Zero Energy Cooling Chamber and Zero Energy Cooling System in Building Wall

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Abstract: **Zero Energy Cooling Chamber (ZECC) is a cooling chamber in which the temperature inside the chamber is 10-15 degree Celsius lower than the outside ambient temperature. And also it can maintain 90% of relative humidity. ZECC is working based on the principle of evaporative cooling. That is the evaporation of water can create a cooling effect. The chamber is an above- ground double-walled structure made up of bricks. The cavity of the double wall is filled with riverbed sand. The rise in relative humidity (90% or more) and fall in temperature (10-15 Degree Celsius) from the ambient condition can be achieved by watering the chamber twice in a day. Performance evaluation of cool chambers at different locations of the country was found to be satisfactory for short term storage. Spoilage of fresh fruits and vegetables was serious problem in tropical countries. Cool storage can prong the life of produce. The study deals with the construction of ZECC with modification in its design and construction and temperature measuring tests were conducted on it to determine the capacity of structure to lower the temperature. The concept of application of evaporative cooling principle to building wall to create natural cooling is also discussed.**

I. INTRODUCTION

Energy is integral to almost every aspect of modern life. It is used for transportation, communication, industrial and domestic purposes like heating, cooling, cooking, lighting as well as other appliances Both economic growth and technological advancement of a country depends on it. Cooling is required to maintain the freshness of fruit and vegetables during storage. Conventional vapor compression cooling systems that use chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) contribute to ozone depletion and global warming. The International Institute of Refrigeration in Paris (IIF/IIR) has estimated that approximately 15% of all the electricity produced in the world is employed for refrigeration and air conditioning processes of various kinds, and the energy consumption for air conditioning systems has recently been estimated at 45% for all households and commercial buildings. Therefore, an eco-friendly cooling system is required to reduce the emissions of harmful gases.

Spoilage of fresh fruits and vegetables is a serious problem in tropical countries. Cool storage can prolong the life of fresh produce, but refrigeration equipment is expensive to buy, expensive to run, and expensive to maintain. There is, however, a practical, low-cost alternative for on-farm fruit and vegetable storage which employs the cooling power of evaporation. Zero energy cool chambers stay 10- 15° C cooler than the outside temperature and maintain about 90 percent relative humidity. And they are easy to build out of locally available materials, such as brick, sand, bamboo, straw, and gunny bags.

The study deals with the application of the principle of evaporative cooling to the building to create natural cooling inside the building and conducting experimental studies on ZECC by using alternative materials as cooling medium.

II. ZERO ENERGY COOLING CHAMBER

As it is named, there is no need for electrical and mechanical energy for the functioning of this storage structure. Cooling chambers works on the principle of evaporative cooling. Evaporative cooling is the reduction in temperature resulting from the evaporation of a liquid, which removes latent heat from the surface from which evaporation takes place. This process is employed in industrial and domestic cooling systems, and is also the physical basis of sweating.

This structure is erupted over a single row of brick floor and double layer of brick wall in sides with an interspace of 7.5cm filled with river sand. The top of the storage space is covered with coconut leaves or gunny cloth in a bamboo structure. The cool chamber is saturated with water for first time thereafter sprinkling of water once in the morning and once in the evening is enough to maintain the required temperature and humidity. These chambers helps to maintain a very high humidity of 95% throughout the year and it also reduce the temperature of the chamber even during summer months. These chambers are ideal for storage for a short period and helpful for small and marginal farmers to store their produce. Fig. 1 and 2 show photographs of typical ZECC to store vegetables.

Fig. 1. Zero Energy Cooling Chamber

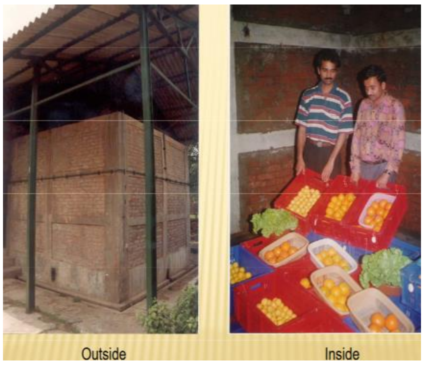

Fig. 2. Commercial scale Cooling Chamber

III. DESIGNED NEW ZECC

A. Materials

The following materials are used to construct a laboratory model of ZECC.

