- The roof slope should be less than 10°.
- The mean roof height should be less than 12 meters.
- The shape of the building should not be irregular.
- The building should not be sensitive to the wind (should not be flexible).

Because hospitals and health centers are considered essential facilities that require to be fully functional immediately after a natural phenomenon, and due to its nature of occupancy – where a large number of people congregate in one area at a specific time – a factor of importance of 1.15 will be used. Additionally, the buildings are assumed partially enclosed, which is the most common situation.

The procedure is as follow:

1. Determine the basic design wind speed.
2. Determine the terrain exposure.
3. For the main wind force resisting system: read wind pressures from Table 1. Wind pressures shall be applied perpendicular to the surface. Wind pressures shall be applied simultaneously, with the combined net pressures of the walls applied to all windward walls and the net pressures of the roof applied to all surfaces of the roof.
4. For components and cladding: read wind pressures from Table 2. These net design pressures shall be applied to all exterior surfaces.

Table 1. Wind pressures for main wind force resisting system.

WIND PRESSURE (kg/m²)									
Location	**Basic Design Wind Speed, V (kph)**								
	135	**145**	**160**	**175**	**190**	**210**	**225**	**240**	**255**
Roof	-120	-135	-165	-195	-230	-270	-315	-360	-410
Wall	75	90	110	125	150	180	205	235	265

Notes:

1. Wind pressures from Table 1 represent the following:
   Roof – Net pressure (sum of external and internal pressures) applied perpendicular to all surfaces of the roof.
   Wall – Combined net pressure (sum of windward and leeward pressures, external and internal) applied perpendicular to all surfaces of the windward wall.

2. The values of Table 1 are based on a regular topography (K_{zt} = 1). When the hospital or health center is located on a hill, ridge, or escarpment, the topographic factor (K_{zt}) shall be computed according to ASCE 7-98 and the values of Table 1 shall be multiplied by this factor.

3. The values of Table 1 are valid for exposure B. For exposure C, multiply the values of Table 1 by 1.40; for exposure D, multiply the values of Table 1 by 1.66.

4. Positive and negative signs indicate pressures directed toward and away from the exterior surface, respectively.

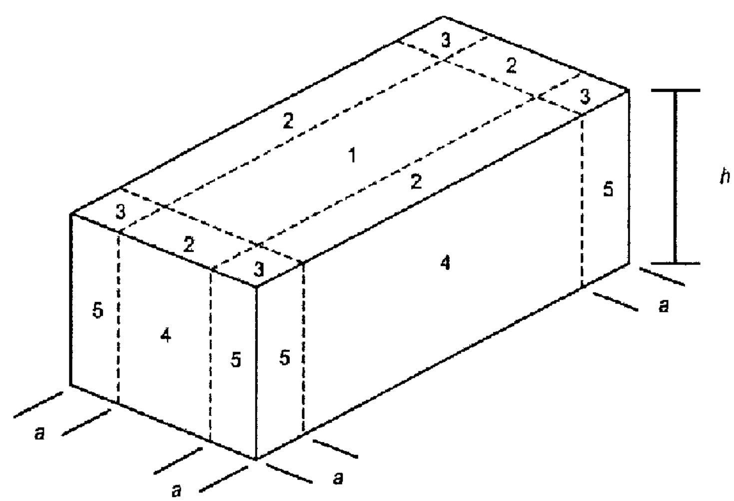
Table 2. Wind pressures for components and cladding.

