The following is a list of general recommendations, some of which may or may not be directly related to the structural aspects of a building, which could reduce the vulnerability of hospitals against hurricane winds.

- Hurricane clips, screws, and metal flashings should be protected against corrosion whenever they are located within 10 kilometers of the ocean.

- Overhangs and Spanish tiles (clay) as roof covering should be avoided. Separation and launching of roof systems usually begin due to overhang failure. Overhangs are exposed directly to wind actions and generally are not provided with proper connections that resist hurricane winds. Figure 19 shows a house whose overhang did not withstand strong winds and its failure led to a partial detachment of the roof. On the other hand, Spanish tiles are susceptible to becoming wind borne missiles that could cause serious damage to neighboring buildings. In addition, the brittle nature of Spanish tiles makes them vulnerable against strong winds to be removed from the roof even without failure of the roof system itself (Figure 20).

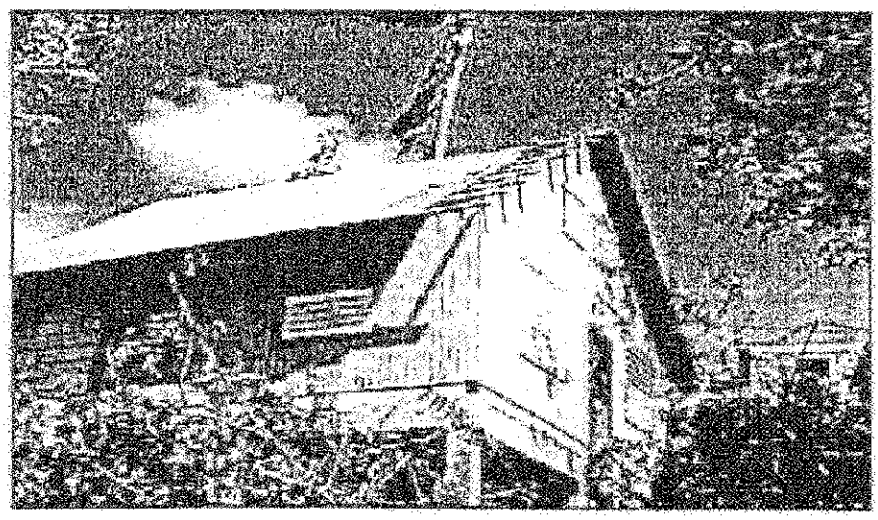

Figure 19. This house was subjected to moderate winds during Hurricane Georges in Puerto Rico (1998). The only damage sustained by the house was in fact the overhangs that failed and led to the separation and launching of the metal sheets, which were not properly fastened.

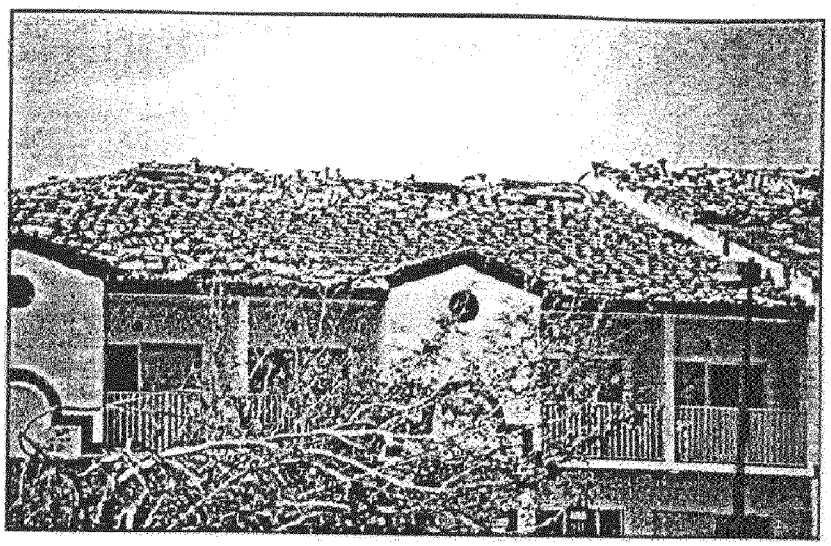

Figure 20. The roof of this house resisted the strong winds of Hurricane Andrew but many of its tiles were detached, turning into dangerous missiles that probably impacted neighboring buildings.

- Hip roofs perform better than gable roofs when subjected to extreme winds (end walls of gable roofs are more vulnerable to wind actions). However, gable roofs are preferred over flat or monoslope roofs whenever the end walls are adequately braced if wooden construction or anchored if masonry construction.

- Roofs can be tied down with steel cables to provide additional resistance against roof detachment. Even though this practice has not been demonstrated through testing, tied down roofs have shown to perform well during hurricanes.

- Construction over hills and ridges should be avoided since wind tends to speed up due to topographic effects. Wind speed acceleration due to sudden changes in topography may increase wind pressures up to 80%.

- Surrounding trees should be kept trimmed to prevent limbs and branches from impacting neighboring hospitals and health centers. Similarly, trees next to hospitals and health centers should be eliminated to avoid situations like the one shown in Figure 21, where a tree fell down on top of a house.

