Minimum Standards for Cyclone Resistant Housing Utilizing Traditional Materials

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MINIMUM STANDARDS FOR CYCLONE RESISTANT HOUSING

UTILIZING TRADITIONAL MATERIALS

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Briefing Paper

MINIMUM STANDARDS FOR CYCLONE RESISTANT HOUSING UTILIZING TRADITIONAL MATERIALS FOUND IN THE THIRD WORLD

INTRODUCTION

The purpose of the following building guides is to provide the housing staff of housing reconstruction programs a guide to the key construction details and components required to produce disaster-resistant safe housing. These guides are intended to be used as the basis for:

A. Developing local building standards to guide post-disaster reconstruction programs.

B. Developing specific design criteria for use by contractors.

C. Developing training aids and manuals for instrumental materials to be used in aided self-help housing reconstruction programs.

D. Developing specifications for housing reconstruction projects.

E. Assessing proposals for assistance in building disaster-resistant housing.

These building guides were developed for residential, low-rise buildings built on individual plots of land. Houses which are attached to one another, those which are higher than one story, or those which are designed for more than two-family occupancy, must be treated as special engineering cases and designed on an individual basis. These building guides also do not apply to commercial structures, industrial buildings, churches, schools, or buildings used for large gatherings.

It should be noted that the purpose of these guides is to define a simple structure which is disaster-resistant. Disaster-resistant does not mean that the house is disaster proof. It means that the house should suffer only limited damage when struck by a disaster agent.

A wind-resistant house is defined as a structure which provides a basic margin of safety in high winds. I should be noted that safety is only provided against winds, not against flooding or storm surges.

For reference, this section is divided into sections according to the type of materials to be used. Users of these standards should note there is often great similarity between recommended measures taken to improve performance of a particular type of house, against both high winds and earthquakes. It should thus be remembered that for those regions where both types of disasters are prevalent, actions taken to improve resistance of the structure against one type of disaster usually have beneficial results in improving its performance against the other type. In those cases where new housing is being designed to withstand both disasters and there is a conflict between these recommendations and those for earthquake resistant construction, the most prevalent type of threat should be the deciding factor.

MINIMUM STANDARDS FOR:

CYCLONE-RESISTANT WOOD FRAME HOUSING

1. SITING

A. In locating a house, take advantage of natural windbreaks such as stands of trees, small hills or hedges to reduce the impact of prevailing winds.

B. Be especially careful of sites on or near tall hills. These can increase wind speeds by as much as 50%.

C. Valleys funnel winds; they can create abnormally high wind speeds.

D. Buildings placed near one another can affect wind speeds. Intense suction can develop on the gable ends of pitched roofs. If the building is in the wake of another, expect turbulence and some high local loading on small elements such as cladding.

E. When building a windbreak or shield, such as a row of trees or a wall, include small gaps to stabilize the flow on the lee side.

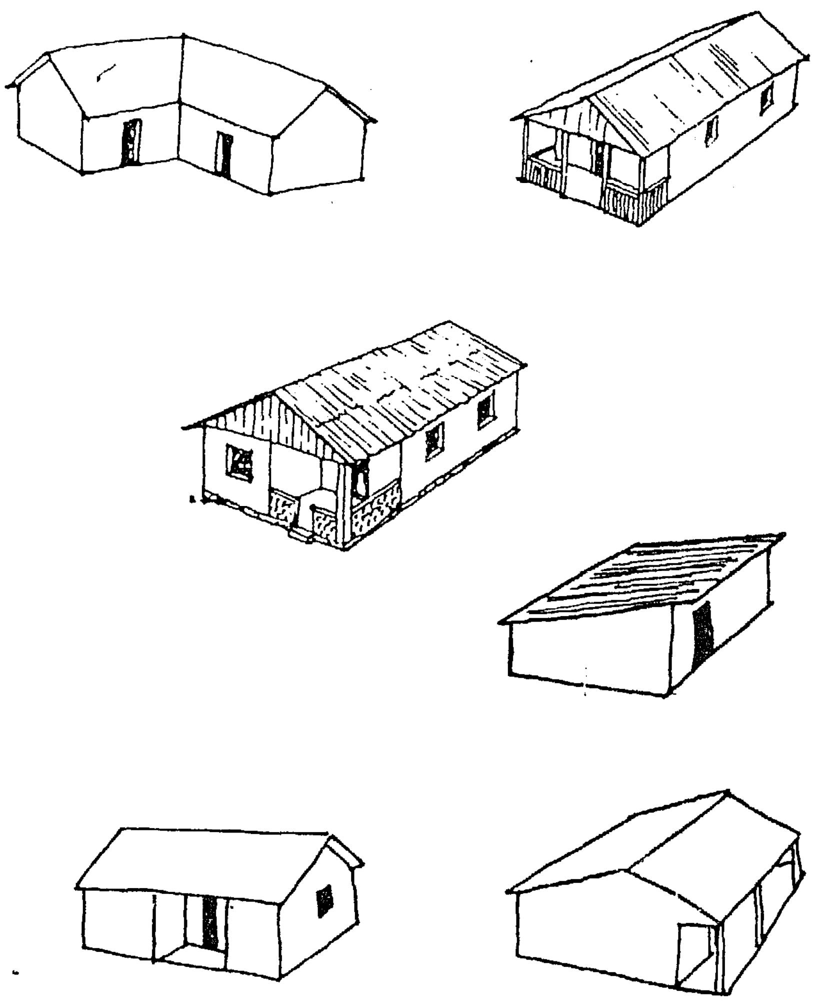
2. CONFIGURATION

A. The best shape of wood frame house to resist high winds is square or retangular. A retangular configuration should have a length to width ratio of 2.5 to 1.