WIND PRESSURE (kg/m^2)											
Location	Zone[7]	Area (m^2)	Basic Design Wind Speed, V (kph)								
			85	90	100	110	120	130	140	150	160
Roof	1	0.93	+65 -105	+65 -120	+80 -150	+100 -180	+120 -210	+135 -245	+155 -285	+180 -325	+205 -370
		1.86	+65 -105	+65 -120	+75 -145	+95 -175	+115 -205	+130 -240	+150 -280	+175 -320	+200 -365
		9.30	+65 -100	+65 -115	+70 -135	+90 -170	+100 -200	+120 -230	+135 -265	+160 -310	+180 -350
	2	0.93	+65 -160	+65 -180	+80 -225	+100 -265	+120 -320	+135 -370	+155 -430	+180 -500	+205 -565
		1.86	+65 -150	+65 -160	+75 -205	+95 -240	+115 -290	+130 -340	+150 -395	+175 -450	+200 -510
		9.30	+65 -115	+65 -125	+70 -155	+90 -185	+100 -225	+120 -260	+135 -300	+160 -350	+180 -395
	3	0.93	+65 -230	+65 -255	+80 -315	+100 -380	+120 -450	+135 -530	+155 -615	+180 -705	+205 -805
		1.86	+65 -190	+65 -215	+75 -265	+95 -320	+115 -380	+130 -450	+150 -515	+175 -595	+200 -675
		9.30	+65 -115	+65 -125	+70 -155	+90 -185	+100 -225	+120 -260	+135 -300	+160 -350	+180 -395
Wall	4	0.93	+105 -115	+120 -125	+150 -155	+180 -185	+210 -225	+245 -260	+285 -300	+325 -350	+370 -395
		4.65	+100 -105	+115 -120	+135 -145	+160 -175	+190 -210	+230 -245	+260 -285	+300 -325	+340 -370
		46.5	+90 -95	+95 -105	+120 -130	+145 -155	+170 -185	+200 -215	+230 -245	+265 -285	+300 -325
	5	0.93	+105 -130	+120 -150	+150 -185	+180 -225	+210 -265	+245 -310	+285 -355	+325 -410	+370 -465
		4.65	+100 -120	+115 -130	+135 -160	+160 -190	+190 -230	+230 -270	+260 -315	+300 -355	+340 -405
		46.5	+90 -95	+95 -105	+120 -130	+145 -155	+170 -185	+200 -215	+230 -245	+265 -285	+300 -325

Table 2. Continued.

Notes:

1. Wind pressures from Table 2 represent net pressures (sum of external and internal pressures) applied perpendicular to all surfaces.
2. The values of Table 2 are based on a regular topography ($K_{zt} = 1$). When the hospital or health center in located on a hill, ridge, or escarpment, the topographic factor (K_{zt}) shall be computed according to ASCE 7-98 and the values of Table 2 multiplied by this factor.
3. The values of Table 2 are valid for exposure B. For exposure C, multiply the values of Table 1 by 1.40; for exposure D, multiply the values of Table 1 by 1.66.
4. Interpolation is permitted for values between tributary areas.
5. Positive and negative signs indicate pressures directed toward and away from the exterior surface, respectively.
6. All elements of the components and cladding shall be designed for positive and negative pressures of Table 2.
7. The zones are:



Where *a* equals 10% of the least horizontal dimension or.4h, the smallest of the two values, but not less than 4% of the least horizontal dimension or 1 meter; h is the mean roof height (in meters).

WIND SPEED MAP FOR HONDURAS

A wind speed map indicates the basic design wind speeds of a region with isotachs[3]. The objective of the map is to facilitate the engineer or architect the selection of the basic design wind speed depending on the geographic zone where the structure is to be designed or analyzed.

The basic design wind speeds are obtained through statistical studies and opinions supplied by a panel of experts in the field of wind engineering. These design wind speeds are usually associated with a probability of 2% that they will be equaled or exceeded (50-year mean recurrence interval). In addition, these wind speeds are given in standard conditions according to international wind provisions: at 10 meters above ground in open terrain with scattered obstructions (exposure C as defined by ASCE 7-98).

The map must clearly state the wind speed averaging time that represents: fastest mile, sustained wind speed, or 3-second wind speed. The map in ASCE 7-98 utilizes 3-second wind speed. It is advisable that the wind speed map for Honduras also utilizes 3-second wind speed to be consistent with ASCE 7-98.

To make the map, 2 types of wind speeds need to be identified: non hurricane and hurricane. For non-hurricane winds, records with information about direction and speed are required. At least 10 years of wind records are recommended in order to achieve results with a greater level of confidence. To make the map of the entire Republic of Honduras it is necessary to obtain wind records from different locations of the country.

Maximum annual wind speeds need to be analyzed using a statistical distribution that approximates extreme wind conditions. The technical literature refers to 3 distributions with these characteristics: Gumbel (Type I), Fisher-Typpett (Type II), and Weibull. There are arguments among experts as to which distribution approximates best extreme wind conditions. Nonetheless, in

[3] Isotachs are lines joining points of equal wind speed.

general the Gumbel is considered the best distribution for extreme winds and the Weibull for hurricane winds.

When there are not enough wind records (less than 10 years of records), it is possible to utilize a modified version of the Gumbel distribution. In this case, monthly records rather than yearly records would be used. It is important to mention that an analysis with a small number of wind records may result in *sampling errors*, which may be as high as 20%. Hence, the smaller the number of wind records, the greater conservatism needs to be exercised when developing the wind speed map.