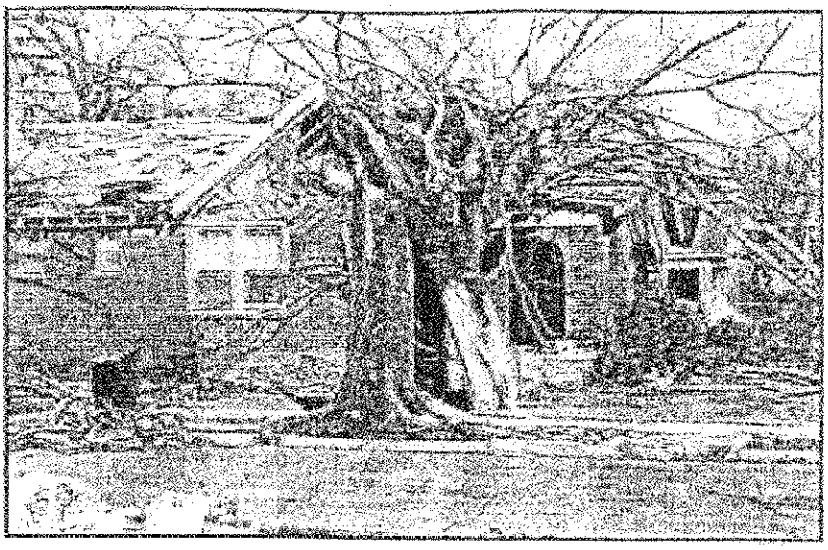

Figure 21. This house resisted the winds produced by a tornado in Little Rock, Arkansas, but a nearby tree caused moderate damage after falling down on it.

- It is important that the surroundings of hospitals be free of loose objects, garbage, and anything that could become a wind borne missile during a hurricane.

- Adjacent buildings should be required to be properly reinforced to protect hospitals from being impacted by missiles that could affect their total or partial functionality immediately after a hurricane (Figures 22 and 23).

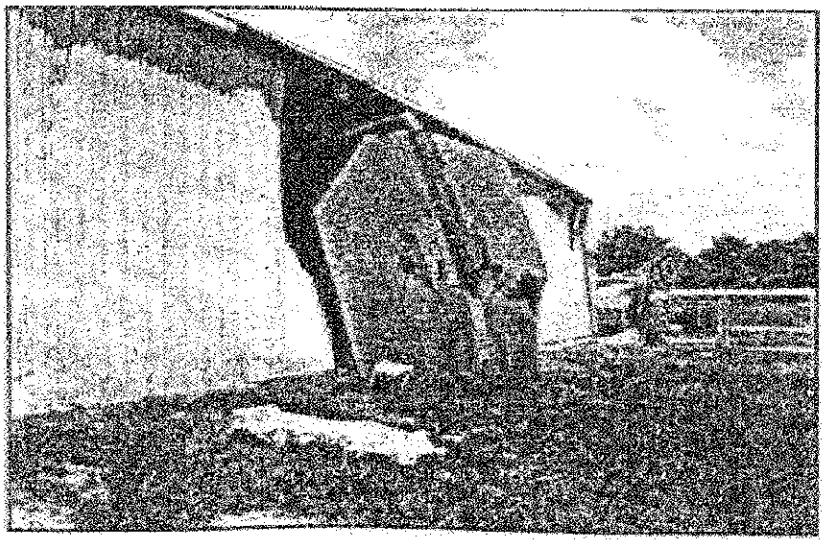

Figure 22. The picture shows a warehouse that was impacted by a roof during a tornado in DeKalb, Texas. The roof belonged to another structure that was located about 100 meters from the warehouse.

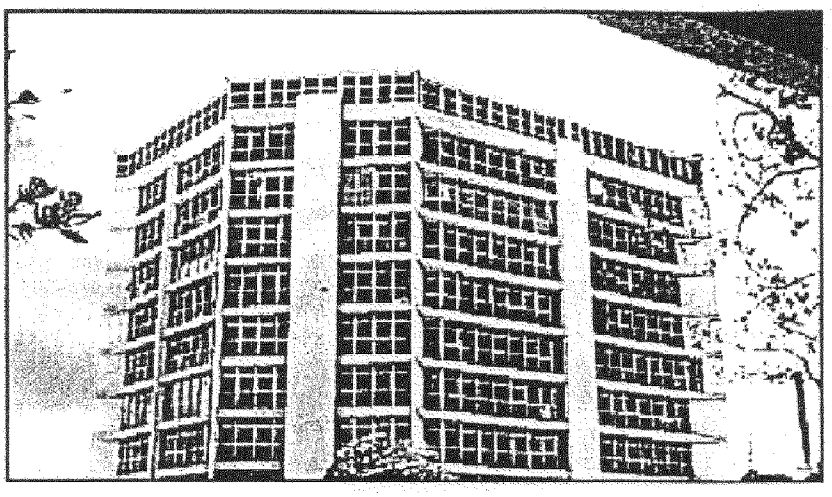

Figure 23. The structural system of this building (located in San Juan, Puerto Rico) resisted the strong winds during Hurricane Georges in 1998. However, many of its windows broke as a result the impact of pebbles from the waterproof system of a roof located across the street. During the storm, water entered the building through the broken windows causing considerable damage.