- Bricks
- Composite mixture of soil, wood powder and coco peat
- Charcoal
- PVC pipes
- Bamboo shoot and coconut leaf
- Clay mortar

B. Construction Procedure

The following procedure is adopted to construct a laboratory model of ZECC.

- An upland having a nearby source of water supply is selected.
- Floor of size 72cm×72cm is made.
- The double wall is erected at a height of 80cm having a cavity of 11cm.
- PVC pipes (5cm diameter) are installed vertically in the cavity in which the distance between adjacent pipes are 40cm.
- Before the installation of PVC pipes, perforations are made on its surface and the perforations should not face the inner and outer wall.
- The bottom portion of the PVC pipes is closed. Fig 3 and 4 show the plan and sectional view of ZECC constructed for the study.
- The cavity layer is filled layer by layer using the following materials,

TABLE I. EVAPORATIVE MEDIUM LAYERS

Layer	Material
First layer (bottom layer)	A composite material consist of soil, coco peat and wood powder (20cm)
Second layer	Charcoal (5cm)
Third layer	Composite material consist of soil, coco peat and wood powder (20cm)
Fourth layer	Charcoal (5cm)
Fifth layer	Composite material consist soil, coco peat and wood powder (20cm)

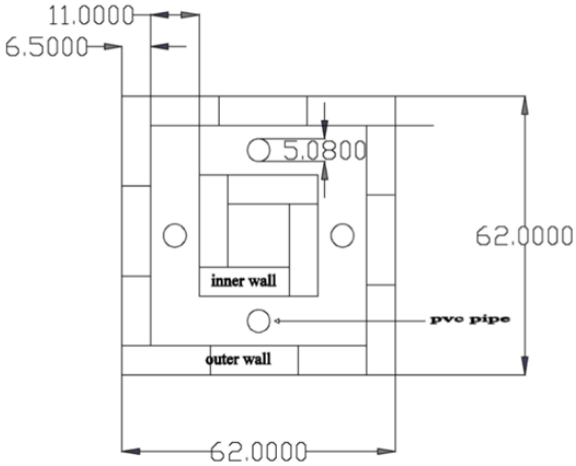

Fig. 2. Designed ZECC top view (Dimensions in cm)

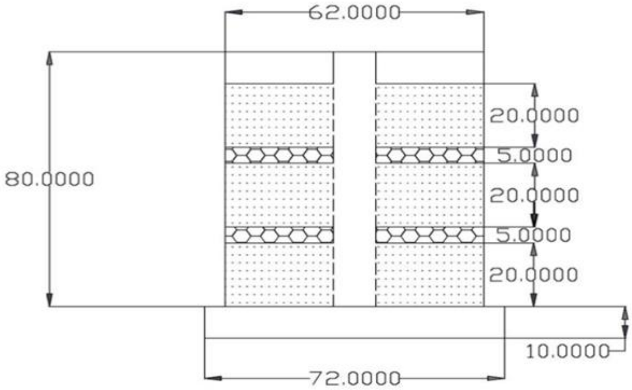

Fig. 4. Designed ZECC sectional view (Dimensions in cm)

IV. WORKING OF SYSTEM

- Sufficient quantity of water is supplied to the evaporating medium of ZECC and fill water in the PVC pipes.
- Close the ZECC by using top cover.
- When the temperature of surrounding area increases due to sunlight the evaporation of water takes place in ZECC as a result of it a cooling effect will be created, thereby the temperature inside the chamber

will be reduced and also maintain the relative humidity.

- The PVC pipes are installed for the proper distribution of water throughout the evaporating medium. Water distribute to the evaporating medium through the perforations made on the PVC pipes. The PVC pipes should be free from perforations at the layers of charcoal. The use of charcoal helps to increase the evaporation rate.

