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FORM DEVELOPMENT OF CLAY MODULE FOR OPTIMIZE EVAPORATIVE COOLING WITH WIND FLOW

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Abstract

Evaporative cooling is one of most important passive cooling systems which is used since ancient times. As a passive cooling system direct evaporative cooling is the basic method. There are most of evidences in use of wetted clay material in evaporative cooling method. Mashrabya and wetted clay conduits used in wind towers are the proofs on this passive cooling system. Clay exhibit excellent properties on evaporative cooling as a porous material. Porous ceramics exhibit properties such as high permeability, low bulk density, high surface area, and low thermal conductivity. There are more possibilities on enhancing the evaporative cooling. The research focused on the form development which multiplying the cooling efficiency. Provide a large surface area to air touching, access to easy air flowing and making a speed for air flow are the archived aims which are multiplying the cooling effect in the research. Various forms have tested in the research with the smoke flows as air flow and identified best form. And the form has developed with the literature which is about clay form development. Close ended form of clay has identified as more efficient on the evaporative cooling. This basic form has a possibility to develop as a sustainable product design for people. The formed product changes the situation of Natural wind or created wind flow as a chilled air by the evaporative cooling in zero energy. In a warming world, heating energy demands should reduce while cooling energy demands rise. Further investigations of the form development respond for this circumstance as a design solution.

Keywords: *Form Development, Air stream, evaporative cooling, passive technique*

1. Introduction

In a warming world, heating energy demands should reduce while cooling energy demands rise. (Mishra, Loomans, & Hensen, 2016). Cooling demand of the world has increased on the circumstance of global warming. Evaporative cooling is one of prevalent method in the world as a passive cooling technique. Evaporative cooling is a heat and mass transfer process that uses water evaporation for air cooling, in which large amount of heat is transferred from air to water, and consequently the air temperature decreases. (O Amer, Boukhanouf, & Ibrahim, 2015)

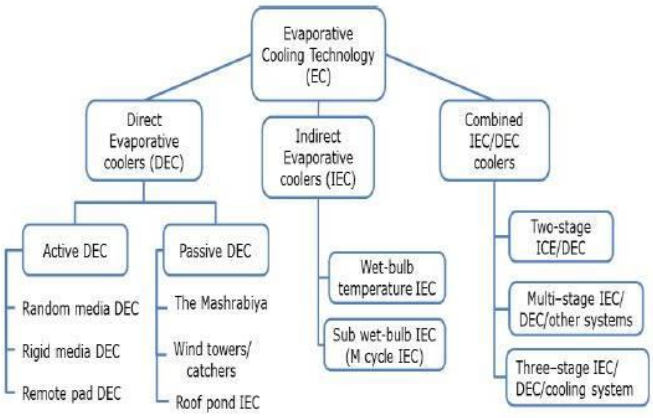

Figure 1, classification of evaporative cooling
(*Source; Ouf, R.Ibrahim, H. G.Amer, O.Boukhan,2015*)

In hot climates, ancient Greeks and Babylonians were used wet mats overhanging doors and windowsand water filled clay jars on balconies to capture a cool breeze into the living spaces.(Omar Amer, 2017) They used simple methods to cool their inner environment depend on the evaporative cooling basics. Mashrabya is a traditional Islamic architectural element which is used as a cooling technique. It is wooden screens/windows provides shad, protection from the sun and allows breezes to flow through into the building for cooling purpose. Mashrabiya system coupled with porous water-jugs to provide evaporative cooling effect for a dwelling and cooling water inside jugs for water drinking.(O Amer et al., 2015)

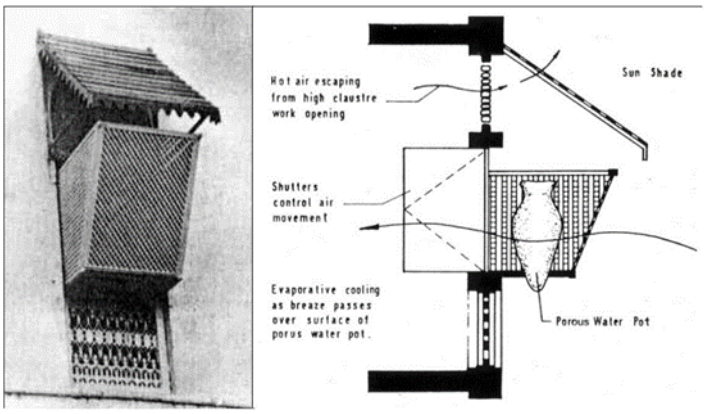

Figure 2, Mashrabya (*Source; Ouf, R.Ibrahim, H. G.Amer, O.Boukhan,2015*)

