In the case of concrete and masonry construction with metallic roof sheathing, the wall-roof connection is automatically achieved by embedding the purlins into the bond beams. Existing buildings with simply supported purlins require proper fixing of the purlins into the walls. In wooden constructions, these connections are better accomplished utilizing the hurricane clips previously discussed. An adequate wall-foundation connection is necessary to transfer the loads to the ground through the foundations.

Windows and doors

Windows and doors are not part of the main wind force resisting system; however, their performance during a hurricane can be the difference between survival and destruction of a building. Although the probability of a window or door to be impacted by flying debris (elements from another building, tree limbs, stones) is very low, such an event could have serious consequences. Figure 10 shows a wooden element, probably a 2"x4", launched by the wind at such high speed that went through a palm tree. Should this had happened to a window, door, or even a wall, the interior of the building would be exposed to the wind, generating positive internal pressures. These internal pressures would probably contribute to severely damage the already weak structure, causing additional damage to the furniture and equipment (usually quite expensive in hospitals) located inside the building. And since hurricanes are frequently accompanied by rain, water would enter the building preventing it from functioning once the storm has ceased.

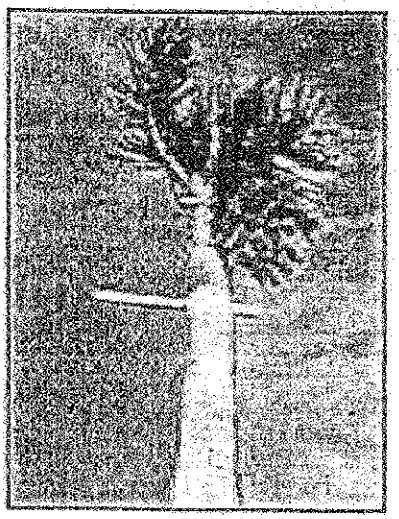

Figure 10. Hurricane winds may reach such high wind speeds that loose objects or structural elements, especially roof elements, are frequently turned into dangerous missiles. The picture shows a wooden element, probably a 2"x4" from a roofing system, that went through a palm tree.

There are windows specially designed and built to withstand hurricane winds. These special windows must comply with the requirements of the American Society for Testing Materials (ASTM), which include but are not limited to ASTM E 1233 (wind resistance) and ASTM E 1886 (impact resistance). These windows are commercially available in a great variety of sizes and colors.

It is recommended to protect the windows from flying objects, whether they are design against hurricane winds or not. Window shutters are the most efficient way to protect the windows. Window shutters are installed on the exterior face of the windows and are designed to withstand high pressure and missile impact from hurricane winds. There are several styles of window shutters, including accordion shutters, removable storm panels, rolling shutters, and Bahamas shutters (Figures 11, 12, 13, and 14) available in galvanized steel, aluminum, and even PVC.

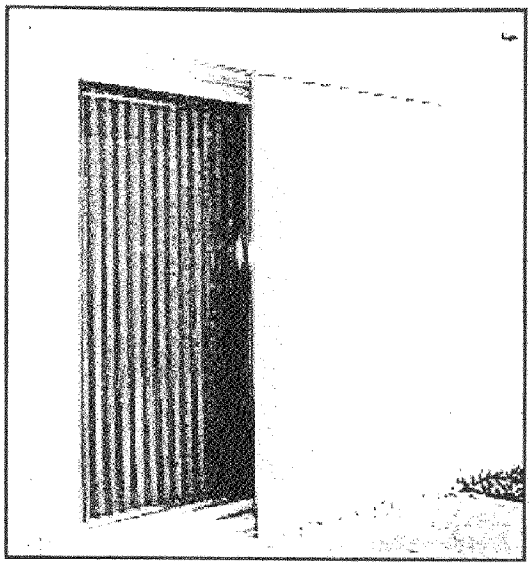

Figure 11. Accordion shutters.