B. The parallel walls of all structures must be of equal length and of equal height.

C. "L" shaped houses should be avoided as they have demonstrated poor performance in high winds.

D. The following configurations can be expected to receive a high proportion of damage due to wind entrapment.



3. ROOF DESIGN

A. Pitched Roofs

(1) If a pitched roof is desired, a hip roof configuration is recommended. This reduces the overall forces lifting on the roof. A gable roof may be used with a wood frame house, but care should be taken to reinforce the roof at the connection between the roof ridge and the gable.

(2) The roof pitch should be approximately 30°, or about one meter in three. (Wind loads are severe when roofs are pitched around 5° to 10°).

(3) Avoid outside overhangs of more than 1/2 a meter, even if supported at the edge by columns. If this is unavoidable, consider using vents or louvers along the roof edge to relieve the upward pressure.

Houses using a pitched roof should use roofing materials which are strong, shatter-resistant, and of medium weight. Recommended are:

- Heavy-gage metal roofing sheets;
- Medium-weight; fiber-reinforced cement roofing sheets (non-brittle);
- Wood sheets; and
- Wood tiles.

Not recommended are:

- Lightweight, metal roofing sheets (30-gague or less);

- Lightweight, fiber-reinforced cement roofing sheets;

- Lightweight, composite tiles and roofing sheets;

- This plywood sheets; or

- Asphalt-impregnated cardboard sheets.

B. <u>Flat Roofs</u>

Flat roofs are not recommended.

4. <u>WIND RESISTANT DESIGN FEATURES</u>

The forces applied to a building by high winds are:

- Upwards
- Sideways or lateral
- Twisting or racking

To build a structure which can resist these forces, there are three basic specifications that must be met:

A. <u>Anchorage</u>

The first specification is to hold the roof on. This entails tying the roof down to the ground or foundation by an adequate and continuous chain of strength. Traditional construction is directed toward holding the roof up. In wind-resistant construction, the purpose is to hold the roof down.

B. Bracing

The second specification is to brace the structure to withstand the lateral wind loadings and the racking effect. The methods used to brace traditional buildings are inadequate for the much larger forces existing in high wind conditions. Strength must be added not only at the corners of the building, but also at key locations throughout each wall.

C. Continuity

The third specification is to provide the structure with integrity, i.e., to ensure all components are properly connected so that they can satisfactorily perform their function. Because the forces are often much larger and in the opposite direction of those occurring normally, for more attention must be given to providing adequate connections between members and components of a building.

There are many design features which can significantly reduce the effect of the forces of high winds on a structure. Most of the building features which are dangerous are designed to provide comfort during normal periods of time. For example, many of the areas where high winds occur encompass subtropical and tropical regions. Houses in these zones generally feature lightweight materials, with large overhanging eaves for shade, elevated openings around the base of the roof and in the gables to facilitate ventilation and large window areas for through ventilation. Each of these features is contrary to ideal requirements for a wind-resistant house, so compromises is the design will have to be made. For the designer, there are several rules of thumb:

(1) Do not build any opening which cannot be closed off during a wind storm.

(2) Do not build openings which cannot be reached to be sealed off. (For example, an opening high on the wall under a gable may be difficult to reach and close prior to the onset of a storm).

(3) Leave openings in suitable locations where pressure can escape. (For example, at the ridge of the roof).

(4) Design the roof to reduce suction and break up lifting patterns.

(5) Design corners to reduce the pressures by allowing wind to slip around the corners. (This can be done often by rounding or beveling the corners of a building).

(6) Avoid creating areas where wind can be trapped and excessive pressure can build up. (For example, sealing off the eave of a house at an agnle parallel to or inclined towards the ground can significantly reduce the uplifting pressures at that point).

(7) Avoid creating courtyards or patios which will increase circular or turbulent winds.

(8) All doors and windows should be a minimum of one meter from the end of a wall.

(9) All doors and windows should be a minimum of one meter from each other.

5. STRUCTURAL SPECIFICATIONS

All wood frame houses must meet the following structural specifications:

A. Walls should be built on concrete footings securely anchored to the ground. Avoid placing wood directly in or on the ground as this will cause rapid deterioration and a subsequent loss of internal and vertical resistance. Posts should be solidly anchored to the footings. Imbed the posts at least 40 centimeters into the footing.

B. The houses should have wood posts in each corner and spaced at appropriate intervals throughout each wall. (Generally, posts should be spaced so that with the floor joists and upper ring beam, they form a square).

C. Vertical posts should be reinforced diagonally with wood braces.

D. Wood siding should be securely nailed to each post.

E. The houses should have a ring beam at the top of the wall formed by the upper part of the frame. Diagonal braces should be added at each corner.

F. Gables must be reinforced where they join the main wall. Preferably a single post running from the gable to the foundation can be used.

G. Interior walls should be fastened to exterior walls securely, and a diagonal brace should be attached at the ring beam.

H. Positive connections should be made between door and window frames and the walls in which they are placed.

I. When connecting the roof frame to the wall, special care must be taken to attach the roof frame securely to the frame of the building. In addition to nailing the roof joist to the frame, a fastener strap or angle iron should be nailed to the joist. Then the ends of the fastener should be attached to the ring beam or post. (Some recommended cyclone fasteners are shown on the last page of this section).

