The Analysis Of Capillary Tube System For Office Buildings In Africa. (A Case Study Of Nigerian And Namibian Climate)

Sulaiman Muhammad kabir, Dr Halil zafer Alibaba

Abstract: The change in climate and the rise in energy rates have become a necessary consideration in the construction industry which has made architects and engineers to arise with improved building design concepts. A focus on creating a comfortable indoor climate in office buildings ensures productive working conditions for the users and reduces global warming. Specific climatic design principles are often disregarded when designing to create a comfortable indoor climate. Sustainable design methods in buildings has been replicated from one zone to another zone without adjustments which results to buildings that do not provide adequate comfort. Capillary tube system is used to provide a comfortable indoor climate for office buildings making an interesting use of geothermal energy. This paper aims to explain its principle using geothermal energy and the effect of climate on the use of this system in office buildings in Africa. A case study of Lagos state lying on the coast of the Atlantic Ocean which is challenged with high rise in sea level as a result of global warming in Nigeria and Windhoek in Namibia is to be taken into consideration as the business hub of its country. These regions comprises of many office buildings to facilitate the countries trade internationally and locally.

Index Terms: Capillary tube mats, condensation, desiccant dehumidifier, heat pumps, radiant cooling, relative humidity, sustainability.

1 INTRODUCTION

Nigeria and Namibia lies in west and East Africa respectively. Lagos is a city in the Nigeria. The city, with its connecting metropolis, is the largest in Nigeria, as well as on the African continent. It is one of the fastest growing cities in the world and also one of the most populous urban mass in the world. It is Africa's major financial Centre and the mega city has the busiest and largest ports. This mega city has the highest GDP in Africa [1]. Windhoek on the other hand, is the capital and largest city of Namibia. On the Khomas Highland plateau area, at around 1,700 metres (5,600 ft.) above sea level, lies Windhoek. It is located almost accurately at the country's geographical Centre [2]. The need for a better thermal performance is increasingly taken into consideration in the design of office buildings. The selected regions as case studies are not left out. As there are change in climate , stern guidelines to meet sustainability targets, the inclination to design energy-efficient buildings continues to arise. Lagos state is challenged with rise in sea level from the Atlantic side of the ocean caused by global warming while Windhoek, is challenged with the issue of paying high bills for electricity where natural resources could be a natural replacement. An energy-efficient way to design is to use the capillary tube System. The system is a form of surface radiant cooling system that uses the underground Temperature of water to create an efficient cooling or heating system. It is a system that is progressively being used for office buildings in temperate regions.

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The system comprises of water carrying tube transporting either cold or hot water that makes a remarkable use of environmental energies such as ground soil, ground water to activate thermally, the building for summer or winter periods.