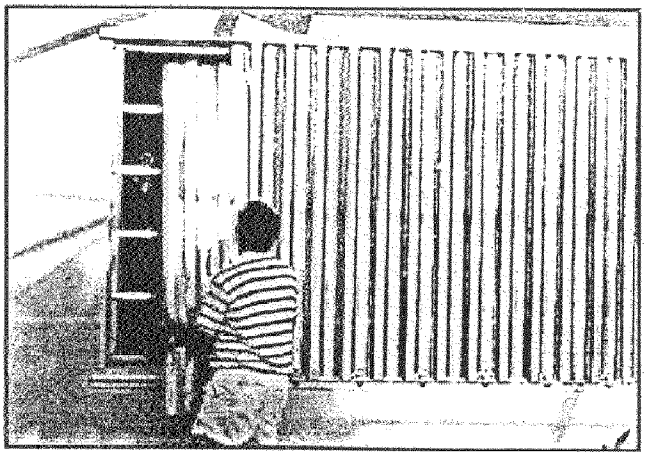

Figure 12. Removable storm panels.

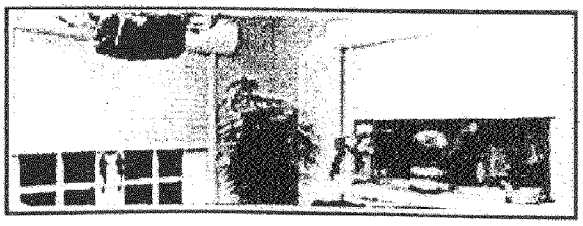

Figure 13. Rolling shutters.

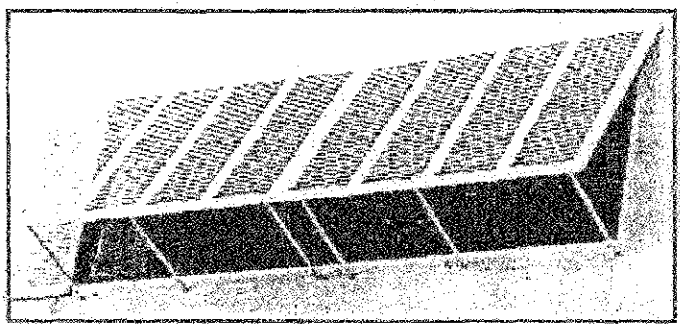

Figure 14. Bahamas shutters

The most commonly used storm shutters are galvanized steel removable panels. This type of shutter should not be anchored directly to the window frame (wooden frames), because the purpose of the shutter is to protect the windows and their frames against wind borne missiles (Figure 15). Instead, it is better to install a permanent steel plate on the exterior wall so the panels can be attached quickly when a hurricane warning is issued (Figure 16). Additionally, metal panels have the advantage that can be utilized again in the event of future storms.

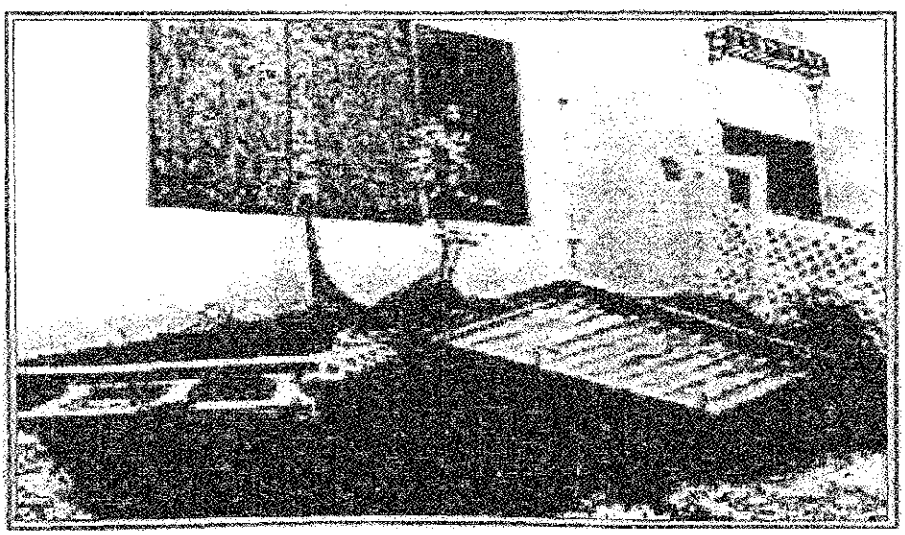

Figure 15. The window shutter of this house was completely removed because its frame did not resist the hurricane winds.

