PN-AAX-912

VENTILATION RECOMMENDATIONS FOR

MLGL/BHC MID-LEVEL HOUSING

Prepared by:

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PREFACE

This report describes a portion of the work undertaken by Mr. Scott Matthews at the Botswana Renewable Energy Technology (BRET) project between December 15, 1984 and April 24, 1985. Mr. Matthews is an architectural consultant for Associates in Rural Development, Inc. (ARD), the contractor which is implementing the BRET project for the U. S. Agency for International Development (AID) under contract number 633-0209-C-00-1024-00.

I. INTRODUCTION

As the result of a meeting with Mr. G. Rabana and Mr. Glass of the Botswana Housing Corporation (BHC), on January 10, 1985, Mr. Philip Niles (an ARD engineering consultant) and Mr. Matthews did some research on design issues which have the potential to improve the comfort of the standard plans that BHC is developing for use in New Naledi. Some of this work (e.g., the thermal performance of various wall construction options, ceiling and insulation recommendations, etc.) was still in progress when this report was written. However, the findings concerning the ventilation performance of the preliminary BHC plan provided for analysis are presented here.

II. VENTILATION

The two driving forces which naturally ventilate a building are:

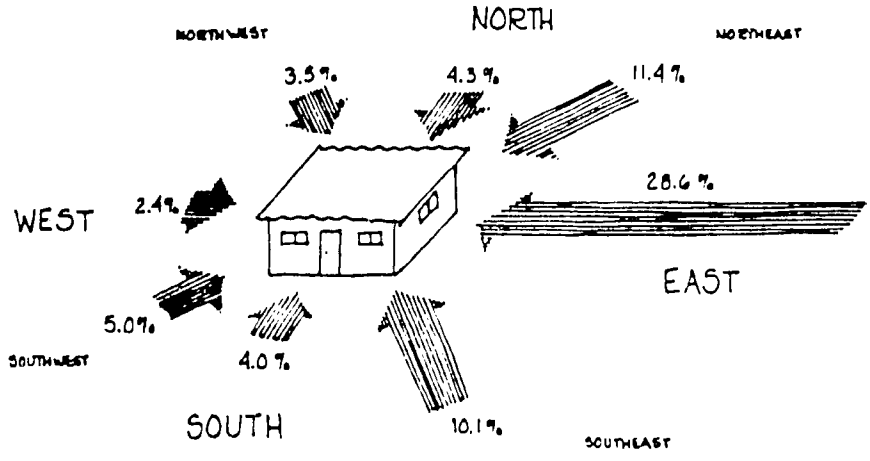
- the difference in air pressure from one side of a building to another caused by the wind; and
- the difference in air density between indoors and outside due to the temperature and height differential between inlet and outlet windows.

The preliminary BHC plan is relatively well suited for wind-driven ventilation in that all the rooms but one can have two windows located on adjacent walls. Extensive experimentation in several countries has shown that windows in adjacent walls generally perform as well as ones on opposite walls in maintaining a respectable fraction of the outdoor wind speed through the house.

Temperature- (or "stack"-) driven ventilation will be less effective since all the windows are on the same level, but will occur to some extent on calm nights, if the doors are left open to provide the needed height differential between the inlet (lower half of the doors) and outlet (upper part of the windows). Thus, it is recommended that design attention be focused primarily on ensuring good cross-ventilation in all rooms.

Gaborone's prevailing breezes during the summer are generally from the east or northeast, and average over 1.25 meters per second (see Figures 1 and 2 on the next page). These conditions are favorable for wind-driven ventilation cooling, and appear sufficiently predictable to justify specific attention to orienting the windows with respect to the prevailing wind. However, this will not be necessary if cross-ventilation is provided in each room (using only the windows, assuming that the doors are closed for security). The improvements recommended in this report will help ensure a ventilation rate that is sufficient to cool the thermal mass of the house's floor and walls as well as provide perceptible air motion for the occupants.