V. Composite Material for Building Wall

Rock wool, coco coir, clay pebbles and soil all have different levels of water holding capacity. Water holding capacity is the ability of the material to hold its own or added water during the application of force, pressure, centrifugation or heating.

Water holding capacity (%) = [(volume of water added to the sample – volume of water run down through the sample) / (volume of water added to the sample)] ×100. Water holding capacities of composite mixes consisting of soil, wood powder and coco peat in various proportions are found out and are shown in Table 2. Apparatus used are Funnel, funnel stand, filter paper, beaker, graduated cylinder, weighting machine and following procedure is adopted to find the property.

- Place 6 funnels in to the funnel supports. Place a beaker under the lower end of the each funnel.
- Fold the filter paper to form cones. Insert them in the funnel.
- Make 50g of samples by mixing soil, wood powder and coco peat by different composition, from this take 15g for the test. Add 15g of samples to each funnel, in which the 6 samples are of in different composition.
- Using a graduated cylinder, measure 50 ml of water. Slowly pour the water in to the funnel with the sample. Don't allow the water to spill over the top of the filter paper.
- Measure the volume of water collected in each beaker which drains through the sample after 20 minutes.
- Do the experiment in three times.

TABLE II. WATER HOLDING CAPACITY

Sample	Soil (g)	Wood powder (g)	Coco peat (g)	Water for test (ml)	Water obtained at the beaker (ml)	Water holding capacity (%)	Average water holding capacity (%)
1	15 15 15	30 30 30	5 5 5	50 50 50	34 35 33	32 30 34	32
2	15 15 15	34 34 34	1 1 1	50 50 50	30 28 30	40 44 40	41.3
3	15 15 15	32 32 32	3 3 3	50 50 50	32 32 34	36 36 32	34.7
4	25 25 25	22 22 22	3 3 3	50 50 50	36 35 36	28 30 28	28.7
5	25 25 25	24 24 24	1 1 1	50 50 50	29 29 30	42 42 40	41.3
6	25 25 25	20 20 20	5 5 5	50 50 50	37 37 38	26 26 24	25.3

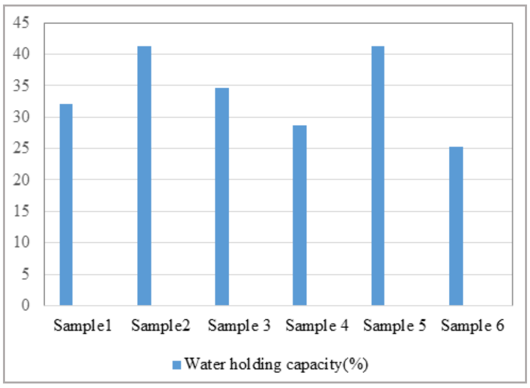

Fig. 5. Water holding capacity analysis

Among the 6 samples, sample 2 is selected for the work. Sample 2 has more water holding capacity compared to the other samples. And the soil to wood powder ratio is more which help to the percolation of water through the composite mix and also reduce its hardening during drying.

VI. Zero Energy Cooling Chamber Construction Stages

Stage 1 : Ground levelling

Ground is levelled by using soil as shown in Fig. 6.

Fig. 6. Levelling of ground

Stage 2 : Basement work

Basement and floor are constructed by using bricks after the leveling of ground as shown in Fig. 7.

Fig. 7. Basement work

Stage 3: Wall construction

Double brick wall is constructed by using clay mortar. 11 cm width of cavity is left between inner and outer brick wall. The wall is constructed up to 80 cm height then installed PVC pipes of 2 inch diameter and 75 cm height at the middle of cavity of each wall. Before the installation of the PVC pipes perforations of 0.5 inch diameter should be made on its surface and the perforations should not face inner and outer wall and bottom of PVC pipes should be closed. Center to center distance between the perforations is 5 cm and perforations should be absent at the charcoal layer zones. After the installation of PVC pipes as shown in Fig.8, filling the composite mix (20 cm) and charcoal (5 cm) as layer by layer is done and finished as shown in Fig. 9.