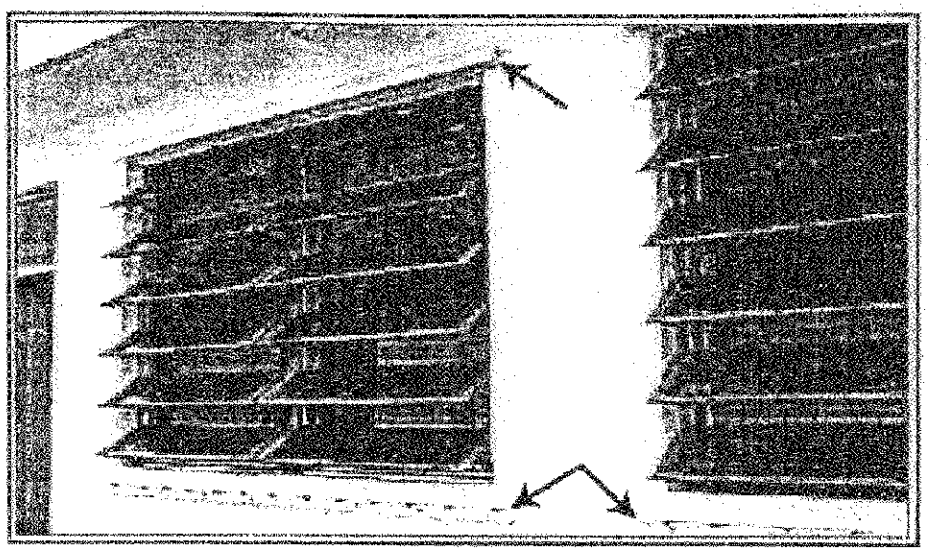

Figure 16. This picture shows the permanently attached angles to which the removable panels would be fixed. The installation of these angles should be done according to specifications supplied by the manufacturer. Usually screws are placed every 15 cm and expansion plugs are utilized.

Sometimes wooden shutters are utilized (typically plywood sheets). Although plywood sheets are less resistant than commercially manufactured shutters, they represent a more economical alternative (short term). This practice is commonly utilized to reinforce, just a few hours prior to the hurricane landfall, windows and doors of those buildings that do not have window shutter systems. New plywood sheets properly installed can provide an acceptable level of protection. However, weathered plywood sheets (which is usually the case) or inadequately installed plywood sheets will probably not withstand hurricane winds and may even become dangerous missiles during the storm.

Doors should also be designed to resist hurricane winds. There is a wide variety of styles commercially available. As a more economical alternative, existing doors can be protected with shutters or reinforced with hinges and screws specially designed to resist high wind pressures.

GENERAL RECOMMENDATIONS

Hospitals and health centers are essential facilities that (1) congregate a large number of people in one area at a particular time, and (2) require to keep functioning immediately after a natural phenomenon. In addition, many of the apparatuses utilized to treat patients with health problems are extremely expensive and sensitive, and frequently difficult to replace. Hence, an investment of a small fraction of the total cost of the hospital to guarantee the life of its occupants and its sophisticated equipment is more than justified.

Taking into consideration these facts and the different alternatives discussed in this document, it is preferable that the construction of hospitals and health centers include reinforced masonry walls, reinforced concrete beams and columns, and a roofing system composed of galvanized steel channels and metal sheathing (galvanized or enamel) properly anchored with screws. It is also recommended the use of windows and doors designed to withstand hurricane winds and steel window shutters.

