Cooling of Buildings by Roof Surface Evaporation in Sri Lanka by Considering the Climate Pattern

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Abstract— Heat on buildings mostly enters through roofs, as these are exposed to sun throughout the day. Many attempts have been made to reduce the ingress of heat by various methods like, by increasing thickness of roofs and providing insulation by covering by reflectors, additional clay tile cover or lime-concrete cover or even reflector painting. Methods like continuous water spraying, intermittent spraying or ponding of water on roofs is either less effective or difficult to adopt. Similarly artificial or mechanical gadgets such as air-conditioners or desert coolers have high energy requirement. This paper is based on a continued research in finding economical, effective and natural way of cooling of dwelling units as well as multi storied buildings. Traditional methods like Khas Khas mats, water fountains, etc. were also analyzed along with the evaporative cooling. The feeling of comfort after taking bath as a result of utilization of body heat for the evaporation of water was also looked into. This lead to the efforts of creating comfortable living and working conditions in buildings by evaporation of water. A process was accordingly developed by this research utilizing the concept of cooling of buildings by roof surface evaporation. Finally this paper recommends some guidelines for Roof Surface Evaporation Cooling System for Sri Lankan climate condition.

Index Terms— aircondotioner , cooling buildings, desert coolers, evaporation, mud-phuska , roof top cooling, roof surface evaporation, water fountains, water surface evaporation,

1 Introduction

COOLING of buildings by using evaporation of water is a well-recognised concept for the reducing the load of mechanical cooling of buildings, especially in hot and dry climates in topical countries like Sri Lanka. Evaporation of water may be used directly inside the building, as in desert coolers which are quite commonly used in tropical countries in Asia and Middle-East. This results in reduction of air temperature and increase in humidity of the indoor air {1]. Alternatively, the exposed surface of the roof may be treated with water producing a cooling effect on the inside air without any increase in humidity

2 Study Area Characteristics

2.1 Climate

Sri Lanka is located within the tropics between 5° 55' to 9° 51' North latitude and between 79° 42' to 81° 53' East longitude, the climate of the island could be characterized as tropical.

2.2 Topography

The central part of the southern half of the island is mountainous with heights more than 2.5 Km. The core regions of the central highlands contain many complex topographical features such as ridges, peaks, plateaus, basins, valleys and escarpments. The remainder of the island is practically flat except for several small hills that rise abruptly in the lowlands. These topographical features strongly affect the spatial patterns of winds, seasonal rainfall, temperature, relative humidity and other climatic elements, particularly during the monsoon season.

2.3 Climate

Climate is defined as the condition of the atmosphere at a particular location over a long period of time starting from one month to many millions of years, but generally we can say 30 years. Climate is the sum of atmospheric elements and their possible variations, solar radiation, temperature, humidity, clouds and precipitation with occurrence and magnitude, atmospheric pressure, and wind with speed and direction.tables and figures will be processed as images.

Rainfall

Rainfall in Sri Lanka has multiple origins. Monsoonal, Convectional and expressional rain accounts for a major share of the annual rainfall. The mean annual rainfall varies from under 900mm in southeastern and northwestern, the driest parts, to over 5000 mm in the western slopes of the central highlands. (Fig. 1).

Regional differences observed in air temperature over Sri Lanka are mainly due to altitude, rather than to latitude. The mean monthly temperatures differs slightly depending on the seasonal movement of the sun, with some modified influence caused by rainfall. The mean annual temperature in Sri Lanka manifests largely homogeneous temperatures in the low lands

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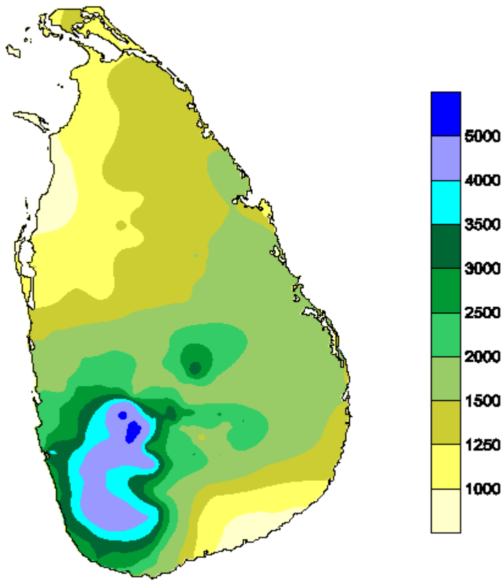