Figure 1. Prevailing Wind Directions for Gaborone in the Summer*



*There is no wind 30.7 percent of the time.

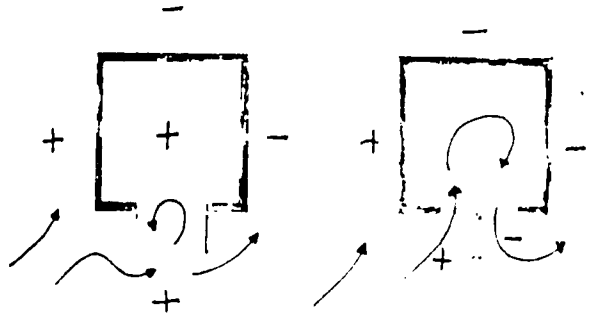
Figure 2. Mean Monthly Wind Speed in Kilometers per Hour (surface roughness coefficient of 0.29)

	GABORONE (1958-80)		MAHALAPYE (1959-80)		FRANCISTOWN (1959-80)		MAUN (1967-80)	
AT:	2m	10m	2m	10m	2m	10m	2m	10m
JAN	4.2	6.9	3.3	5.3	6.3	10.9	5.3	9.4
FEB	3.7	6.9	2.9	4.6	6.7	10.7	5.6	9.1
MAR	3.1	5.0	2.7	4.3	6.7	10.7	5.9	9.4
APR	3.0	4.8	2.4	3.8	5.7	9.1	5.5	8.9
MAY	3.2	5.1	2.1	3.4	4.9	7.8	5.4	8.6
JUN	3.0	4.8	2.4	3.8	4.9	7.8	5.7	9.1
JUL	3.1	5.0	2.2	3.5	5.4	8.6	5.0	8.5
AUG	4.1	6.4	2.9	4.6	6.4	10.2	6.5	10.4
SEP	4.3	7.3	3.7	5.9	8.0	12.9	7.7	12.3
OCT	3.7	5.1	4.3	6.9	9.0	14.4	8.6	13.8
NOV	5.1	8.2	3.3	5.2	7.3	12.6	7.5	12.1
DEC	4.5	7.2	3.5	5.6	7.1	11.4	6.7	10.7
ANNUAL	4.0	6.4	3.0	4.8	6.6	10.6	6.4	10.3

