IMPLEMENTATION PROPOSAL FOR OUÉLÉSSÉBOUGOU CLIC, MALI: USAID/MALI

Jennifer L. Borofka
Clare T. Caron
Kelly M. Kanz
Stefan A. Yanovsky
Camille George, PhD
John Abraham, PhD

School of Engineering
University of St. Thomas, Minnesota
May 2005
FINAL DESIGN DESCRIPTION

Ouéléssébougou CLIC Overview

The CLIC in Ouéléssébougou is a more common building layout for the Mali CLICs. It is located in a single room building which is much smaller than the Kangaba CLIC. The building is 4.5 meters by 9 meters. It contains a large computer room as well as a smaller office. There are 8 computers, a printer/copier, fax machine, radio, television, VCR, and DVD player. The roof is made of cement and has a border, 43 centimeters high, 21 centimeters thick, that surrounds the entire perimeter. The walls are 21 centimeters thick and made of stucco. Inside walls are 3 meters tall, floor to ceiling. Outside walls are 4 meters in height from the ground to the border around the roof. There are 5 widows, 109 centimeters wide, 112 centimeters tall. There are two doors, each 1.2 meters wide.
The entire town of Ouéléssébougou is run on a diesel generator. Most brown-outs occur during the hottest time of the day. At times, there is not enough power to turn on the computers. Three to four people use the internet for one to two hours per day. The computers are only turned on while they are in service. Most people come to use the photo copier.

The budget for the Ouéléssébougou pilot site is between $500 and $1000. Concentration on local products is recommended. Importation of fans is allowed. Powering with solar panels is unnecessary at this point. The design should be created with the dish in place. Only three of the CLICs in Mali have metal roofs, and the remaining have cement roofs.

**Modified Evaporative Cooler**

In an attempt to make the evaporative cooler more effective and cheaper to operate, modifications are needed. Since the evaporative coolers in Mali were not properly installed, they were not effective in cooling the rooms, and would eventually make the inside of the building so humid that it would be worse than without using the evaporative cooler. A permanent hookup to the geothermal cooling system that allowed access to the inside of the cooler to add water was designed. More efficient fans were found and mounted in the cooler to reduce power requirements. A passive system of soaking the pads was considered to lower power requirements, but rejected because the need for constant flowing water for the pads to be effective. Additionally alternative pads that could be locally manufactured were researched, but contacts in Mali working on the problem said that no alternative could be found.

In order to modify the evaporative cooler the inside of the evaporative cooler was stripped. Instructions on how to do this are attached. A sheet metal cover that surrounded the location of one of the side pads, and extended 2.5 inches away from the cooler was built. This box has a hole to connect to the geothermal cooling pipe and can be seen in Figure 3.
The hole is cut at a height that matches up with the geothermal pipe, coming in through the wall, when the cooler is resting on the floor. The pad was slid into place and this cover was pop riveted to the cooler, and the geothermal pipe was connected to the hole in the sheet metal. Both were sealed with caulk so the cooler would draw as much air as possible through the geothermal cooling system. In this design this pad would be the only pad in use.

The face on the opposite side is used to mount the fans. To mount the fans in this side, the pad would be removed and a piece of sheet metal is attached in its place covering the entire opening. The sheet was attached using pop rivets and sealed airtight using caulk. The fans have a lip surrounding the cage that is used to hold the two pieces of the fan housing together using screws. To mount the fans inside the evaporative cooler, the holes for these screws were used. The sheet has two circular holes in it with diameters of 25.5 cm. The size of these holes matches the diameter of the fans, minus the lip of the cage, which is used to mount the fans. Holes were drilled in the sheet metal to match up with the holes for the screws in the housing. The fans were then mounted into the evaporative cooler using longer .3 cm screws. These fans were found to use 145 Watts together and still blow 240 CFM of air through a simulated geothermal pipe. This is a substantial decrease in power from the original fan (which used 303 Watts with the pump) and moved over twice as much air through the geothermal pipe as the original fan, which moved 105 CFM.
The face of the evaporative cooler that originally had the exhaust for the cooled air is used to mount the controls for the fans and pump. The on/off switch box was removed from the cooler. The wires for the original fan were removed, but the wires from the plug and to the pump are still used. An outlet with two sockets was attached to the top face of the on/off switch. The two fans are plugged into the outlet and the outlet is connected to the on/off switch that controls the fan. Any exposed electrical wire was covered using electrical tape. The box was mounted to the metal lip that used to be attached to the fan housing so that it is flush with the outer surface of the evaporative cooler. This face was then covered with a piece of sheet metal with an opening for the switch, attached with pop rivets, and sealed with caulk.
One of the panels remains removable to allow the users to add water to the cooler, and to allow for replacement of the pad if necessary. For this purpose the panel opposite the original evaporative cooler exhaust was designed to be removable. The bag of pad material was removed from its metal frame and a piece of sheet metal was cut that would cover all the openings on the frame. The sheet metal was attached with pop rivets and sealed airtight using caulk. The frame was then slid back into place. When in place this panel would restrict air flow enough to cause air to be drawn through the panel attached to the geothermal cooling system, but could be removed to allow a person to replace a pad from the inside of the cooler, and add water as needed. To make sure that the water did not leak out of the cooler a small piece of sheet metal was used to cover the opening on the bottom of the evaporative cooler. This sheet was also attached with pop rivets and sealed using caulk.