The basic design wind speed for hurricane-prone regions (north of Honduras) present a special problem. Since Honduras is affected by hurricanes with a relatively low frequency (once every 6.2 years, on average), the number of records of hurricane winds is insufficient to perform a suitable statistical analysis. This problem can be handled through Monte Carlo simulation. The simulation involves a mathematical model that reproduces a wind field based upon certain parameters (radius of maximum winds, hurricane forward velocity, minimum central pressure, and Coriolis) defining a hurricane. These parameters may be inferred from historical hurricanes of the region. The simulation requires a sufficiently large number of iterations in order to obtain a reliable database that can be utilized to develop a hurricane wind speed map for the north region of Honduras.

A local commission formed by engineers, architects, and experts in the area of wind should discuss the final result of the statistical analysis and establish, jointly, the wind speed map for the Republic of Honduras.

CONSTRUCTION DETAILING AND REINFORCEMENT

The key for a hospital or health center to be able to survive the unpleasant visit of a hurricane is simple: prevent wind and water from entering the building. In order to achieve this objective. all structural elements as well as non-structural elements need to withstand the wind pressures. This section discusses the most susceptible zones of a building during a hurricane and advances some mitigation measures to reduce the vulnerability of hospitals and health centers against hurricane winds.

The wind effects discussed in the previous section will have different impacts on structures depending upon their geometry, roof type, roof slope, construction materials utilized, and the condition of the structure, to name a few. Likewise, there are certain zones of the building that, for a variety of reasons, are more vulnerable against wind actions (Figure 5). It is these zones where the highest suctions are produced due to vortices generated by high-localized pressures. If the engineer or architect recognizes these zones, it is possible to design a new structure or retrofit an existing one in such a way that the structure and its components can withstand the high pressures generated during a tropical storm.

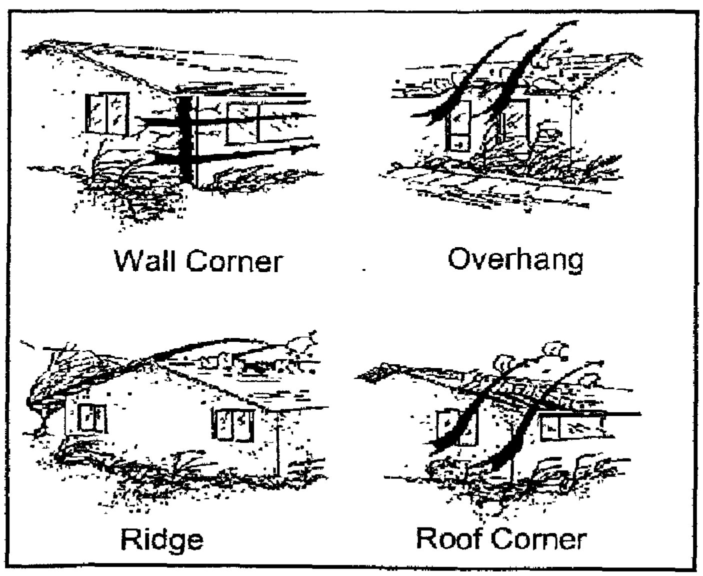


Figure 5. Most vulnerable zones of a building against strong winds.

Roofs

The most common type of failure during a hurricane begins on the roof. On the roof corners and ridges high-localized pressures generate due to the wind-structure interaction. As a consequence, part of the roof covering in these zones is detached by the wind, exposing the interior of the building and other parts of the structure to the wind, wind-borne missiles, and rain that generally accompanies a hurricane. To prevent this from happening it is necessary to provide an adequate anchorage to the roof covering. In Honduras the type of roof covering most commonly used is the galvanized steel sheet, which is screwed into the roof structure. The steel sheets need to resist gravity loads as well as wind loads produced by external and internal pressures (which usually act upward during a hurricane, resulting in separation and launching of complete roof systems). The roof sheeting should be heavy, with a minimum width of 0.5 mm when they are made of steel and a minimum width of 0.9 mm when they are made of aluminum. The asbestos cement sheets are not recommended because they are fragile and more susceptible to be damaged by wind-borne missiles. It becomes necessary that roof sheeting providers emphasize their recommendations regarding the connection of their manufactured sheets to the supporting beams. The use of screws is preferred over nails, since screws have a greater capacity to fasten the sheets against pullout. Figure 6 shows the areas of the roof requiring a greater concentration of fixings since those areas are subjected to higher wind pressures.