Fig. 8. Pipe installation and cavity filling

Stage 4: Top cover for Zero energy cool chamber

A top cover is provided for zero energy cooling chamber made of coconut leaf and bamboo shoots.

Fig. 9. Finished Zero Energy Cool Chamber

VII. Measured Temperature Values

A. Quantity of Water for the Working of ZECC

From the data obtained from water holding capacity test on sample 2;

The average water holding capacity of sample 2 = 41.3%

15g of sample can hold 20.7 ml of water.

1kg of sample will hold 1.38 liters of water.

Weight of sample required for the chamber = 31.1kg.

Maximum quantity of water in which 33.1kg of sample can hold= 33.1×1.38 = 45.67 liters.

By considering the safety of wall supply 60% of maximum quantity of water, that is approximately 28 liter water.

B. Temperature Measurement test on ZECC

The temperature inside and outside the chamber and at the room is measured by using Generic digital thermometer (Fig.10). Range of measurement Generic digital thermometer is 50° C to 70° C. The temperature values are shown in Table 3.

Fig. 10. Generic Digital Thermometer

VIII. RESULTS AND DISCUSSIONS

The temperature measured inside, outside and at the room during different time intervals in different days. The temperature readings are taken after the watering of Zero energy cool chamber. That is 28 liter water is supplied to Zero energy cool chamber on 08/04/19. The outside temperature is varying with time and intensity of sunlight but the inside temperature remains nearly same at all the time of temperature measurement in a day. The day to day variation in temperature inside the chamber is considerably low. From Fig. 11, it is clear that the temperature inside the chamber slightly increases with day after the watering. It is better to done watering once in a week for good working of chamber.

From the experimental study conducted on Zero energy cool chamber, it is clear that Zero energy cool chamber can reduce the inside temperature 10° C to 15° C lower than the outside temperature (Table 3). And also it can maintain a constant temperature inside the chamber.

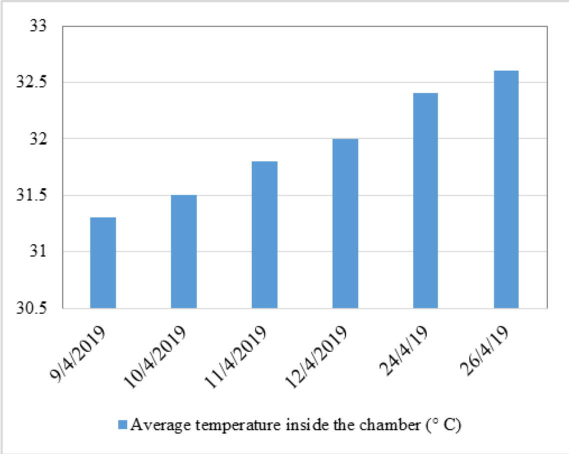

Fig. 11. Average temperature inside the chamber

TABLE 3. MEASURED TEMPERATURE VALUES

Date	Time interval	Temperature inside the chamber (° C)	Temperature outside the chamber (° C)	Room temperature (° C)	Average temperature inside the chamber (° C)
09/04/19	9:30am to 10am 1:15pm to 1:45pm 3pm to 3:30pm	31.3 31.3 31.3	36 45.2 35.4	33.2 37.4 33.2	31.3
10/04/19	9:30am to 10am 1:15pm to 1:45pm 3pm to 3:30pm	31.5 31.5 31.5	35.8 46.4 36	33 37.6 33.1	31.5
11/04/19	9:30am to 10am 1:15pm to 1:45pm 3pm to 3:30pm	31.7 31.9 31.9	36.1 44 35	33.7 36.8 33.4	31.8
12/04/19	9:30am to 10am 1:15pm to 1:45pm 3pm to 3:30pm	31.9 32.1 32.2	34 39.4 35.2	33.4 36.2 33.1	32
24/04/19	9:30am to 10am 1:15pm to 1:45pm 3pm to 3:30pm	32.4 32.5 32.5	36.2 38.4 35.1	34.5 36.2 35.1	32.4
26/04/19	12pm to 12:30pm 3:15pm to 3:45pm	32.6 32.6	38.6 34.9	36.3 33.1	32.6

IX. EVAPORATIVE COOLING PRINCIPLE TO BUILDING WALL

The aim of this study is to apply the evaporative cooling principle to building wall to create natural cooling effect inside the building and to encourage the sustainable building construction. The building wall can be constructed as same that of zero energy cool chamber wall by making some changes in design and applying some new evaporative cooling technologies.