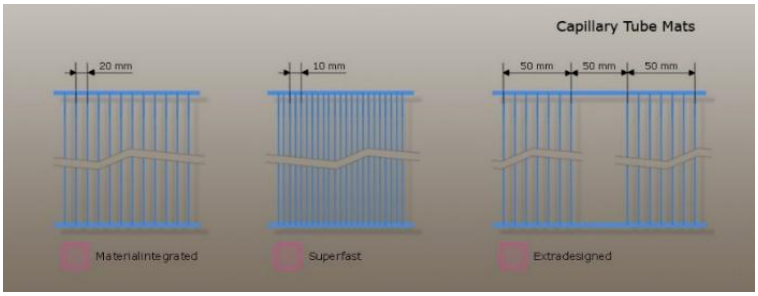

Fig. 1: *capillary tube mats [3]*

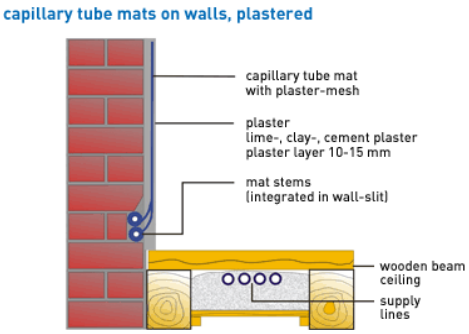

Fig. 2: *capillary tube mats on walls [4]*

Capillary tube mats are installed directly below the surface or in the core of one or more room enclosure surfaces. They could be the ceilings, walls as seen in fig 2 or flooring. To heat or cool rooms, cool or warm water flows through the capillary tubes having an external diameter of about 3.4mm or 4.3mm. Interior surfaces installed with capillary tube mats are delivered with constant temperature control and enable a quick dissipation of cooling loads or delivery of heat requirement which is approximately 60 percent through radiation and 40 percent through convection [4]. So therefore, in the use of this

system there is a transfer of energy without noise, even with low temperature differences between active room surfaces and room air as seen in figure 6 and 7. However, Installations of radiant systems like the capillary tube systems in cold climatic zones are constrained majorly by heating capacity of the system while using the system where humidity is high is restricted by need to avoid condensation. Operation of the thermally activated elements effectively reduces the size of the ventilation system. It is not designed to take extract cooling loads or heat the building but dissipate fresh air for the inhabitants. This indicates that lower air change rates can be used. If cooling is done slightly, supply air can also offer some extra cooling, when it is hot [5]. This leads to a Research Question: Is the application of the capillary tube system sustainable for use in office buildings in Lagos and Windhoek taking into consideration there climatic conditions whilst lying in the same continent?

1.2. Problem Statement

More and more offices are being designed in Lagos and Windhoek as these city serves as the business hub of their countries. In Lagos state, neglecting sustainable design in office buildings has led to global warming which in turn causes rise in the sea level that bothers it, therefore putting the city at the verge of collapse while in Windhoek, These offices lack sustainable designs and therefore spend more on electricity to power active systems to cool these buildings. With the exploration of geothermal potentials in these selected regions, Alternative sustainable means to solve these problem of high consumptions in these buildings and rise in sea level could minimize these arising issues.

1.3. Aim

This paper aims to analyze the use of capillary tube systems as a way of sustainable design in office buildings and its compatibility for Lagos and Windhoek in West Africa and East Africa respectively

1.4. Scope

The scope of the research is limited to the intelligent use of capillary tube system in Lagos city and Windhoek city during its hot periods

1.5. Methodology

Published literature reviews containing successful experiments in the use of radiant cooling system served as a basis for this paper research.

2. MATERIALS AND METHODS

The capillary tubes system is a kind of radiant cooling system. Radiant cooling systems minimizes energy demand because the energy used by its pump is lower than fan in all air systems [6]. Using the radiant cooling systems, the room air temperature in summer could also be higher than that of air systems so that the cooling load would become minimized. As a result, the energy demand can be further reduced [7]. Researches and investigations in Europe by Giovani, showed that radiant cooled ceilings are able to extract high cooling loads with an apparent good thermal comfort [8]. Also, a practical experiment done by, Niu in 1994, it was established that cooled ceiling in conjunction with displacement ventilation can consequently create an environment which is thermally comfortable having a cooling load up to 50 W/m, in comparison with 40 W/m using only displacement ventilation. Nonetheless, the issues arising were found out in the following context: In the experiments made by Vangtook and Chirarattananon 2006 on radiant cooling with natural ventilation in the hot and humid climate of Thailand, The temperature of the cool water passed through the pipe was restricted to 24ºC to avoid condensation on the ceiling panels. It was understood that the low heat response capacity of the panel would limit its use only to situations when the loads are on the minimal side. Apparently, it is an efficient system and sustainable system for dry climate and could be challenging when humidity is high especially in buildings which has high latent load space, which might be a source of discomfort [9]. In another sustainable system named concrete core thermal control system which works using the same principle as the capillary tube systems, barriers due to climate and other factors were also realized [5]. It was found that the effect of passive utilization of the thermal mass is dependent on the climate context. The surface area where the water carrying tubes or pipes are installed needs to be satisfactorily large to ensure enough heat transfer rate. The system alone cannot extract latent load and pollutants, such as volatile organic compounds. Therefore it is needed to be backed up with ventilation. The system is more functional for buildings having low heating or cooling loads of about 40 – 50 W/m2. Building envelope needs high thermal insulation and adequate solar shading. For effective usage of this system, there should be an equilibrium in heat loss and cooling loads the same heat exchange surface is used for both cooling and heating [5].