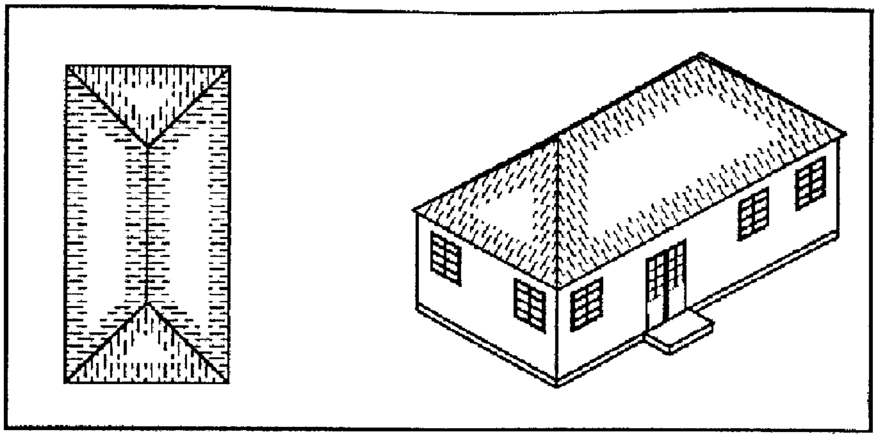


Figure 6. Typical distribution of those areas of roof coverings requiring a greater concentration of fixings (Illustration: Tony Gibbs).

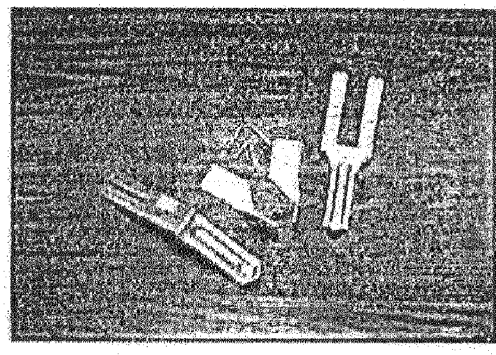
Continuous contact with weather actions tends to reduce the resistance capacity of screws and nails, often resulting in removal of roof sheathings even under normal[4] conditions. When screws and nails wear out, the roof system is no longer safe against future tropical storms. To ensure proper roof anchoring, periodic inspection of screws and nails is warranted to make sure that rust has not developed and that all fixings are in place and adequately secured.

Structural elements of the roof also need to be securely anchored between them in order to resist wind pressures. Galvanized steel channels embedded in reinforced concrete beams provide an excellent resistance capacity against wind pressures because of the restricting condition to move horizontally and vertically. This is important because in addition to gravity loads (downward) and wind loads (lateral and downward), the roof structure must be able to resist uplift forces imposed by the wind. In case of wooden roof structures, the structural elements should be fastened preferably with screws; if nails are used, these should be galvanized.

Additionally, wooden members should be secured utilizing hurricane clips made out of galvanized steel (Figure 7). These clips help transfer the loads and provide the roof system with the required capacity against uplift forces and

[4] Normal conditions are referred to as effects of non-hurricane winds, which may reach wind speeds up to 120 kilometers per hour (sustained wind speed).

hence, protect the roof from being removed and thrown away. The cost of hurricane clips is relatively low, their installation is simple, and their use increases considerably the capacity of the structure to withstand hurricane winds.



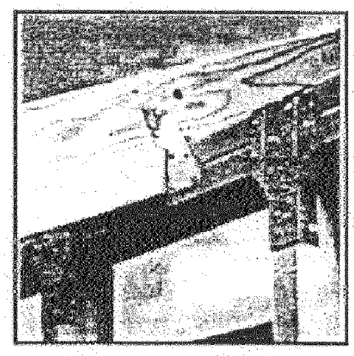


Figure 7. Samples of metal connectors used to secure timber elements.

End walls of buildings with gable roofs are subjected to high wind pressures during hurricanes. This type of roof requires additional reinforcement to guarantee that the roof system can withstand the lateral forces. Figure 8 shows an example of reinforcing by bracing the trusses of a wooden roof system with 2"x4" that are 8 feet long or more.