A. *Evaporative Cooling Building*

Evaporative cooler building of 215.3 square feet floor area and 4.25 m height is designed and proposed as an example (Fig. 12). The Evaporative cooler building is working under the principle of evaporative cooling. The building should be constructed on upland having nearby source of water.

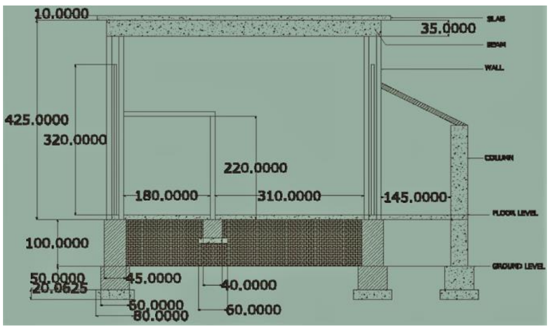

Fig. 12c. Building section A-A

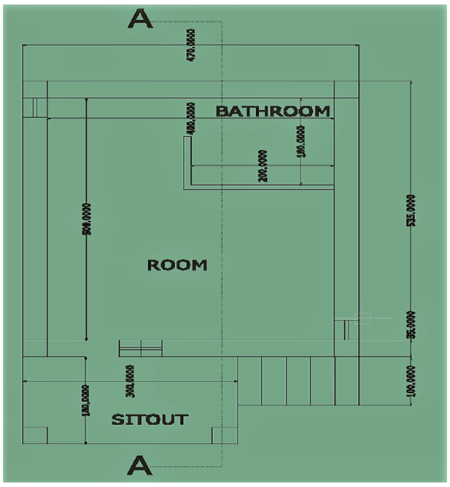

Fig. 12a. Plan of the building

Fig. 12b. Elevation of the building

B. Wall construction

Construct RCC columns of cross section 35cm × 35cm and 3.9m height at the four corners of the building. The columns are constructed to take load from the beam which carry load from roof. The columns will helps to make the walls free from carrying the load. Construct double brick wall and left a cavity of width 15cm between the inner and outer wall up to a height of 3.9m. Place PVC pipes of diameter 2 inches and height 3.2m vertically in the cavity in which the center to center distance between the adjacent PVC pipes are 40cm. the bottom portion of each PVC pipes should be closed before its installation. The remaining portion of the cavity is filled with composite mix (soil, wood powder, and coco peat) as alternate layers as shown in Table 4.

TABLE IV. LAYERS OF BUILDING WALL

1st layer	Composite mix (80cm)
2nd layer	Charcoal (20cm)
3rd layer	Composite mix (80cm)
4th layer	Charcoal (20cm)
5th layer	Composite mix (80cm)

C. Water supply system

Water is supplying from the water tank placed on the top of building. Water flows down under gravity. A pipe of diameter 1.5 inch carries water from the tank to the rectangular pipe system installed in the cavity of double wall at a height of 3.4m from the floor level. The branching pipes connected to rectangular pipe system carry water to the main PVC pipes, which is placed vertically in the cavity of wall. The center to center distance between the branching pipes are 40cm. The flow of water to the pipe system can be controlled by providing valve system. The sectional view of water supply system has showed in Fig.13.

Holes of diameter 0.5 inch should be made on the PVC pipes on both sides at the zone of composite mix and the center to center distance between the holes is 16cm. the holes should not face into inner and outer wall.