III. WING-WALLS AND WINDOW DESIGN

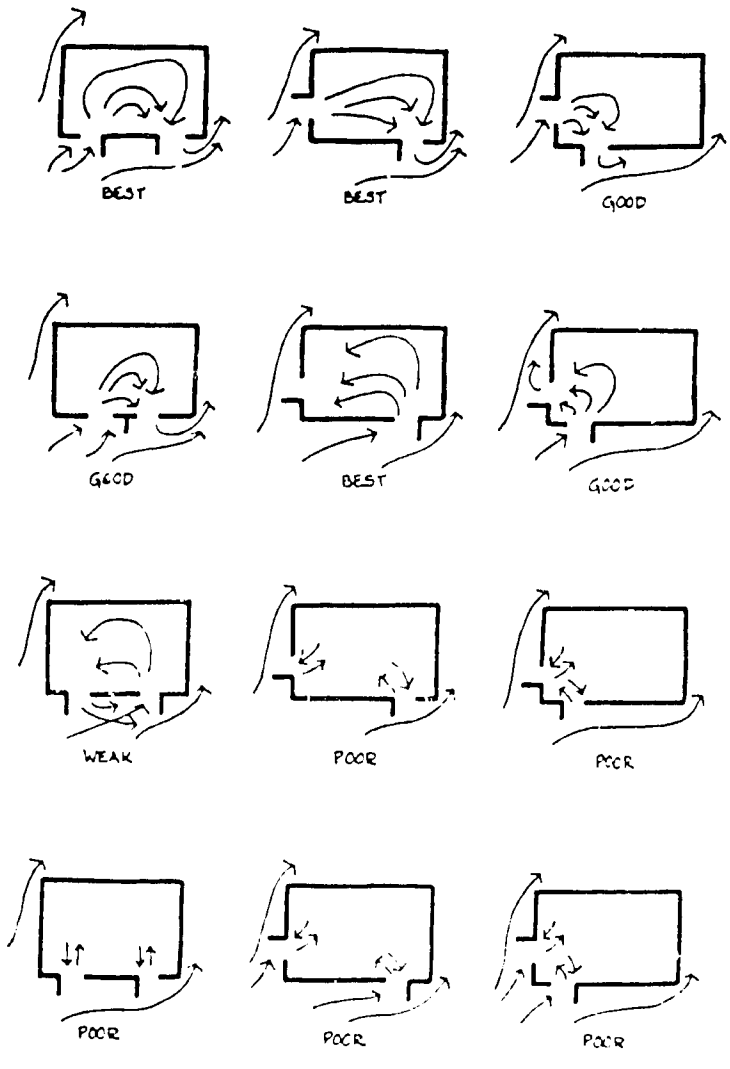
The wind does not always blow perpendicular to a building's windows, so projected windows or shading fins can either funnel the breeze into a window or deflect it away. Standard, two-pane, casement window patterns available in Botswana are hinged on the outside frame, which creates two wind-deflecting fins when both sides are opened. This does not seriously reduce ventilation if the room has cross-ventilation since the pressure differential between the building's windward and leeward sides will draw air through the window anyway. However, if the room has only one window, as will often be the case, and its door to the rest of the house is closed, cross-ventilation will effectively be stopped. Vents above the door (with a much larger free area than an air-brick) could maintain cross-ventilation, but at the cost of acoustic privacy. Anotner solution would be to hinge the openable windowpanes on the inner frame of the window, thus moving the "fin" to the center of the window opening (see Figure 3). This would have the effect of generating a pressure differential between the window's two open sides, thus drawing air into the room through the upwind opening and exhausting it through the downwind one. Figure 4 (on the following page) illustrates more elaborate versions of the same concept that employ wing-walls placed adjacent to the windows to produce the same effect.

Figure 3. Effect of Center-Hinged Windowpanes on Air Flow



Wing-walls can also be used to substantially increase air velocity through windows on adjacent walls beyond that provided by the building's shape alone. For instance, given a breeze approaching the corner of a house at a 45^{0} angle, the air velocity through the home can be increased by 25 percent if wing-walls are properly located (see the examples labeled "good" in Figure 4). However, for basic housing, the addition of masonry fins or wing-walls, which do not also serve some structural purpose or form the walls of a shed, is likely to be more costly relative to the benefits gained than some other improvements. For this reason, it

Figure 4. Use of Wing-Walls



(Source: Florida Solar Energy Center)

is recommended that BHC pay special attention to selecting windows for each orientation of the standard plans so that the open casement can act like a wing-wall. In this regard, Mr. Tones Mjier, who is working with the BRET project, has discussed the production of center-hinged windows with a supplier in Gaborone. Reportedly, that manufacturer (and presumably others) is interested in adding such a window to its product line, if there is sufficient demand.

This company provided preliminary estimates of the unit cost increases for a variety of popular patterns:

- ND7 -- 27 percent additional cost per unit,
- D7H -- 25 percent additional cost per unit, and
- ND4, D4H, ND2 and D2H -- no added charge.

In all likelihood, a large order would reduce the cost increases for the patterns with two panes that both open (ND7 and D7H). The added cost of center-hinged windows appears to be low enough to justify serious consideration. Therefore, it is recommended that BHC make official inquiries of suppliers to determine more accurate cost figures and the number of suppliers that would respond to a tender for such windows.

IV. WINDOW SELECTION AND LOCATION

As already noted, the BHC's preliminary standard plan is well suited for cross-ventilation, provided that the occupants keep the interior doors open at night. If it is assumed that the doors are not left open reliably, some alterations in the schematic design are recommended. Modifications of the building's dimensions and the size and layout of the rooms was not considered, since there was not enough information about program and cost constraints to evaluate such alternatives. However, it does appear that three very small bedrooms are too cramped for this small house. Despite the usual size of families in New Naledi, the floor plan would probably be more comfortable with two bedrooms.