2.1. Case Study: Vienna Twin Tower, Austria

The Vienna twin tower is located in Austria. These twin towers located in Austria is a high rise building that cools its self with these sustainable cooling systems. It approximately uses 29,000m² radiant cooling surface as metal ceiling in conjunction with capillary tubes system for heating and cooling [10].

***Fig 3**: Vienna Twin Tower, Austria [10].*

3. CLIMATIC ANALYSIS

3.1. Climate of Lagos state

According to the koppen climatic classification, Lagos city lies in the tropical savanna climate, as there's a significant rainfall difference between the wet season and the dry season. From April to October lies its wet season while November to march lies its dry season. The city's location to the equator give it a constant temperature with no apparent difference between the

hottest and coolest month. The month of March having an average temperature of 28.5 °C is the hottest month, while the month of August which comes with an average temperature 25.0 °c is the coolest month. [11]

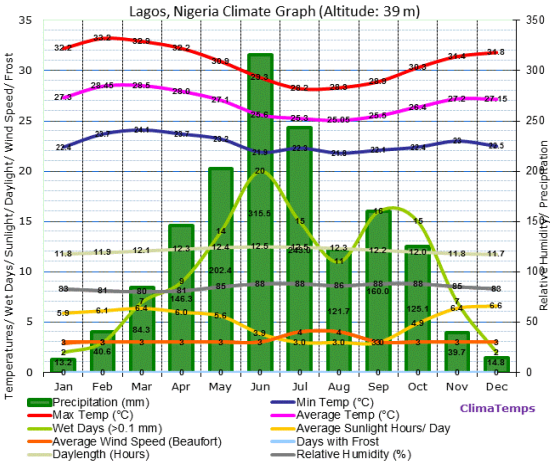

Fig. 4: *climatic graph for Lagos, Nigeria [12].*

3.2. Climate for Windhoek City

Windhoek is located in the semi-arid region. They are comprised of days which are mostly warm with very hot days in summer, while nights are generally cool. Its average annual temperature reads at 19.47 °C, which is considered high for a place at such a high altitude on the tropical edge. This occurs owing up to the frequent warm airflow from the northern area and the mountains to the south, which shelters the city from the southern wind [11].

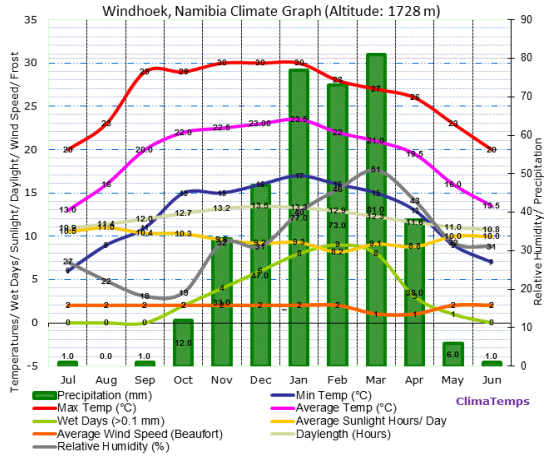

Fig. 5: *climatic graph for Windhoek, Namibia [12].*

4. RESULTS

For cooling as shown in figure 4, using the capillary tube mats, which are better installed on the ceiling, the surface temperature of the ceiling is usually 19°C approximately, dependent on the specified temperature at a spread of just 2k to 3K between takings in and returning. [4]