Wind tower is a example in usage of direct evaporative cooling technique. Wind towers with wetted columns consist of unglazed ceramic conduits stacked lengthwise on top of one another or thick dampers. Water is uniformly sprayed on the surface of the column, dampening the entire column. (Dehghani-Sanij, Soltani, & Raahemifar, 2015) And also air spraying systems and water filled clay jars have used in wind catchers to cool the air-stream

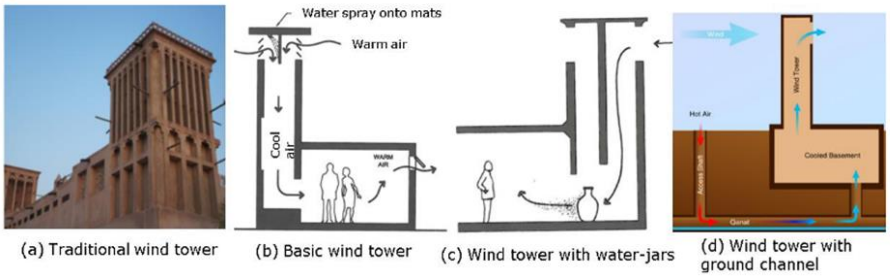

Figure 3, Wind tower (*Source; O Amer et al., 2015*)

These passive direct evaporative cooling systems were mostly used in regions which was in cooling demand. Properties of the clay material has maintained the capacity of evaporative cooling. In general, porous ceramics exhibit excellent mechanical properties, chemical and abrasion resistance, and thermal stability. Cooling is a function of porosity, configuration, and water supply pressure. A high surface area is preferred because the evaporative surface area is crucial to the evaporation rate. (Emdadi et al., 2016) Most of the ancient direct evaporative cooling applications emerge with the clay material property. Ancient designers mainly focused on the material quality but not on-air flowing space.

The research investigates the space which is covering by the air stream causes to evaporative cooling. Path of airstream defined by the research to enhance the cooling effect exclusive of clay material quality.

2. Methodology

The research mainly focused on the problem which is facing contemporary world. The literature review identifying the circumstance of global warming and Historic simple passive techniques used against the problem. Material quality and the usability of evaporative cooling technique investigates. Specific

requirements and elements of the passive direct evaporative cooling has identified by these preliminary studies and literature review. The study conducted on the space usage of airstream in the evaporative cooling application. In the form development stage various shapes has tested by the air streams. And finalize a better form according to the experiments and air stream obsevations to develop a new design on clay material for passive direct evaporative cooling.

3. Form Development.

3.1. PRELIMINARY STUDIES

Main Historic Applications of "Passive direct evaporative cooling" has used as preliminary studies in the research. Mashrabya and wind towers are the main passive direct evaporative cooling techniques according to O. Amer, R. Boukhanouf, and H. G. Ibrahim. These couple of building elements highly considered on the airstream. Air movement (velocity) influences the performance of an evaporative cooling system. Consequently, configurations that stimulate high air mass flow (velocity) and have large surface areas for seepage flows to navigate have high cooling rates. (Emdadi et al., 2016). The preliminary studies are deeply investigating the air movement on these elements and how the surface area influenced to cool the air stream.

3.1.1 Mashrabya

Mashrabya is a passive direct evaporative cooling technique which is used in ancient Islamic regions. It is some kind of natural ventilating system. They build a separate partition to arrive air stream to indoor with clay water jar. The air stream makes a contact with the outer surface of water jar when reach to inner enclosed space. It makes airstream cool through evaporative cooling technique. That is the basic theory of the mashrabya building integrated system.