The windows and doors of the preliminary BHC plan were considered in relationship to two factors given the prevailing wind direction and the sun's path. First, the basic plan must be flexible enough to allow the front door to face any direction, since people apparently feel strongly about having the door of their home face the road. Second, BRET research on the thermal performance of buildings with uninsulated masonry walls indicates that in winter, the entire north wall acts as a solar collector. Hence, the addition of glazing on the north side to improve the solar heating performance of such houses is not nearly as effective as it is for insulated homes, but these windows do increase the structure's rate of heat loss.

Window design options were developed for four versions of the standard plan, with each intended to permit the orientation of the front door within 45^{o} of the cardinal directions. The recommended alterations of the standard plan for each of the four orientations are presented in the remainder of this section.

A. Front Door Facing West

If the front door of the plan is facing west (see Figure 5 on the next page), the following modifications are recommended:

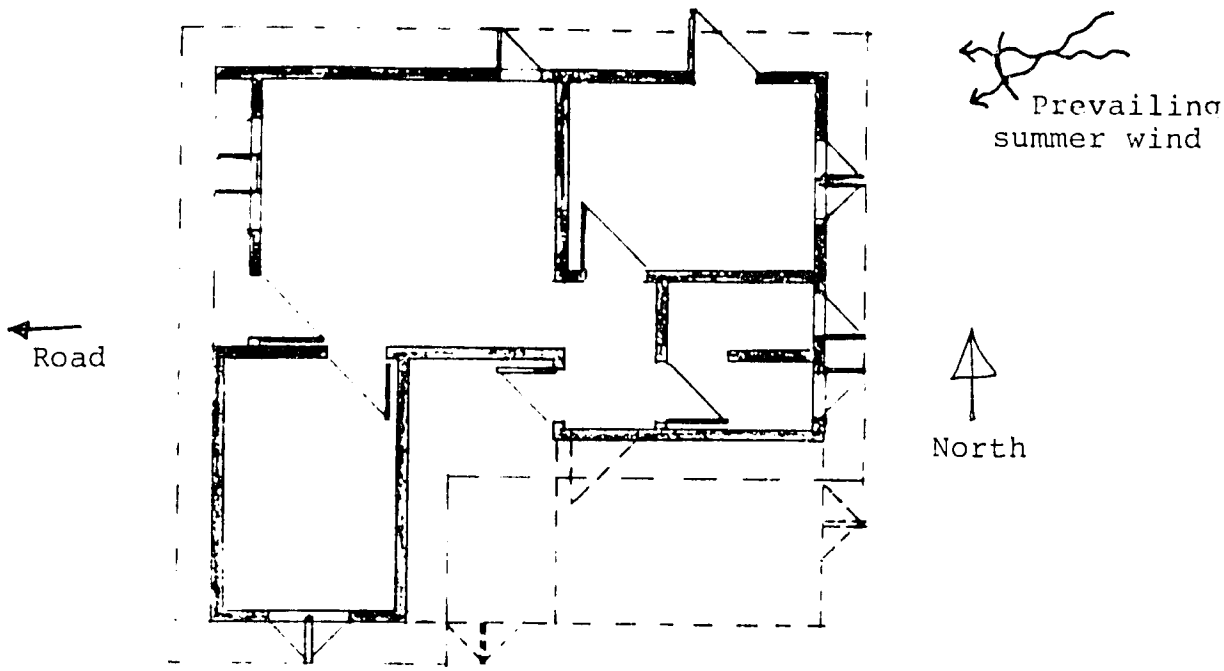
- the kitchen window should have a center hinge to increase the inlet air velocity from the prevailing wind;
- reverse the direction that the kitchen door opens--this way, if it is propped open, it can act as wing-wall for the prevailing breeze;
- add a window with a single openable pane to the northeast corner of the lounge to promote cross-ventilation--it should open as shown in Figure 5 to create a wing-wall effect;

- the main window in the lounge should be center-hinged to improve ventilation from directions other than that of the prevailing wind;

- all of the bedroom windows should be center-hinged to provide ventilation when the interior doors are closed; and

- the bathroom windows should open toward each other to produce a wing-wall effect.