Fig. 1 Annual Rainfall in Sri Lanka Temperature

and rapidly decreasing temperatures in the highlands. In the lowlands, up to and altitude of 100 m to 150 m, the mean annual temperature various between 26.5^0C to 28.5^0C, with an annual temperature of 27.5^0C. In the highlands, the temperature falls quickly as the altitude increases. The mean annual temperature of Nuwaraeliya, at 1800 m sea level, is 15.9 ^{0}C

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The coldest month with respect to mean monthly temperature is generally January, and the warmest months are April and August. The mean annual temperature varies from 27^0C in the coastal lowlands to 16^0C at NuwaraEliya, in the central highlands (mostly 1900m above mean sea level). This relatively unique feature manifesting as sunny beaches to rain forests inland is a tourist attraction.

Climate Seasons

The Climate of Sri Lanka is dominated by the above mentioned topographical features of the country and the Southwest and Northeast monsoons regional scale wind regimes. The climate experienced during 12 months period in Sri Lanka can be characterized in to 4 climate seasons as follows.

1. First Inter-monsoon Season - March - April
2. Southwest monsoon season - May - September
3. Second Inter-monsoon season - October - November
4. Northeast Monsoon season - December - February

First Inter-monsoon Season (March - April)

Warm and uncomfortable conditions, with thunderstorm-type rain, particularly during the afternoon or evening, are the typical weather conditions during this season. The distribution of rainfall during this period shows that the entire South-western sector at the hill country receiving 250 mm of rainfall, with localize area on the South-western slops experiencing rainfall in excess of 700 mm (Keragala 771 mm). Over most parts of the island, the amount of rainfall various between 100 and 250 mm, the notable exception being the Northern Jaffna Peninsula (Jaffna-78 mm, Elephant pass-83 mm).

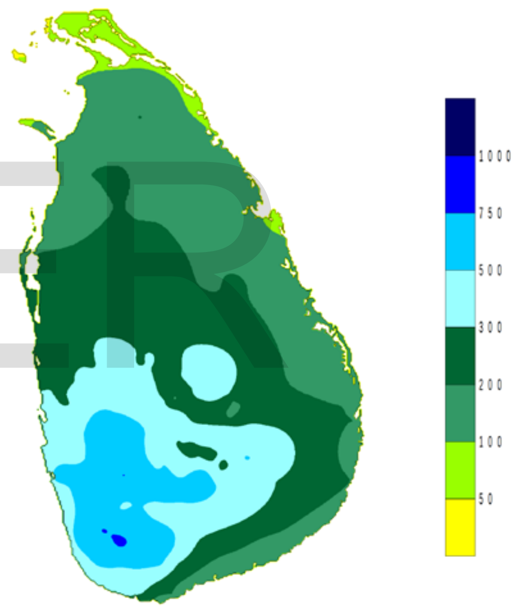

Fig. 2 First Inter-Monsoon Rainfall Pattern South-West Monsoon Season (May - September)

Windy weather during this monsoon eases off the warmth that prevailed during the 1st Inter monsoon season. Southwest monsoon rains are experience at any times of the day and night, sometimes intermittently mainly in the Southwestern part of the country. Amount of rainfall during this season varies from about 100 mm to over 3000 mm. The highest rainfall received in the mid-elevations of the western slops (Ginigathhena- 3267 mm, Watawala- 3252 mm, Norton- 3121 mm). Rainfall decreases rapidly from these maximum regions towards the higher elevation, an in Nuwara-eliya drops to 853 mm. The variation towards the Southwestern coastal area is less rapid, with the Southwestern coastal belt experiencing between 1000 mm to 1600 mm of rain during this 5 month

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long period. Lowest figures are recorded from Northern and Southeastern regions.