J. Corregated roofing materials, such as metal roofing sheets, asbestos cement roofing sheets, or composite materials should be secured at every corregation along the bottom purlin (at the eaves), at every corregation along the top purlin (at the ridge), at every corregation on the end sheets (at the gable end), and at every third corregation over the rest of the roof. To secure the roof sheets, it is recommended that self-drilling screws be used if possible. Nails are premissible, as long as the nail is long enough to penetrate deep into the purlin. When either screws or nails are used, a washer of at least 20 millimeters in diameter (approximately 3/4 of an inch) should also be used. (Note: Special roofing nails with a wide, flat head are often supplied with roofing sheets. The quality and length of these nails vary, and before they are used in high wind areas, it should be determined whether these are suitable).

K Corregated roofing should be fastened to purlins through the top of the corregations.

L. All wood joints and splices should be securely fastened and reinforced. Suggested fastenings are shown on the last page of this section.

6. MATERIALS

Wood chosen for use should be of high quality and strength and should be properly and sufficiently seasoned and treated with an approved preservative. All load bearing timbers must be treated by a pressure treatment method. Wood siding may be treated by immersion or brush application methods. All exterior wood should be painted with a water resistant paint.

7. SAFETY MEASURES

A. Doors and windows should be designed so that storm shutters can be placed over them during wind storms.

B. Windows should be designed so that glass panes are relatively small and the window frame is supported by a wooden super-structure.

C. Window frames should be designed so that if screens are used on the outside, they can be removed before a storm period and attached to the inside to provide protection against flying glass or other debris. All louvered windows must have outside storm shutters and be designed to lock into a closed position.

D. One specific area should be designed to be especially strong so it can be used as an in-house shelter during wind storms. This area may be a closet, or any small room of the house which can be strengthened.

MINIMUM STANDARDS FOR:

RESISTANT BLOCK HOUSING

1. SITING

A. In locating a house take advantage of natural windbreaks such as stands of trees, small hills or hedges to reduce the impact of prevailing winds.

B. Be especially careful of sites on or near tall hills. These can increase wind speeds by as much as 50%.

C. Valleys funnel winds; they can create abnormally high wind speeds.

D. Buildings placed near one another can affect wind speeds. Intense suction can develop on the gable ends of pitched roofs. If the building is in the wake of another, expect turbulence and some high local loading on small elements such as cladding.

E. When building a windbreak or shield, such as a row of trees or a wall, include small gaps to stabilize the flow on the lee side.

2. CONFIGURATION

A. The best shape of a house to resist high winds is circular. In those areas where circular houses are used traditionally, reconstruction programs should encourage continued use of this configuration.

B. A retangular configuration may be used provided that the length to width ratio does not exceed 2.5 to 1.

C. The parallel walls of all structures must be of equal length and of equal height.

3. ROOF DESIGN

A. Pitched Roofs

(1) If a pitched roof is desired, a hip roof configuration is recommended. This reduces the overall forces lifting on the roof. A gable roof may be used as long as adequate diagonal bracing is used between the roof trusses to provide lateral resisting strength for the roof, and when the gables are adequately reinforced so that they will not topple into the house.

(2) A roof pitch should be approximately 30^{o}, or about one meter in three. (Wind loads are severe when roofs are pitched around 5^{o} to 10^{o}).

(3) Avoid outside overhangs of more than half a meter, even if supported at the edge by columns. If this is unavoidable, consider using vents or louvers along the roof edge to relieve the upward pressure.

Houses using a pitched roof should use roofing materials which are strong, shatter-resistant, and of medium weight. Recommended are:

- Heavy-gague metal roofing sheets;
- Medium-weight, fiber-reinforced cement roofing sheets (non-brittle);
- Wood sheets;
- Wood tiles; and,
- Concrete panels (those which can be fastened to the roof frame).

Clay tile may also be used, provided that a suitable substructure is built which will prevent individual tiles from falling inward and striking occupants should the roof be hit by missiles propelled by the wind, and provided that they can be securely fastened to the roof structure. Not recommended are:

- Lightweight metal roofing sheets;
- Lightweight fiber-reinforced cement roofing sheets;
- Lightweight composite tiles and roofing sheets
- Thin plywood sheets
- Asphalt-impregnated cardboard sheets.

B. Flat Roofs

(1) A flat roof may be used as long as the roofing material is monolithic and is firmly attached.

(2) A parapet should be used around the edge of a flat roof to help reduce high suction along roof edges. (This will have little effect, however, on overall roof uplift).

If a flat roof is desired, the following materials are recommended:

- Reinforced concrete
- Ferrocement

Flat roofs made of other materials such as metal or wood roofing sheets are not recommended.

4. WIND RESISTANT DESIGN FEATURES

The forces applied to a building by high winds are:

- Upwards
- Sideways or lateral
- Twisting or racking

To build a structure which can resist these forces, there are three basic specifications that must be met:

A. Anchorage

The first specification is to hold the roof on. This entails tying the roof down to the ground or foundation by an adequate and continuous chain of strength. Traditional construction is desired toward holding the roof up. In wind-resistant construction, the purpose is to hold the rood down.

B. Bracing

The second specification is to brace the structure to withstand the lateral wind loadings and the racking effect. The methods used to brace traditional buildings are inadequate for the much larger forces existing in high wind conditions. Strength must be added not only at the corners of the building, but also at key locations throughout each wall.

C. Continuity

The third specification is to provide the structure with integrity so that they can staisfactorily perform their function. Because the forces are often much larger and in the opposite direction of those occurring normally, far more attention must be given to providing adequate connections between members and components of a building.

