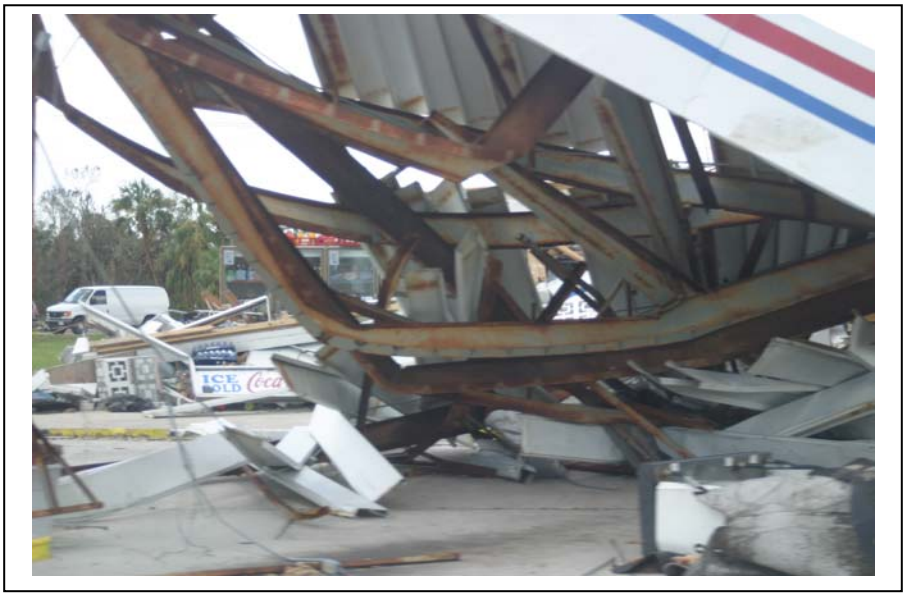
There were many examples of tile and shingle failures in Punta Gorda. In minor cases only a few tiles were lost at the ridgelines (areas of high vortex generation) and in more severe cases large portions of the tile roof were lost. In many subdivisions tiles are often mandated by covenant. Consequently, wind-borne tiles pose a significant threat to neighboring buildings. When missiles breach the building envelop of adjacent buildings, progressive failure may occur from internal pressurization. Tiles set only in a mortar adhesive detached readily to become airborne missiles. Homes with the newer architectural shingles performed significantly better than traditional shingles or tiles adhered with mortar only.

Classical damage pattern to gable end roofing material.

In those instances where tiles have no mechanical attachment but only adhered with mortar failure rates were dramatic.

Although this building is reinforced concrete, because it has an EIFS cladding, the true vulnerability may not be taken into account. The building is located near downtown Disney and within the weak wind field of Charley. In this dense area of commercial hotels no adjacent buildings were observed to have suffered noticeable damage.

Most commercial signs, billboards and overhead canopies located within the wind field suffered varying amounts of damage. Structural failures were not uncommon, but plastic lettered inserts generally failed at lower wind speeds.



Many small businesses located near missile sources (adjacent buildings with gravel roofs) suffered from broken windows.

Conclusion

Losses from Hurricane Charley varied widely among different forms of construction. Buildings built in compliance with the new Florida Building Code were found to withstand hurricane force winds significantly better than older construction. However, given that strong winds persisted across Florida underlines the need for maintaining strong code requirements throughout the interior of the state. Construction detailing had a large impact on the damage caused by hurricane force winds. Poorly detailed vinyl sofits were significant contributors to progressive roof failures and internal wall/ceiling damage. Non-hurricane rated garage doors were also a leading cause of progressive failures. The newer wind rated shingles performed noticeably better than tiles set only in a mortar adhesive. Manufactured homes built to the most recent standards held up better than older homes; however, add-on structures often initiated progressive failures. Tie downs were observed to mitigate foundation sliding and/or rollover in manufactured homes. Many light metal building roof failures were initiated from the leading edge with metal sheathing failures attributed to poor attachment methods in areas of high suction loads. Most commercial signs, billboards and overhead canopies located within the wind field suffered damage, with plastic lettered inserts generally failing at the lower wind speeds found near the edge of the storm.