Figure 5. Standard Plan with the Front Door Facing West



B. Front Door Facing North

The recommendations for this orientation (see Figure 6 on the following page) are similar to those for the plan with the door facing west, except that:

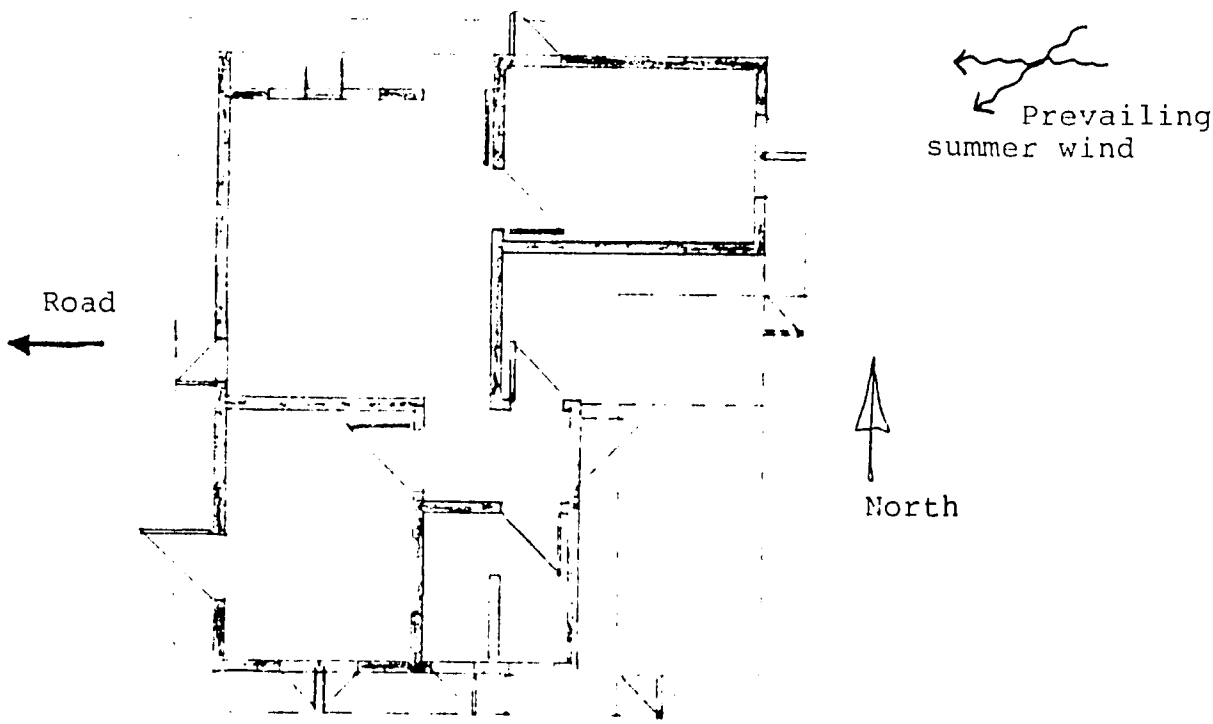
- the plan should be flipped so that the unfinished area faces southeast to provide a shaded outdoor area for summer afternoons;

- the addition of a second bedroom window that opens toward the west should be considered to increase ventilation through the house;

- the corner window in the lounge should open toward the south to improve the wing-wall effect; and

- consideration should be given to changing the kitchen door from steel to solid wood to reduce radiant heat gain on summer afternoons--a wood door would require substantially more maintenance since it faces west, but would be much more comfortable than a 55°C metal surface.

