Performance of New Homes in a Category 4 Hurricane

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Summary

Over a twelve year period, Florida experienced two very large hurricanes. The first of these, Hurricane Andrew, a category 5 hurricane made landfall near Miami in 1992 causing significant damage to 70% of roof systems in homes in its path. This led to sweeping changes in the manner in which buildings were designed and constructed in Florida. The new rules were put to test in 2004 when Hurricane Charley a compact, category 4 hurricane made landfall in southwest Florida in the Port Charlotte area. This severe storm had wind velocities estimated to range from 120 mph (55.7 m/s) to 160 mph (74.2 m/s) that exceeded the 114-130 mph (52.9-60.3 m/s) design wind velocity for Charlotte County.

The eye of Charley crossed Punta Gorda Isles (PGI) shortly after it made landfall and therefore all homes were subjected to the strongest winds. A USF research team conducted a detailed survey of 425 of 747 new homes in PGI using aerial photography and special software to quantify damage to the roof. The survey showed that only 14% of these homes sustained roof damage with nearly 50% completely unscathed (see photo below). Damage refers to localized failure of the connection of the roof tiles to the underlying sheathing since there were no structural failures in the 425 new homes.

Fig. 1: *View of Damage Caused by Hurricane Charley (Courtesy William Bracken, Bracken Engineering)*

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The absence of damage under higher-than-design wind loads indicates that the structures were over-designed. This paper attempts to quantify the extent of the over-design using a simplified code-based analysis. In the analysis, the irregular roof is idealized as a simple gable and the highest pressure coefficient determined through parametric studies in which the effect of changes to building geometry, wind velocity and exposure were assessed.

In the code, the highest localized pressure coefficient is a function of the „effective area" which varies with its location on the roof. However, for the roof corner where the pressure coefficient is the highest, the effective area is a function of the geometry of the building, namely its minimum width and roof slope. The narrower the building and the shallower its roof slope the smaller the effective area and the greater the pressure coefficient. By the same token, pressures were lower for wider buildings. This may explain why there was so little damage in the buildings in PGI because they were typically larger, wider structures.

The effect of exposure and increased wind velocity was considered in a simple manner by normalizing velocity effects with respect to Exposure B that corresponds to urban suburban areas. This made it possible to provide multipliers that can be used to estimate the extent of over-design. The largest multiplier for a typical single story home with a 4.6 m mean height was 2.17 corresponding to 160 mph (74.2 m/s) wind in Exposure C if the original design was to Exposure B and 120 mph (55.7 m/s) wind.

It should be noted that the design wind velocity is based on statistical considerations. US codes use a 500-year return period for hurricane wind forces. However, a return period of 500 years implies that over a 50-year life of a structure, there is a 10% probability that this velocity will be exceeded in any given year. Although there are other resistance factors unaccounted for in our analysis, it may be prudent to routinely over-design corner connections given their importance in ensuring the overall integrity of the structure under higher loads over its life.

The analysis presented is simplified and does not account for shape sensitivity of the roof to changes in localized pressure. Wind tunnel tests have demonstrated that whereas changes in shape have less effect on the main wind force resisting system, it can greatly affect pressures in components and claddings. However, this is outside the scope of this paper.