- Similarly, billboard signs near hospitals (even those not belonging to the hospital) should be designed to resist wind loads according to ASCE 7-98. Otherwise, a hospital may withstand wind loads successfully but a sign flying at over 200 km/h could impact the hospital destroying an exterior wall or part of its roof system. This recommendation is not limited to signs, as other structures such as water storage tanks, radio antennas, and fences could cause similar damage. Figure 24 shows a health center in Isla Culebra, Puerto Rico, that survived the strong winds during Hurricane Georges (1998) but a water storage tank of a house located over 100 meters away impacted its roof. The breached roof allowed water to enter the building causing severe damage and forcing several areas of the hospital to close down.

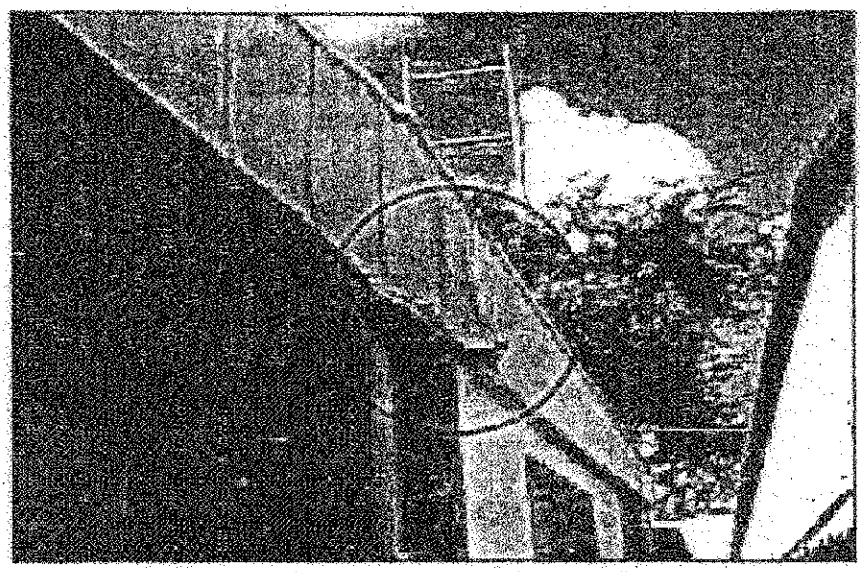

Figure 24. Health center in Isla Culebra affected by the water storage tank of a neighboring house during Hurricane Georges in 1998.

- Energy is usually supplied to hospitals through elevated cables that connect primary posts located in the vicinity of the hospital to secondary posts located just outside the hospital. If wind borne missiles strike these secondary posts during a hurricane, the power supply of the hospital could be interrupted; this would be devastating. Underground connections from the primary posts to the secondary posts could be implemented in order to reduce the probability of power outages in hospitals. In addition, it is recommended that hospitals have permanent access to emergency power generators with enough capability to ensure the operation of the hospital under minimum conditions.

- The geometry of hospitals should be kept as symmetric as possible, avoiding at all moments complex and unusual shapes.

- All mechanical equipment (air conditioners, power generators) located outside the hospital should be properly anchored with bolts and nuts to protect them from becoming flying missiles.

- All existing health centers should be retrofitted to resist hurricane wind loads. Some of the considerations to be taken into account in determining the order of priority of hospitals for retrofitting against hurricanes include: (1) level of care the hospital provides, (2) age of the hospital (this implies its actual condition, which depends upon its maintenance), (3) type of construction, and (4) degree of vulnerability.

- A national technical committee should be formed to develop and advise on mitigation measures against hurricanes for hospitals and health centers. This

committee should include technical personnel involved in health care as well as maintenance departments of the Ministry of Health, government technical personnel and project management agencies responsible for hospitals, and representatives of professional institutions of engineers and architects.

- Personnel working in health centers should be trained on the appropriate measures that need to be taken before, during, and after a hurricane. The objective is to make sure all personnel know where to go, where not to go, what to do, and what not to do before and during a hurricane. This measure may help to prevent the chaos that is usually created because of the anxiety produced by fear, impotence, and lack of knowledge on what to do during an event of this magnitude.

- Designers and contractors in charge of construction of new hospitals and retrofitting of existing ones should have technical knowledge and experience in the design against hurricane winds. Otherwise, they should work under the supervision and advise of an expert in such field.

- Finally, it becomes an imperious issue the enforcement of those regulations established by local building codes through institutions such as associations of engineers and architects, departments issuing building permits, and other government organisms. Damage documentation and investigation conducted after some historical hurricanes (Alicia in Galveston, U.S., 1983; Georges in Puerto Rico, 1998) demonstrated that most severely damaged buildings did not comply with local building codes.