Figure 6. Standard Plan with the Front Door Facing North



C. Front Door Facing East

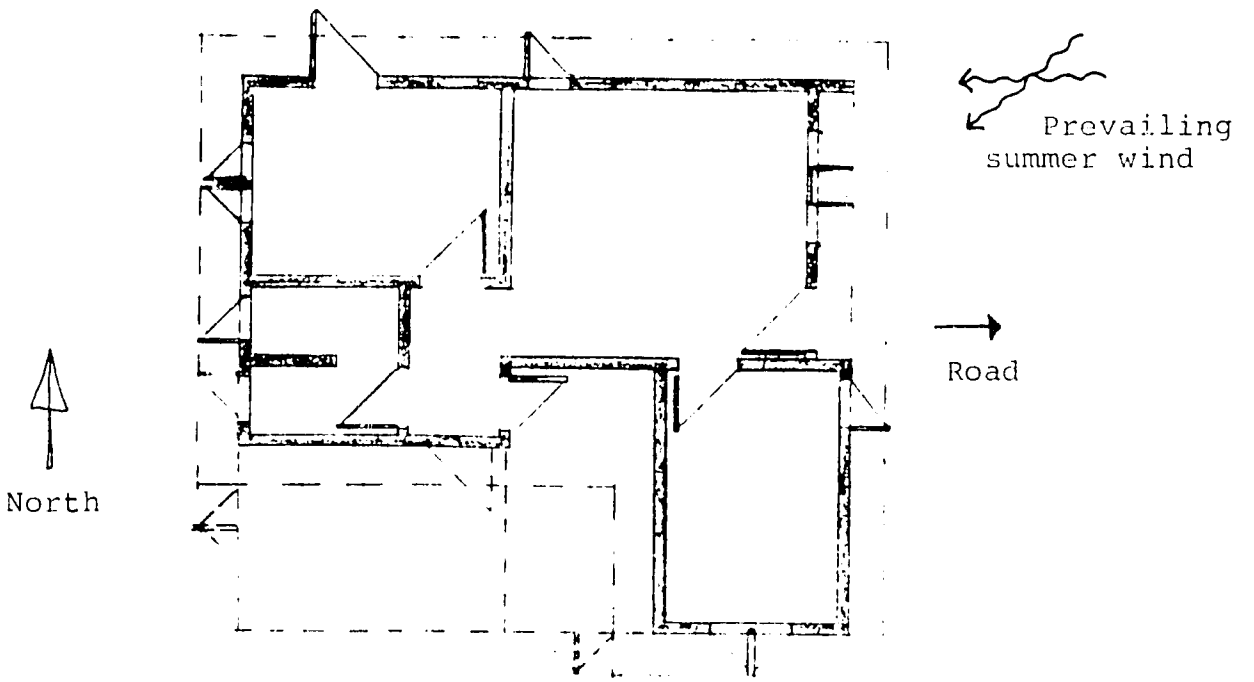
The alterations for this orientation of the standard BHC plan (see Figure 7 on the next page) are similar to those given for a front door facing west, except that:

- the plan should be flipped so that the unfinished area faces southwest to give some outdoor summer shade until mid to late afternoon;

- the corner window in the lounge and the kitchen door should both open toward the west to create a wing-wall effect; and

- the addition of a second bedroom window that opens toward the south for a wing-wall effect should be considered to move more air through house from the prevailing direction.

Figure 7. Standard Plan with the Front Door Facing East



D. Front Door Facing South

The modifications for this version of the preliminary standard plan (see Figure 8 on the following page) are similar to those for a west-facing front door, except that:

- the plan should be flipped so that the unfinished area faces northeast to provide a shaded outdoor space in afternoon;

- consideration should be given to making the kitchen door solid wood; and
- the addition of a second bedroom window that opens toward the west should be considered to improve cross-ventilation.

Figure 8. Standard Plan with the Front Door Facing South