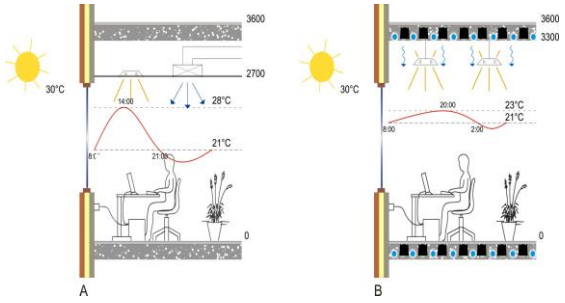

Fig. 6: *Indoor temperature fluctuations [13]*

Diagram A shows large change in temperature while Diagram B using capillary tubes installed in the core of the floor and ceiling in heating mode showing little fluctuation in temperature. During its heating mode as shown in figure 6**,** capillary tube system flows water heated water up to 28°C-35°C. The ceiling surface temperature in this scenario lies in the range of 27–30°C. As a result, radiation energy from the human skin at a temperature approximately 32°C is dissipated to the ceiling even when heating. Investigations have shown that, up to a capacity of approximately 60–70 W/m² and depending on radiation asymmetry, no forfeit in comfort is expected when heating with the room ceiling [15].

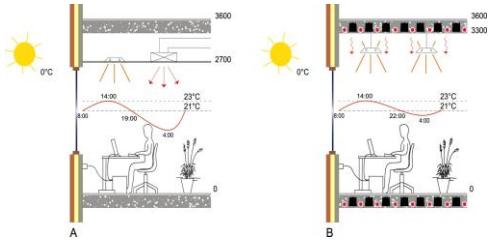

Fig. 7: *Indoor temperature fluctuations [13].*

Diagram A shows large fluctuation in temperature while Diagram B with capillary tubes in heating mode showing no little fluctuation in temperature**.** From the climatic chart/analysis in figure 4, Lagos state relative humidity is seen to be high when the temperature is hot. Its relative humidity increases from 81% to 85% between march to June and air temperature ranges from 35°c to 38°c in its hot period from march to June as the chart describes of which There is a higher cooling demand in office buildings in these months. Deductions from the chart show relative humidity to be high in the hot months where cooling demands are higher. It can be deduced that using capillary tube systems in its cooling mode which is between 18°c to 23°c would result in a rapid increase of indoor air relative humidity when in contact with the cooled surface. The risk of condensation is bound to happen on the cooled surface when the indoor air reaches its dew point. This is one of the pitfalls mentioned earlier on in the literature review. Condensation on the cooling surface happens when the warm air being absorbed comes in contact with the cooled surface thereby dropping the temperature of the warm air suddenly. As a result of the sudden drop in temperature of the warm air, its relative humidity increases and the air reaches its saturation point quickly thereby resulting to condensation occurring on the cold surface. While in Windhoek, the relative humidity is as low as from 18% to 32% as shown in figure 4 in its hottest month which has a maximum temperature of 28°c to

30°c from the month of August to December. The risk of condensation on the capillary tube system is apparently low because of its low relative humidity and has a favorable hot air temperature.