There are many design features which can significantly reduce the effect of the forces of high winds on a structure. Most of the building features which are dangerous are designed to provide comfort during normal periods of time. For example, many of the areas where high winds occur emcompass subtropical and tropical regions. Houses in these zones generally feature lightweight materials, with large overhanging eaves for shade, elevated openings around the base of the roof and in the gables to facilitate ventilation and large window areas for through ventilation. Each of these features is contrary to ideal requirements for a wind-resistant house, so compromises in the design will have to be made. For the designer, there are several rules of thumb:

(1) Do not build any opening which cannot be closed off during a wind storm.

(2) Do not build openings which cannot be reached to be sealed off. (For example, an opening high on the wall under a gable may be difficult to reach and close prior to the onset of a storm).

(3) Leave openings in suitable locations where pressure can escape. (For example, at the ridge of the roof).

(4) Design the roof to reduce suction and break up lifting patterns.

(5) Design corners to reduce the pressures by allowing wind to slip around the corners. (This can be done often by rounding or beveling the corners of a building).

(6) Avoid creating areas where wind can be trapped and excessive pressure can build up. (For example, sealing off the eave of a house at an angle parallel to or inclined towards the ground can significantly reduce the uplifting pressures at that point).

(7) Avoid creating courtyards or patios which will increase circular or turbulent winds.

(8) All doors and windows should be a minimum of one meter from the end of a wall.

(9) All doors and windows should be a minimum of one meter from each other.

5. STRUCTURAL SPECIFICATIONS

All houses built of cement block must meet the following structural specifications:

A. Block walls should be built on a continuous concrete footing in a trench. Avoid placing blocks directly on the ground, as this will cause the building to settle unevenly, causing wall cracks and openings for wind to penetrate.

B. The houses should have vertical columns made of reinforced concrete in each corner and spaced at appropriate intervals throughout each wall. (Generally, columns should be spaced so that with the foundation and upper ring beam, they form a square.)

C. All windows and doors should have vertical columns on each side of the openings.

D. Blocks should be solidly anchored to the foundation using dowels, reinforcing bars, or tie rods. Imbed the anchors at least 25 centimeters into the footing.

E. Walls should be anchored to the foundation with 15 millimeter rods spaced not more than two meters apart.

F. Blocks should be laid according to a running bond rather than a stack bond method.

G. To control cracking, blocks should be reinforced internally, using metal rods imbedded in grout. Be sure to maintain a tight bond between reinforcement and the surrounding materials.

H. To reduce costs, split cane, bamboo or other suitable tie material may also be used.

I. Corner columns or posts should be securely tied to adjacent walls, using tie bars and/or horizontal reinforcement.

J. Intersecting walls should be made continuous by means of tie bars and/or horizontal reinforcement that extends into neighboring walls and partitions.

K. The houses should have a minimum of one horizontal ring beam placed close to the center of the wall.

L. The houses should have ring beams at the top of the wall.

M. Gables must be reinforced with vertical columns and surrounded by poured concrete on all sides.

N. Interior walls should be jointed to exterior walls at a vertical column.

O. Positive connections should be made between door and window sills, posts and lentels, and the walls in which they are placed.

P. When connecting a timber roof frame to a block wall, special care must be taken to attach the roof frame securely to the structure of the building. The roof joists must be ready prior to the pouring of the upper ring beam. As the upper ring beam is poured, the roof joist is put in place. A fastener strap should be placed over and around the roof joist, then nailed to the joist. Then the ends of the fastener should be imbedded in the concrete to a depth of 25 centimeters.

Fasteners may be made by cutting strips of galvanized sheet metal to deminsions of 30 millimeters by 50 centimeters. Galvanized sheets should be 28 guage or thicker.

Q. Corregated roofing material, such as metal roofing sheets, asbestos cement roofing sheets, or composite materials should be secured at every corregation along the bottom purlin (at the eaves), at every corregation along the top purlin (at the ridge), at every corregation on the end sheets (at the gable end), and at every third corregation over the rest of the roof. To secure the roof sheets, it is recommended that self-drilling screws be used if possible. Nails are permissible, as long as the nail is long enough to penetrate deep into the purlin. When either screws or nails are used, a washer of at least 20 millimeters in diameter (approximately 3/4 of an inch) should also be used. (Note: Special roofing nails with a wide, flat head are often supplied with roofing sheets. The quality and length of these nails vary, and before they are used in high wind areas, it should be determined whether these are suitable).

R. Corregated roofing should be fastened to purlins through the top of the corregations.

S. All wood joints and spliced should be securely fastened and reinforced. A summary of suggested fastenings is shown on the following page.

Fasteners may be made by cutting strips of galvanized sheet metal to deminsions of 30 millimeters by 50 centimeters. Galvanized sheets should be 28 guage or thicker.

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R. Corregated roofing should be fastened to purlins through the top of the corregations.

S. All wood joints and spliced should be securely fastened and reinforced. A summary of suggested fastenings is shown on the following page.

6. MATERIALS

Blocks chosen for use should be of high quality and strength and should be properly and sufficiently cured.

A. Strength

Blocks chosen for use in cyclone-resistant housing should have a compressive strength of 800 psi after normal curing.

B. Fabrication

Blocks may be fabricated from any ratio of sand to cement that provides the above compression strength.

C. Fillers

The use of pumice sand as a filler is premissible provided the sand does not contain, or is mixed with, any clay soils.

7. SAFETY MEASURES

A. Doors and windows should be designed so that storm shutters can be placed over them during wind storms.

B. Windows should be designed so that glass panes are relatively small and the window frame is supported by a wooden super-structure.

C. Window frames should be designed so that if screens are used on the outside, they can be removed before a storm period and attached to the inside to provide protection against flying glass or other debris. All louvered windows must have outside storm shutters and be designed to lock into a closed position.