![Figure 6: Side Panel Removed](image)

**Evaporative Cooler Fan**

Since one of the goals of our project was to reduce the amount of energy consumed by the evaporative coolers that the CLIC’s currently possess, we looked at the components of the cooler to see what we could change. The two components that require energy are the water pump and the fan. The pump only required 29 Watts, but the fan needed 360 Watts to operate, so one of the possibilities was to replace the existing fan with a more power efficient one.

We wanted to reduce the power consumption without compromising much on the volumetric air flow rate. To test the air flow, we built a pipe out of sheet metal with an opening that was restricted enough to simulate the drop in pressure that our underground pipe in Mali would produce. This drop in pressure is due to the geometry of the pipe (i.e. friction due to the number of bends and length of the pipe), and is related to the dimensions of the pipe as shown in equation 1.1. We started with a 6” diameter pipe, and found the diameter of the restricted opening with the following calculations:
\[
\Delta P_o = \frac{1}{2} \rho V_o^2 = (6k_b + f \frac{L}{D_d} + 1) \frac{1}{2} \rho V_d^2 \quad (1.1)
\]
\[
V_o^2 = V_d^2 \left( \frac{D_d}{D_o} \right)^4 \quad (1.2)
\]

Where \( \Delta P \) is the pressure drop, \( \rho \) is the air density, \( k_b = 0.8 \), \( f = 0.02 \), \( L \) is the length of the pipe in Mali, and \( D_d \) is the diameter. We can substitute (1.2) into (1.1) to get:
\[
\left( \frac{D_d}{D_o} \right)^4 = 6k_b + f \frac{L}{D_d} + 1 \quad (1.3)
\]

Knowing the diameter of the pipe in Mali, \( D_d = 20 \) cm or 7.87 in, we solved for the diameter of the restricted opening, \( D_o \), and found that it equaled 4.7 in. We then fit a cardboard piece with a 4.7 inch hole to the end of our test pipe. We attached the fan to the opposite end of the pipe and measured the air velocity through a small hole in the pipe near the fan. We used the air velocity to calculate the volumetric flow rate.

The first fan that we tested was a 6” diameter, 14 Watt, Air King brand fan that was rated to provide 1637 CFM. We found that this information was inaccurate however and also that the fan was very sensitive to the restricted air flow of the pipe. It only produced about 74 CFM through the pipe.

After looking at several other fans, we purchased a Honeywell fan for $14.99 that requires 57 Watts of power, and provides between 800 and 1000 CFM on its own. To ensure that we would get enough air flow through the pipe and the pad, we purchased two of these fans to install in the cooler. These were the most efficient fans that we could find for a low price that provided enough air flow for our application. We connected these two fans to the existing switch by simply adding an outlet inside the cooler where the two fans would remain plugged in and turned to the on position. We then wired the outlet to the outer switch so that when the switch was turned on, both fans would be turned on high.