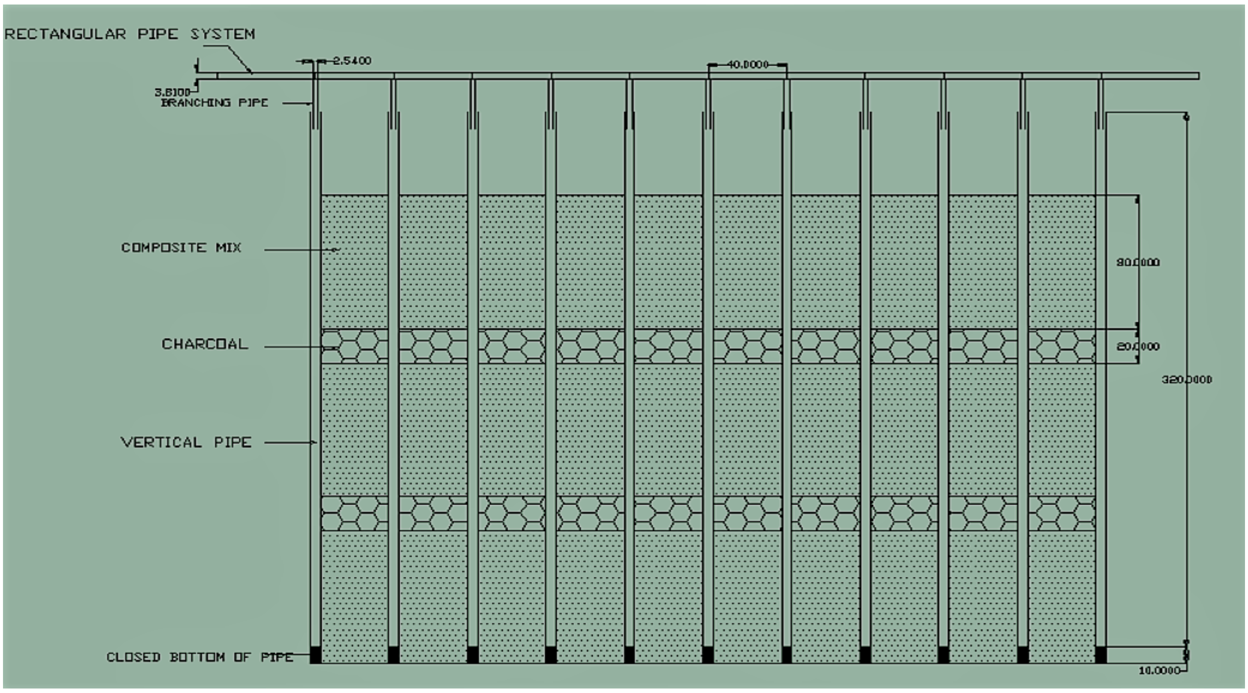

Fig. 13. Layers of wall

X. Interpretation of Results

From the experimental investigation carried out, it was observed that the zero energy cool chamber reduced the inside temperature 10 to 15 degree Celsius lower than the outside temperature.

Analyzed the inside and outside temperature of the cool chamber after the first watering. It is observed that the temperature is in between 31 to 32 degree Celsius in the first week of measurement. The temperature inside the chamber slightly increases with days until the next watering. After the next watering the inside temperature falls down to initial values.

Generally sand is used as evaporative medium. In our experiment a composite mixture (soil, wood powder and coco peat) and charcoal is used as evaporative medium. The water holding capacity of composite mixture is higher than that of sand and it is cheaper. The efficiency of each chamber is same in reducing the inside temperature. Any other materials can be used as evaporative medium for further studies.

XI. Conclusions

Based on the experimental investigation conducted on zero energy cool chamber the following conclusions were drawn.

- The constructed zero energy cool chamber reduced the inside temperature 10 to 15 degree Celsius lower than the outside temperature.
- The inside temperature in the cool chamber remains nearly constant when the outside temperature varies with time and intensity of the sun light.
- The day today variation in temperature inside the chamber is considerably low.
- The temperature inside the chamber slightly increases with days after the watering.
- It is better to watering once in a weak for good working of chamber.
- Around 28 liter water is supplied for the cooling of chamber.
- Designed zero energy cool building of dimension

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