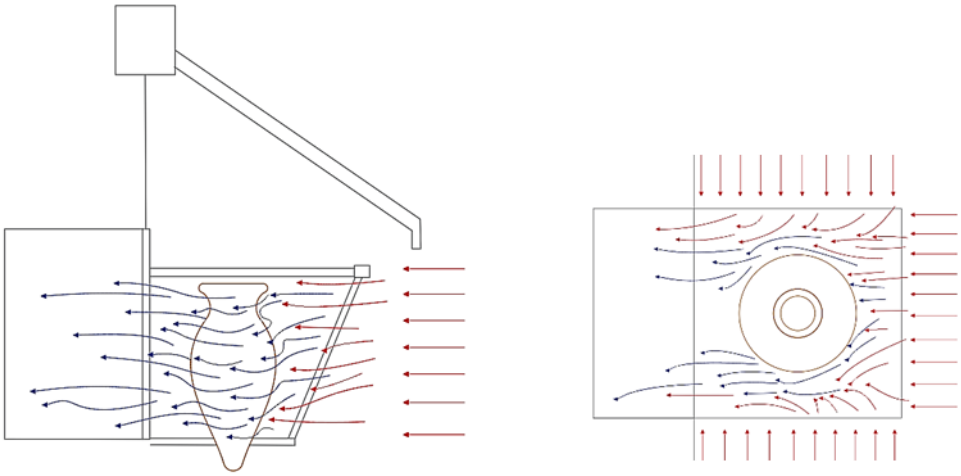

Figure 4, Airstream operation of Mashrabya (side view,top view)

The form of clay jar makes 360° contact with air stream. Although fully surface area opened to the air stream, only the nearest air stream makes coolness depend on the form. Open spherical form diverging path to the air stream. The form maintains the speed of air stream with spherical form. Divergent way which maintain the open spherical form is one of negative quality identified in the case study. It dissipates the air velocity without cooling.

3.1.2 Wind tower

The wind tower, also called wind catcher is a traditional Passive cooling technique of buildings, existed hundreds of years ago in the Middle East and Iran, known as "Burj al hawaa" the air tower. A capped tower with one face opening or multi-face openings at the top of tower, the tower is placed on the roof of a dwelling. Wind towers/catchers could be divided according airflow patterns inside the tower into: downward airflow towers and upward airflow towers. (O. Amer, Boukhanouf, & Ibrahim, 2015). Wind towers are the building elements to make an airstream path to inner enclosed space. Some of them are modified with evaporative cooling technique to make the wind cool.