**Geothermal Piping**

For the original testing in Mali, PVC piping was used as the ground piping for the geothermal cooling. While in Mali, the group researched additional materials to supplement the imported and costly PVC piping. Clay pottery piping was found to be a viable replacement material for the geothermal ground piping. Currently, these clay pipes are manufactured and used in Mali as rain gutters on housing. The decision to implement this material for the underground piping is based off of several factors. First, several producers manufacture the current clay rain gutters locally. The manufacturers are easily able to custom make the piping to the specific diameters, thicknesses and piece.
sizes necessary. Contacts in Bamako cited an estimate of $15 to $20 for a 20 cm diameter, 50 cm length piece of piping. Clay pottery is also more environmentally friendly and will biodegrade with time.

![Geothermal Piping Design](image)

**Figure 7: Geothermal Piping Design**

The clay piping also possesses technical benefits over some manmade material, such as PVC. For instance, the thermal conductivity, the rate at which heat flows through a material, is approximately five times greater for clay pottery versus PVC. A higher rate of conduction or heat flow is preferred in this situation since it is desired that the material will easily transfer the heat of the warmer air to the cooler surrounding earth, thus cooling the passing air.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity, ( k ) (W / m-K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>0.19</td>
</tr>
<tr>
<td>Fired Clay</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Table 1: Thermal Conductivity Values for Materials**

**Placement Location of Geothermal Piping and Evaporative Cooler**

The greatest factor in determining the location for the placement of the geothermal piping is the movements of the sun. In order to insure the coolest ground temperatures available, the optimal location for the piping is situated on the east side of the CLIC building. This conclusion was reached through researching the sun’s daily and yearly
paths at Bamako’s latitude using an applet model of the sun’s path sponsored by the Australian National University.

At 12.34° N, the sun’s path travels for eight months of the year, September to April, in the southern hemisphere. This is known as the dry season in Mali. For the remaining four months, May through August, also known as the wet season, the sun travels in the northern hemisphere. Therefore, the southern wall of the CLIC receives exposure from the sun for eight months and shade for four months. The opposite is true for the northern wall.

![Figure 8: Sun's Daily Course in July (left) and in January (right)](image)

In addition to traveling between the southern and northern hemispheres throughout the year, the sun travels daily from the eastern hemisphere to the western hemisphere. This daily movement has the greatest effect upon the placement location of the geothermal piping. The eastern ground and side of the building experience the morning sun during the coolest daylight period. During the afternoon, the hottest period of the day, the eastern ground and wall are located in the shade while the western ground and wall are exposed.

![Figure 9: Sun's Daily Course and Noted Shading at 9 am (left) and 3 pm (right) during September](image)
Therefore, the ideal ground location for the geothermal piping is on the northeastern side of the CLIC. Shading is realized throughout the day in this location during the dry season, the time period being addressed in this project. In addition, the eastern portion receives shading during the afternoon, the hottest period of the day. For the pilot site, the ground east of the building is free of landscape. Additionally, this is the best site for the placement of the evaporative cooler in the Ouéléssébougou CLIC. The eastern wall is uninterrupted, lacking windows or technical equipment.

![CLIC Specs](image)

**Figure 10: Building Diagram for Ouéléssébougou CLIC**

**Shading Barrier**

The shading design for the Ouéléssébougou CLIC does not include shading of the roof since it has a single cement roof. However, shading of the doors and windows is an option that could be used to block much of the solar radiation. The shading material is light colored cotton, which is easily found in Mali. The material is sewn around two curtain rods located at the top and bottom of each window, shown in Figure 16. The curtain rods are fastened to the outside of the building using hooks and screws, commonly used with all curtain rods in Mali. Prior to sewing, the material for each window measures 138 centimeters in height by 130 centimeters in width. The shading design for the doors is very similar to that of the windows. However, rather than the curtain rods hanging on the building, they will be placed on the top and bottom of each door. There are two doors in the Ouéléssébougou CLIC; however one is a double door. Prior to sewing, the material for the single door measures 229 centimeters in height by 118 centimeters in width. The material for the each of the double doors measures 229 centimeters in height by 59 centimeters in width. The total material used is 14.4 square meters. Depending on the width of the fabric used, the material may need to be pieced together. An 8 centimeter seam will be sewn on both the top and bottom of each piece of fabric in order to insert the curtain rod. Since the windows already have curtains on the
inside of the building, shading on the outside may not provide a significant difference, therefore shading may or may not be used on the Ouéléssébougou CLIC.