D. In large buildings, or those which have numerous rooms, one specific area should be designed to be especially strong so it can be used as an in-house shelter during wind storms. This area may be a closet, a work room, an area beneath the main floor or the house (if flooding is not a threat) or any small room of the house which can be strengthened without undue additional cost.

MINIMUM STANDARDS FOR:

CYCLONE-RESISTANT BRICK HOUSING

1. SITING

A. In locating a house, take advantage of natural windbreaks such as stands of trees, small hills or hedges to reduce the impact of prevailing winds.

B. Be especially careful of sites on or near tall hills. These can increase wind speeds by as much as 50 percent.

C. Valleys funnel winds; they can create sbnormally high wind speeds.

D. Buildings placed near one another can affect wind speeds. Intense suction can develop on the gable ends of pitched roofs. If the building is in the wake of another, expect turbulence and some high local loading on small elements such as cladding.

E. When building a windbreak or shield, such as a row of trees or a wall, include small gaps to stabilize the flow on the lee side.

2. CONFIGURATION

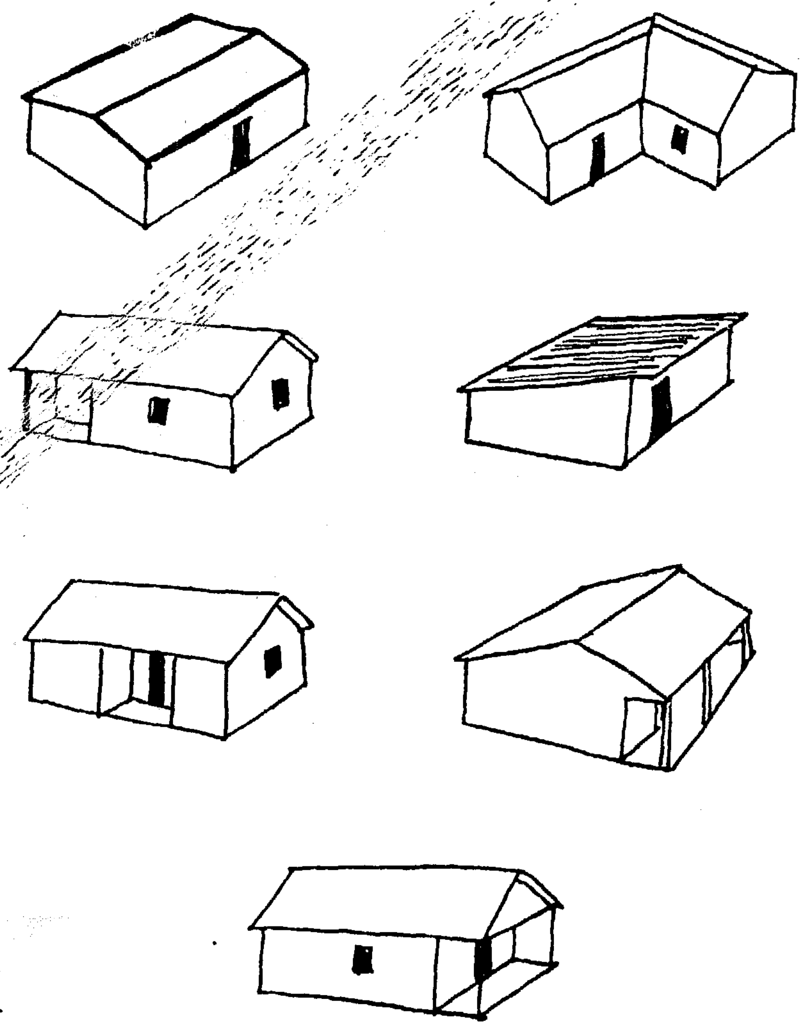
A. The best shape for a brick house to resist high winds is square or rectangular.

B. The length to wideth ratio should not exceed 2.5 to 1.

C. The parallel walls of all structures must be of equal length and of equal height.

D. An "L" shaped configuration should be avoided. (These buildings have a high percentage of failure due to racking in high winds).

E. The following configurations are especially prone to major damages in high winds.



3. ROOF DESIGN

A. Pitched Roofs

(1) If a pitched roof is desired, a hip roof configuration is recommended. This reduces the overall forces lifting on the roof. A gable roof may be used as long as adequate diagonal bracing is used between the roof trusses to provide lateral risisting strength for the roof, and when the gables are adequately reinforced so that they will not topple into the house.

(2) A roof pitch should be approximately 30^{o}, or about one meter in three. (Wind loads are severe when roofs are pitched around 5^{o} to 10^{o}).

(3) Avoid outside overhangs of more than 1/2 a meter, even if supported at the edge by columns. If this is unavoidable, consider using vents or louvers along the roof edge to relieve the upward pressure.

Houses using a pitched roof should use roofing materials which are strong, shatter-resistant, and of medium weight. Recommendations are:

- Heavy-gague, metal roofing sheets;
- Medium-weight, fiber-reinforced cement roofing sheets (non-brittle);
- Wood sheets;

- Wood tiles; and,
- Concrete panels (those which can be fastened to the roof frame).

Clay tile may also be used, provided that a suitable substructure is built which will prevent individual tiles from falling inward and striking occupants should the roof be hit by missiles propelled by the wind, and provided that they can be securely fastened to the roof structure. Not recommended are:

- Lightweight, metal roofing sheets;
- Lightweight, fiber-reinforced cement roofing sheets;
- Lightweight, composite tiles and roofing sheets;
- Thin plywood sheets; or
- Asphalt-impregnated cardboard sheets.

B. Flat Roofs

(1) A flat roof may be used as long as the roofing material is monolithic and if firmly attached.