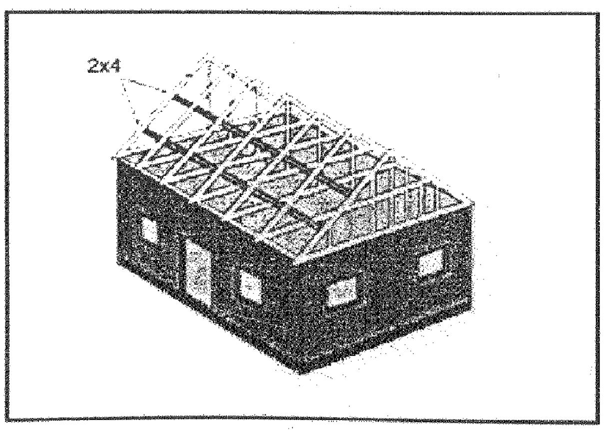


Figure 8. Gable roof reinforced with 2"x4"x8' elements. The distance between reinforcing elements should no be greater than 1.20 m.

Even though wood as a material for structural elements in Honduras is rarely utilized anymore, certain recommendations about its use have been incorporated in this document because (1) there is always the possibility of using wood as a material in the future, and (2) there are existing hospitals and health centers built out of wood that may – and should – be retrofitted in order to provide them with the necessary capacity to resist high wind pressures.

Overhangs

Overhangs, frequently utilized in constructions in Honduras and Central America, are also one of the weak spots of roof systems, making them vulnerable against wind actions. External pressures concentrate underneath overhangs, contributing to the separation of part – and sometimes all – of the roof system. The use of overhangs should be avoided when possible, especially for health centers located in coastal zones in the north of Honduras. When the use of overhangs is inevitable, then it is recommended that overhangs (1) be isolated from the roof structure so that an eventual overhang failure does not compromise the structural integrity of the roof, (2) be as short as possible, and (3) be protected with a metal flashing[5] in the perimeter of the roof between the roof sheathing and the purlins (Figure 9).

[5] Flashing is a component utilized to seal the roof system in those areas where roof sheathing (e.g., steel sheets) are interrupted or end. Flashings are constructed in galvanized steel, aluminum, copper, or PVC.

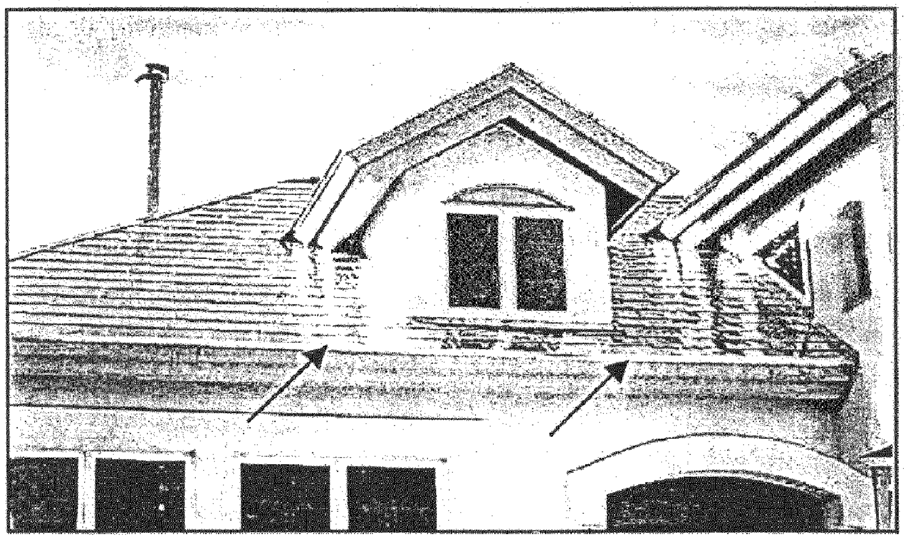


Figure 9. The main purpose of the metal flashing is to prevent the wind from entering between the roof covering and the exterior beam, which would initiate the separation of the roof covering creating an initial point of failure for the entire roof system.

Walls

Walls in Honduras are built primarily in concrete and masonry. When reinforced with steel, concrete and masonry walls provide an excellent resistance against hurricane winds; without steel reinforcement, their resistance capacity against hurricane winds reduces dramatically. In a few regions of Honduras, walls are also made out of wood. Wooden walls are capable to resist hurricane winds as long as careful attention is given to their design as well as during their construction phase.

The connection details between walls-roof and walls-foundation should not be overlooked. A building can only withstand wind loads when it successfully transfers such loads to the ground through a continuous load path (Figure 4). To ensure this, it is imperative that all structural elements be adequately interconnected. Each structural element of the roof system should be properly fastened and the roof should be firmly anchored to the exterior walls. When connections are not adequate, roofing systems tend to be completely detached and thrown away, turning into dangerous wind borne missiles that can impact adjacent buildings.