Figure 11: Window Shading Barrier
Attachment 1: Instructions for connecting the outlet to the evaporative cooler switch

1. Original switch has three connections:

2. Using 18-gauge wire for all connections.

3. Connect the hot wire on the outlet to the high connector on the switch.

4. Connect the white wire on the outlet to the neutral wires of the pump and switch.

5. Connect the hot wire of the power cord to the hot connector on the switch.

6. The low connector on the switch is not used.

7. Connect all the ground wires of the power cord, pump, and outlet together and to the metal casing of the switch.

8. The outlet remains on the inside of the evaporative cooler with both fans plugged in and set to high.

9. When the switch is turned to high, both fans are turned on. When the switch is turned to off or low, both fans are turned off.

10. The pump remains connected to the switch as it was originally.
Attachment 2: Instructions for Modifying the Evaporative Cooler

1) Remove the four screws on the face plate and then remove the face plate

2) Remove the two screws holding the panel in place and open the panel and open panel
3) Remove the green ground screw and cut the wires attached to the black box

4) Remove all wire connectors and separate the wires
5) Disconnect all the wires from the switches and remove clips attached to wire clusters

6) Open side panel

7) Pull wires into main housing
8) Remove 4 screws holding fan motor in place and remove fan

9) Remove 12 screws holding exhaust port in place and take off port

12) Pry motor housing away from evaporative cooler frame
13) Attach the outlet to the top of the switch housing. Connect the wires to the switch housing as described in the wiring section. Drill pilot holes and mount the switch housing to the left lip of exhaust opening with the face of the switch flush with the evaporative cooler.

14) Remove all panels from the evaporative cooler except for the one on the right side (when facing the exhaust port). Remove the metal bar, cage and panel from the panels. Cut a piece of sheet metal 58cm X 43 cm. Line the edge of the panel with caulk. Place the panel over the vents on the metal evaporative cooler pad frame and allow the caulk to dry (4 hours). Drill holes 1.25 cm in from the edge the same size as the rivets (1cm recommended) and rivet the sheet metal to the panel, three on the short sides, four on the long sides, and line the edges with caulk to ensure an air tight seal.
15) Cut piece of sheet metal that is 28cm X 38cm and a hole 7 cm in from the left and top that is 3.5cm x 11 cm (big enough to allow the access to the switch) with a notch in the bottom for the power cord. Line the edges of the sheet metal with caulk and place it over the exhaust port with the hole over the switch and the power cord coming out of the hole and let the caulk dry. Drill holes 1.25 cm from the edge, rivet the panel to the evaporative cooler frame (3 on the short side 4 one the long) and line the edges of the sheet metal with caulk.
16) Cut a piece of sheet metal to the dimensions shown. Fold it in on the red dotted line and out on the green dotted line (90 degrees). Cut a 20cm diameter hole in the panel that will match up with the geothermal pipe when attached to the cooler and the cooler is resting on the floor.
17) Line the edges of the sheet metal box with caulk and place it over the installed pad and frame (the right side when facing the exhaust) and allow the caulk to dry. Drill holes 1.25 cm from the edge, rivet the box to the evaporative cooler (3 on the short side 4 on the long side) and seal all edges and opening with caulk.

18) Cut a piece of sheet metal 48.5cm x 56 cm. Cut two 25 cm holes in the sheet metal, one centered 15.5 cm from the top and 15.5 cm from the right, and one 15.5 cm from the bottom and 15.5 cm from the left. Separate the front cage from the fan by removing the screws. Drill four .3 cm holes in the sheet metal around the 25 cm holes that match up with the holes on the lip of the cage. Line the edge of the sheet metal with caulk, cover the face of the left panel (when looking at the exhaust) with the sheet metal and allow the caulk to dry. Drill holes and rivet the sheet metal to the evaporative cooler (three on the short sides four on the long) and seal the edges with caulk. Mount the fans on the sheet metal, with the front cage on the outside and a rear cage and the fan on the inside using longer .3 cm screws through the holes on cages and the holes in the metal. Plug the fans into the outlet.

19) Cover the hole in the bottom with a small piece of sheet metal and seal it with caulk.
20) Remove the black plastic spout from the top inside of the evaporative cooler. Fill the two holes of the spout that are over the sides without pads. Allow caulk to dry and replace the spout to the top inside of the evaporative cooler.

21) Replace the panel that is covered in sheet metal to the rear side of the evaporative cooler (when facing the exhaust).