(2) A parapet should be used around the edge of a flat roof to help reduce high suction along roof edges. (This will have little effect, however, on overall roof uplift).

If a flat roof is desired, the following materials are recommended:

- Reinforced concrete
- Ferrocement

Flat roofs made of other materials such as metal or wood roofing sheets are not recommended.

4. WIND-RESISTANT DESIGN FEATURES

The forces applied to a building by high winds are:

- Upwards
- Sideways or lateral
- Twisting or racking

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A. Anchorage

The first specification is to hold the roof on. This entails tying the roof down to the ground or foundation by an adequate and continuous chain of strength. Traditional construction is directed toward holding the roof up. In wind-resistant construction, the purpose is to hold the roof down.

B. Bracing

The second specification is to brace the structure to withstand the lateral wind loadings and the racking effect. The methods used to brace traditional buildings are inadequate for the much larger forces existing in high wind conditions. Strength must be added not only at the corners of the building, but also at key locations throughout each wall.

C. Continuity

The third specification is to provide the structure with integrity, i.e., to ensure all components are properly connected so that they can staisfactorily perform their function. Because the forces are often much larger and in the opposite direction of those occurring normally, far more attention must be given to providing adequate connections between members and components of a building.

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(1) Do not build any opening which cannot be closed off during a wind storm.

(2) Do not build openings which cannot be reached to be sealed off. (For example, an opening high on the wall under a gable may be difficult to reach and close prior to the onset of a storm).

(3) Leave openings in suitable locations where pressure can escape. (For example, at the ridge of the roof).

(4) Design the roof to reduce suction and break up lifting patters.

(5) Design corners to reduce the pressures by allowing wind to slip around the corners. (This can be done often by rounding or beveling the corners of a building).

(6) Avoid creating areas where wind can be trapped and excessive pressure can build up. (For example, sealing off the eave of a house at an angle parallel to or inclined towards the ground can significantly reduce the uplifting pressures at that point).

(7) Avoid creating courtyards or patios which will increase circular or turbulent winds.

(8) All doors and windows should be a minimum of one meter from the end of a wall.

(9) All doors and windows should be a minimum of one meter from each other.

5. STRUCTURAL SPECIFICATIONS

All houses built of brick must meet the following structural specifications:

A. Brick walls should be built on a continuous concrete footing in a trench Avoid placing bricks directly on the ground, as this will cause the building to settle unevenly, causing wall cracks and openings for wind to penetrate.

B. The houses should have vertical columns made of reinforced concrete in each corner and spaced at appropriate intervals throughout each wall. (Generally, columns should be spaced so that with the foundation and upper ring beam, they form a square).

C. All windows and doors should have vertical columns on each side of the openings.

D. Bricks should be laid according to a running bond rather than a stack bond method.

E. Corner columns or posts hsould be securely tied to adjacent walls, using tie bars and/or horizontal reinforcement.

F. Intersecting walls should be made continuous by means of tie bars and/or horizontal reinforcement that extends into neighboring walls and partitions.

G. The houses should have a minimum of one horizontal ring beam placed close to the center of the wall.

H. The houses should have ring beams at the top of the wall.

I. Gables must be reinforced with vertical columns and surrounded by poured concrete on all sides.

J. Interior walls should be jointed to exterior walls at a vertical column.

K. Positive connections should be made between door and window sills, posts and lentels, and the walls in which they are placed.

L. When connecting a timber roof frame to a brick wall, special care must be taken to attach the roof frame securely to the frame of the building. The roof joists must be ready prior to the pouring of the upper ring beam. As the upper ring beam is poured, the roof joist is put in place. A fastener strap should be placed over and around the roof joist, then nailed to the joist. Then the ends of the fastener should be imbedded in the concrete to a depth of 25 centimeters. (Fasteners may be made by cutting strips of galvanized sheet metal to dimensions of 30 millimeters by 50 centimeters. Galvanized sheets should be 28 guage or thicker).

M. Corregated roofing material, such as metal roofing sheets, asbestos cement roofing sheets, or composite materials should be secured at every corregation along the bottom purlin (at the eaves), at every corregation along the top purlin (at the ridge), at every corregation on the end sheets (at the gable end), and at every third corregation over the rest of the roof. To secure the roof sheets, it is recommended that self-drilling screws be used if possible. Nails are permissible, as long as the nail is long enough to penetrate deep into the purlin. When either screws or nails are used, a washer of at least 20 millimeters in diameter (approximately 3/4 of an inch) should also be used. (Note: Special roofing nails with a wide, flat head are often supplied with roofing sheets. The quality and length of these nails vary, and before they are used in high wind areas, it should be determined whether these are suitable).

N. Corregated roofing should be fastened to purlins through the top of the corregations.

O. All wood joints and splices should be securely fastened and reinforced. A summary of suggested fastenings is shown on the following page.

6. MATERIALS

Bricks chosen for use should be of high quality and strength and should be properly fired.

7. SAFETY MEASURES

A. Doors and windows should be designed so that storm shutters can be placed over them during wind storms.

B. Windows should be designed so that glass panes are relatively small and the window frame is supported by a wooden super-structure.

C. Window frames should be designed so that if screens are used on the outside, they can be removed before a storm period and attached to the inside to provide protection against flying glass or other debris. All louvered windows must have outside storm shutters and be designed to lock into a closed position.

D. In large buildings, or those which have numerous rooms, one specific area should be designed to be especially strong so it can be used as an in-house shelter during wind storms. This area may be a closet, a work room, an area beneath the main floor of the house (if flooding is not a threat) or any small room of the house which can be strengthened without undue additional cost.