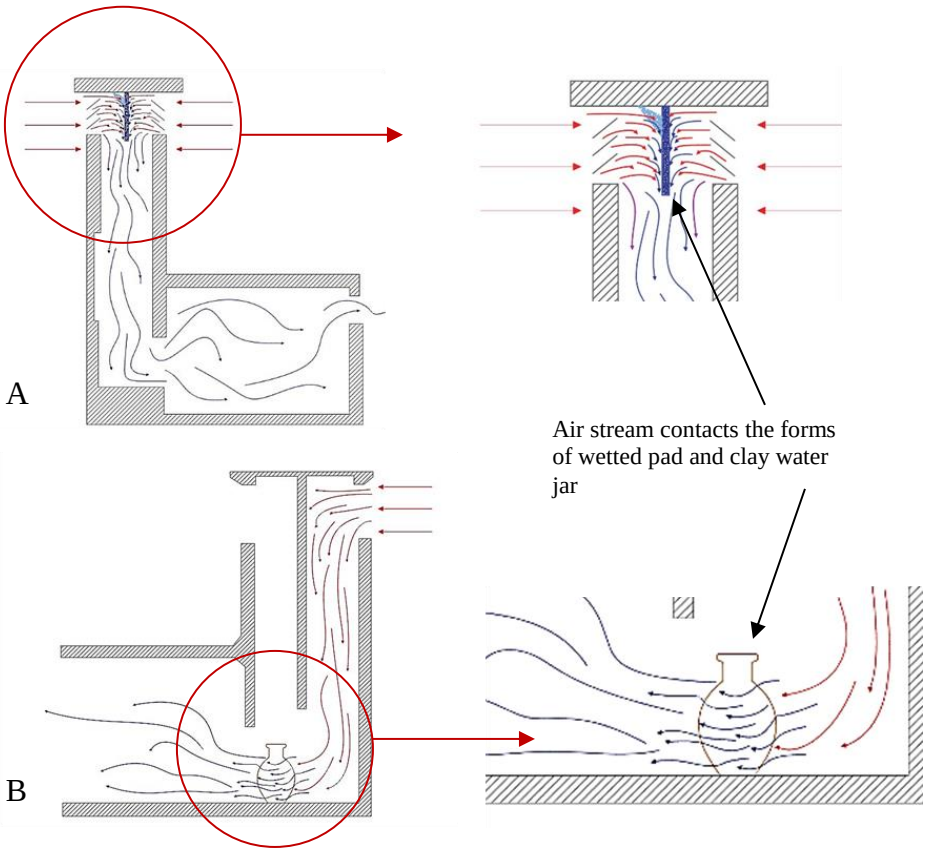

Figure 5, Airstream operation of wind

First wind catcher makes air stream cool with wet pads. Air stream straightly impact with wet pads and it makes the path to air stream. It decreases the probability of airstream which enter the tower without cool. Rigid form opposes the speed of air stream. Second one works same as the Mashrabya.

3.2. FORM EXPERIMENTS- AIR FLOWING IN SPACE

According to the research findings air stream is on of most considerable facts in passive direct evaporative cooling technique. The air flowing pattern influence the cooling effect coupling with material quality. Touching large surface area and maintain the speed of airstream are the main requirements of form development. Studied couple of cases consist with basic two forms as open spherical and straight to make a path for airstream.

The research is based on the different types of form analysis based on Straight, curve forms. (A,B,C,D,E) These experiments to identify the best formation to fulfill the requirements of provide large surface are and maintain air velocity.

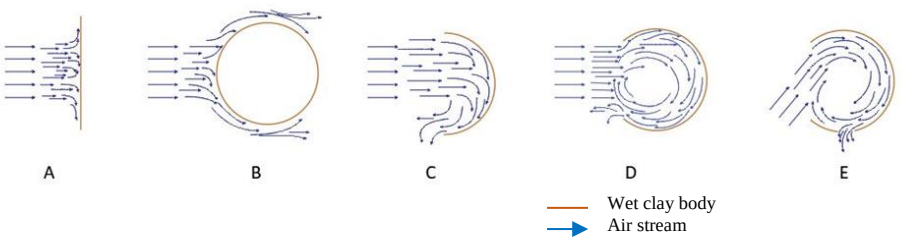

Figure 6, Airstream experiments on various forms

A is a straight wet module. It contacts airstream properly. But the form opposes the speed of air stream as an obstruction. It same as the first type of wind towers evaporative cooling element.

B is a form which works same as Mashrabya and second type of wind towers cooling pot. It also makes a good contact with the airstream and create an air path divergently. Air speed is maintaining by the spherical form.

C form make half rotation for the air stream with maintaining the air speed. There is a possibility to develop the form with continuing convergent rotation.

D is a close ended form which continuing the air stream in convergent path. Continuous rotation makes high surface area to touch the air stream. And it maintains the air speed as well.

E is a development stage of the form D. The efficiency of the form has tested by the incline the arriving air stream. It repeats the rotation in the form by contacting more surface area.

4. Results and Discussions

According to the investigation air stream mostly influenced to the enhance efficiency of evaporative cooling. Provide high surface area and maintain the speed of airstream are the main requirements for airstream in efficient evaporative cooling. The research identifies a basic form after the experiments on various forms. Close ended spherical form fulfills both requirements according to the experiments. Efficiency of the form has enhanced with changing the path of arriving airstream.

The basic form which makes a path to airstream in evaporative cooling technique has revealed by the study. It adduces the possibility of develop an efficient passive cooling system for sustainable world. Form based product design can develop for the any kind of ventilator as a passive cooling unit.

4. Conclusion

Air stream is a highly considerable fact in the passive direct evaporative cooling systems. Main ancient examples of Mashrabya and wind towers are highly considered on the wetted media of evaporative cooling system. The study identifies the operation of airstream on these basic forms and the defects of action in air stream for efficient evaporative cooling. Clay body is a better media in evaporative cooling technique. Finally, the research identifies a competent form to make a path for airstream of direct evaporative cooling system. Close ended spherical form with angular entering of air stream is the best basic method according to the experiments. Efficiency of the evaporative cooling is effect by the air stream integrated with mechanical and chemical properties of the clay body. The basic form convinces the possibility of developing a form based passive direct evaporative cooling system. There is a requirement in sustainable solutions in all the problems in the world. Global warming is one of considerable problem in near future. The research makes a path for product design sector to develop a zero-energy clay module to optimize cooling as a solution for highest cooling demand.

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