5. DEDUCTIONS/CONCLUSIONS

It can be deduced from the result that introducing this sustainable system of cooling in Lagos would lead to a problem of condensation which is a disadvantage in the use of capillary tube system as a form of radiant system. While the risk of condensation in using this integrated systems in Windhoek is low. In Windhoek city, the use of the capillary tubes system in conjunction with solar panels installed on the roofs to make use of the sunlight, could be connected to the heat exchanger thereby providing the system with a sustainable electricity to power the pump that generates water into these pipes. Integrating these system in the capital of Namibia which contains most of its office buildings would be a sustainable means for cooling these buildings. The climatic chart of Windhoek city in figure 12 shows that its temperature is not on the high side with an apparent lower humidity. If the same heat exchange surface is used for both cooling and heating, efficient use of this system with geothermal energy would save more energy for the office buildings. However, if this sustainable method is to be adopted in the tropical region of Lagos, precautions are needed to be taken to enable this system work sustainably and efficiently for its climatic condition., if this cooling system is to be adopted, to avoid condensation on a cooled surface there is a need to take into account on the restriction on water temperature established on the space dew temperature. The temperature of water supplied, average water temperature or flow rate can be measured from zone to zone. So therefore a zone control is best to use. In situations where the capillary tubes are installed in the core of the ground as shown in figure 12 and 13, and a well-designed building with low cooling or heating loads, the concrete slab can be controlled to a constant core temperature year round. If for example the core of its installation is maintained at 20°c it will cool when the room temperature is above 20°c and supply heat when the room temperature is below 20°c if the system is used for heating. However if concrete slabs have a constant temperature, its surface temperature and absolute humidity is recommended to be controlled by setting the lower limit for the supply water temperature to equal the absolute humidity in space. When the dehumidification is performed by a ventilation system the cooling capacity can also be increased [14]. An alternative efficient way of using this system in Lagos city is using desiccant dehumidified ventilation for the capillary tube system. This could be efficient enough in a situation where there is high humidity. The Desiccant dehumidified ventilation system can dissipate with little moisture to reduce the supply air flow rate, since the humidity ratio is lower than that attained with the normal vapor compression chiller used for the conventional air systems. This feature makes the capillary tubes system favorable for buildings in humid regions where the risk of condensation is very high because of high humidity level. In Windhoek city, a smart and efficient way to use the capillary tube systems in office buildings may lead to a reduction of high power demands at night by saving energy and releasing it in daytime. Heat gains during active periods in these buildings are piled up in the active structure component and can be extracted at night by circulating cool water or by free night cooling. Since there is apparently a considerable general night cooling in the region, a considerable peak shaving can be realized by transferring partial loads to the night hours. A dynamic computer simulation was used to study summer performance based on time of system operation, and supply water temperature by Olesen in an earlier study. It was found that the system operation at night was satisfactory and supply of water temperature can controlled over the season based on outside temperature [5]. Therefore the use of this cooling system can be advantageous and recommended if the condensation risk precautions are being practiced and are being used smartly in these cities.

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REFERENCES

[1] Lagos and Its Potentials for Economic Growth". 2 July 2015. Retrieved 26 October 2015

[2] Namibia tourism board, retrieved on 4th December 2016 from www.namibiatourism.com

[3] The new generation of capillary tube system. www.geoclimadesign.com

[4] Capillary tube technology for cooling and heating systems, www.clina.de/index.php

[5] Olesen, B.W., et al. 2006. “Dynamic evaluation of the cooling capacity of thermo active building systems.” ASHRAE Transactions 112(1).

[6] Sodec, F. 1999, Economic viability of cooling ceiling systems, Energy and Buildings, volume 30, no. 2: page195-201.

[7] Feustel, H.E., Stetiu, C., 1995, Hydronic radiant cooling-preliminary assessment, Energy and Buildings, vol. 22, no.3: page 193-205.

[8] Niu, J.L., Zhang, L.Z., Zuo, H., 2002, Energy savings potential of chilled-ceiling combined with desiccant cooling in hot and humid climates, Energy and Buildings, vol. 34, no. 5: p487-495

[9] Givoni, B., 1991, Performance and applicability of passive and low-energy cooling systems, Energy and Buildings, vol. 17, no. 3: p177-199.

[10] Fuksas, http://www.fuksas.it

[11] Koppen climatic classification, www.climate-data.org

[12] Climatic guide to world weather and climate, www.climatemps.com

[13] Air deck intelligent floor systems, http://www.airdeck.be

[14] Meierhans, R.A. 1993. “Slab cooling and earth coupling.” ASHRAE Transactions 99(2). . Meierhans, R.A. 1996. “Room air conditioning by means of overnight cooling of the concrete ceiling.” ASHRAE Transactions 102(2).