MINIMUM STANDARDS FOR:
CYCLONE RESISTANT WATTLE AND DAUB HOUSING

1. SITING

A. In locating a house, take advantage of natural windbreaks such as stands of trees, small hills or hedges to reduce the impact of prevailing winds.

B. Be especially careful of sites on or near tall hills. These can increase wind speeds by as much as 50%.

C. Valleys funnel winds; they can create abnormally high wind speeds.

D. Buildings placed near one another can affect wind speeds. Intense suction can develop on the gable ends of pitched roofs. If the building is in the wake of another, expect turbulence and some high local loading on small elements such as cladding.

E. When building a windbreak or shield, such as a row of trees or a wall, include small gaps to stabilize the flow on the lee side.

2. CONFIGURATION

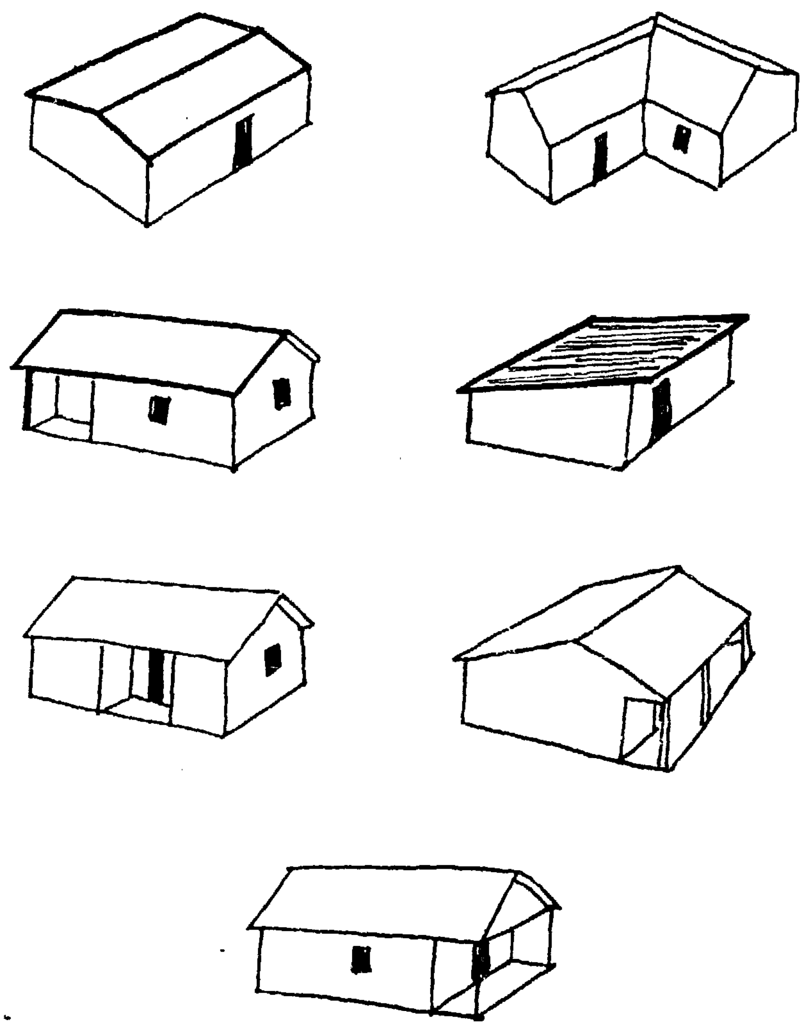
A. The best shape of a house to resist high winds in circular. In those areas where circular houses are used traditionally, reconstruction programs should encourage continued use of the configuration.

B. A rectangular configuration may be used provided that the length to width ratio does not exceed 2.5 to 1.

C. The parallel walls of all structures must be of equal length and of equal heigth.

D. An "L" shaped configuration should not be built. (These buildings have a high percentage of failure due to racking in high winds).

E. The following configurations are especially prone to roof damage in high winds.



3. ROOF DESIGN

A. Pitched Roofs

(1) If a pitched roof is desired, a hip roof configuration is recommended. This reduces the overall forces lifting on the roof. A gable roof may be used as long as adequate diagonal bracing is used between the roof trusses to provide lateral resisting strength for the roof, and when the gables are adequately reinforced so they they will not topple into the house.

(2) A roof pitch should be approximately 30°, or about one meter in three. (Wind loads are severe when roofs are pitched around 5°to 10°).

(3) Avoid outside overhangs of more than 1/2 a meter, even if supported at the edge by columns. If this is unavoidable, consider using vents or louvers along the roof edge to relieve the upward pressure.

Houses using a pitched roof should use roofing materials which are strong, shatter-resistant, and of medium weight. Recommended are:

- Heavy-gague metal roofing sheets;
- Medium-weight, fiber-reinforced cement roofing sheets (non-brittle);
- Wood sheets;
- Wood tiles; and,

- Grass, straw, or palm leaf roofs built in a traditional style (provided that proper reinforcing is added and they are securely fastened).

Clay tile should not be used, as it is too heavy for the frame and wind loadings would cause it to collapse the walls. Asphalt-impregnated cardboard sheets are also not recommended.

B. Flat Roofs

Flat roofs are not recommended for wattle and daub houses due to structural problems.

4. WIND-RESISTANT DESIGN FEATURES

The forces applied to a building by high winds are:

- Upwards
- Sideways or lateral
- Twisting or racking

To build a structure which can resist these forces, there are three basic specifications that must be met:

A. Anchorage

The first specification is to hold the roof on. This entails tying the roof down to the ground or foundation by an adequate and continuous chain of strength. Traditional construction is directed toward holding the roof up. In wind-resistant construction, the purpose is to hold the roof down.