It is important to realize that wooden construction is perfectly feasible as long as (1) the wood is treated with chemicals against insects, (2) the wood is protected with a waterproof product, (3) the elements are adequately anchored (preferably with screws), (4) hurricane clips are utilized to secure the structural elements, and (5) a continuous load path is provided. However, wooden structures require a great deal of attention during design and construction, as well as meticulous maintenance once they have been built. Figures 17 and 18 show two houses built out of wood and exposed to hurricane winds of similar intensities; one of them did not resist the high wind pressures (Figure 17), while the other one suffered no damage at all (Figure 18).

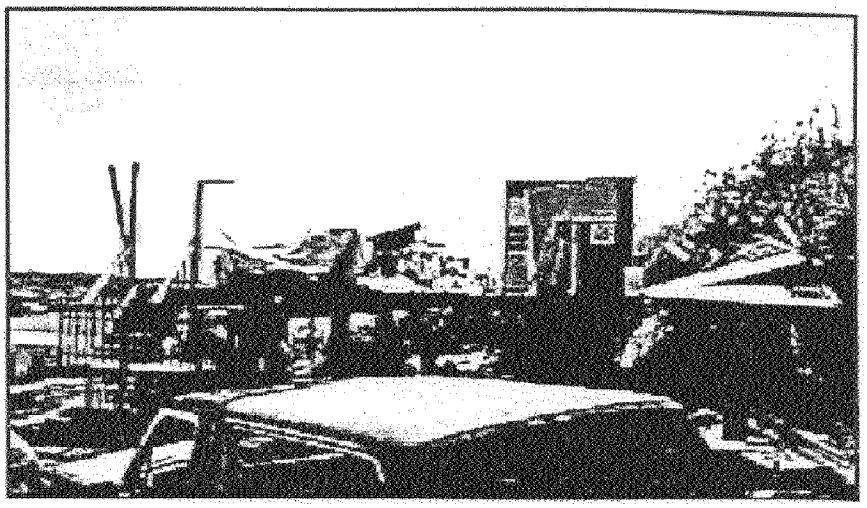

Figure 17. This wooden house was completely destroyed during Hurricane Georges in Puerto Rico, 1998.

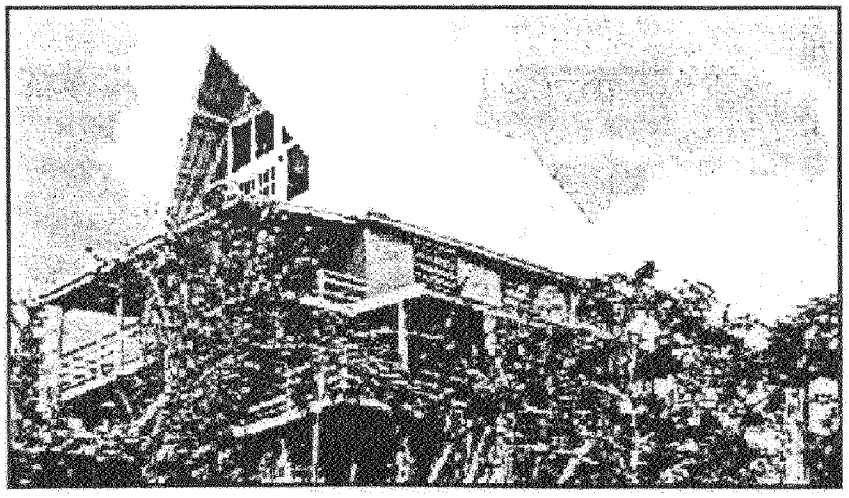

Figure 18. This wooden house stood up to the strong winds generated during Hurricane Georges in Puerto Rico, 1998.

Regardless of the construction technique or construction materials utilized, it is imperative that appropriate connections are furnished to successfully transfer the loads to the ground. Most failures during hurricanes occur as a result of poor connections.