B. Bracing

The second specification is to brace the structure to withstand the lateral wind loadings and the racking effect. The methods used to brace traditional buildings are inadequate for the much larger forces existing in high wind conditions. Strength must be added not only at the corners of the building, but also at key locations throughout each wall.

C. Continuity

The third specification is to provide the structure with integrity, i.e., to ensure that all components are properly connected so that they can satisfactorily perform their function. Because the forces are often much larger and in the opposite direction of those occurring normally, far more attention must be given to providing adequate connections between members and components of a building.

There are many design features which can significantly reduce the effect of the forces of high winds on a structure. Most of the building features which are dangerous are designed to provide comfort during normal periods of time. For example, many of the areas where high winds occur encompass subtropical and tropical regions. Houses in these zones generally feature light-weight materials, with large overhanging eaves for shade, elevated openings around the base of the roof and in the gables to facilitate ventilation and large window areas for through ventilation. Each of these features is contrary to ideal requirements for a wind-resistant house, so compromises in the design will have to be made. For the designer, there are several rules of thumb.

(1) Do not build any opening which cannot be closed off during a wind storm.

(2) Do not build openings which cannot be reached to be sealed off. (For example, an opening high on the wall under a gable may be difficult to reach and close prior to the onset of a storm).

(3) Leave openings in suitable locations where pressure can escape. (For example, at the ridge of the roof).

(4) Design the roof to reduce suction and break up lifting patterns.

(5) Design corners to reduce the pressures by allowing wind to slip around the corners. (This can be done often by rounding or beveling the corners of a building).

(6) Avoid creating areas where wind can be trapped and excessive pressure can build up. (For example, sealing off the eave of a house at an angle parallel to or inclined towards the ground can significantly reduce the uplifting pressures at that point).

(7) Avoid creating courtyards or patios which will increase circular or turbulent winds.

(8) All doors and windows should be a minimum of one meter from the end of a wall.

(9) All doors and windows should be a minimum of one meter from each other.

5. STRUCTURAL REQUIREMENTS

All houses built of wattle and daub must meet the following structural specifications:

A. Walls should be built on a coutinuous rock footing with a moisture barrier. Avoid placing the wall directly on the ground, as moisture may cause deterioration at the base of the wall.

B. The houses should have wood posts in each corner and spaced at appropriate intervals throughout each wall. (Generally, columns should be spaced so that with the foundation and upper ring beam, they form a square).

C. All windows and doors should have posts on each side of the openings.

D. Posts should be solidly anchored in the foundation (approximately one meter) and anchors should be attached or cut into each post.

E. All posts should be reinforced diagonally with wood or wire corss braces at suitable locations.

F. Posts should be reinforced horizontally with wood or wire at suitable locations.

G. Intersecting walls should be made continuous by tying the wires so that they extend to neighboring posts.

H. The houses should have a wooden ring beam at the top of the wall.

I. Diagonal braces should be placed across each corner of the ring beam.

J. Gables must be reinforced with a center post extending into the foundation.

K. Interior walls should be jointed to exterior walls at a vertical column and a diagonal brace should be added at the ring beam.

L. Positive connections should be made between door and window sills, posts and lentels, and the walls in which they are placed.

M. When connecting the roof frame to the wall, special care must be taken to attach the roof frame securely to the frame of the building. A fastener strap should be placed over and around the roof joist, then nailed to the joist. Then the ends of the fastener should be attached to the ring beam or to the posts.

Fasteners may be made by cutting straps of galvanized sheet metal to dimensions or 30 millimeters by 50 centimeters. Galvanized sheets should be 28 guage or thicker.

N. Corregated roofing materials, such as metal roofing sheets, asbestos cement roofing sheets, or composite materials should be secured at every corregation along the bottom purlin (at the eaves), at every corregation along the top purlin (at the ridge), at every corregation on the end sheets (at the gable end), and at every third corregation over the rest of the roof. To secure the roof sheets, it is recommended that self-drilling screws be used if possible. Nails are permissible, as long as the nail is long enough to penetrate deep into the purlin. When either screws or nails are used, a washer of at least 20 millimeters in diameter (approximately 3/4 of an inch) should also be used. (Note: Special roofing nails with a wide, flat head are often supplied with roofing sheets. The quality and length of these nails vary, and before they are used in high wind areas, it should be determined whether these are suitable).

O. Corregated roofing should be fastened to purlins through the top of the corregation.

P. All wood joints and splices should be securely fastened and reinforced. A summary of suggested fastenings is shown at the end of this section.

6. MATERIALS

Wood chosen for use should be of high quality and strength and should be properly and sufficiently cured and treated. Recommended wood treatments are:

- Creosote
- Pentachorophenol

Also permissible are:

- Oil with a mix of aldrin or dieldren
- Charcoal burning of the base of the post

Note: Pressure-treated wood is far more durable than wood treated by immersion or brushing.

7. SAFETY MEASURES

A. Doors and windows should be designed so that storm shutters can be placed over them during wind storms.

B. Windows should be designed so that glass panes are relatively small and the window frame is supported by a wooden super-structure.

C. Window frames should be designed so that if screens are used on the outside, they can be removed before a storm period and attached to the inside to provide protection against flying glass or other debris. All louvered windows must have outside storm shutters and be designed to lock into a closed position. In large buildings, or those which have numerous rooms, one specific area should be designed to be especially strong and which can be used as an in-house shelter during wind storms. This area may be a closet, a work room, or any small room of the house which can be strengthened without undue additional cost.