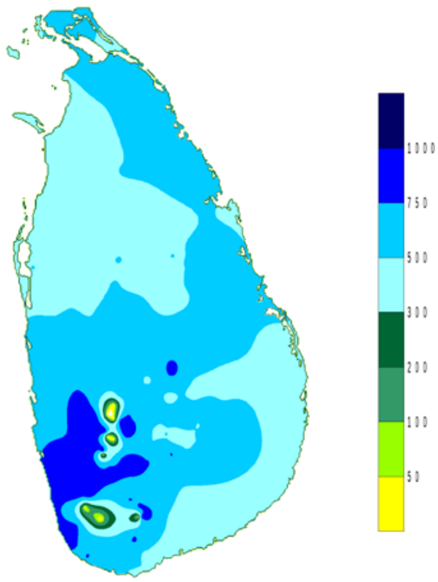


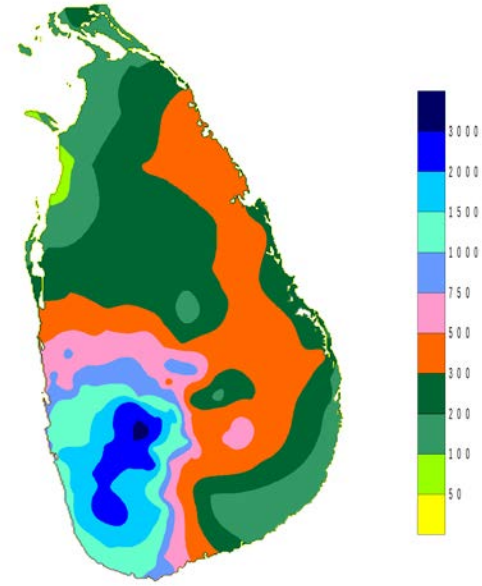
Fig.3 Southwest –monsoon Rainfall Pattern Second Inter-monsoon Season (October-November)

The thunderstorm-type of rain, particularly during the afternoon or evening, is the typical climate during this season. But unlike in the Inter-monsoon season, the influence of weather system like depression and cyclones in the Bay of Bengal is common during the second Inter-monsoon season. Under such conditions, the whole country experiences strong winds with wide spread rain, sometimes leading to floods and landslides. The second Inter-monsoon period of October – November is the period with the most evenly balanced distribution of rainfall over Sri Lanka. Almost the entire island receives in excess of 400 mm of rain during this season, with the Southwestern slops receiving higher rainfall in the range 750mm to 1200 mm (Weweltalawa Estate in Yatiyantota recording 1219 mm)

North-East monsoon Season (December - February)

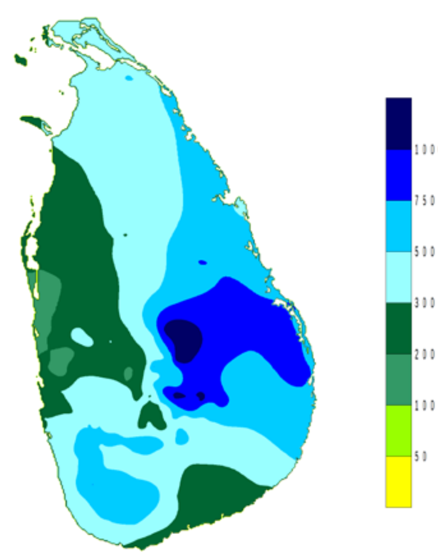
The dry and cold wind blowing from the Indian land-mass will establish a comparatively cool, but dry weather over many parts making the surrounding pleasant and comfortable weather except for some rather cold morning hours. Cloud-free skies provide days full of sunshine and pleasant and cool night. During this period, the highest rainfall figures are recorded in the North, Eastern slopes of the hill country and the Eastern slopes of the Knuckles/Rangala range. The maximum rainfall is experience at Kobonella estate (1281 mm), and the minimum is in the Western coastal area around Puttalam (Chilaw- 177 mm) during this period.

Fig. 4 Second Inter-monsoon Rainfall Pattern



Humidity is typically higher in the southwest and mountainous areas and depends on the seasonal patterns of rainfall. At Colombo, for example, daytime humidity stays above 70 percent all year, rising to almost 90 percent during the monsoon season in June. Anuradhapura experiences a daytime low of 60 percent during the inter-monsoonal month of March, but a high of 79 percent during the November and December rains. In the highlands, Kandy's daytime humidity usually ranges between 70 and 79 percent.

Fig. 5 North-East Monsoon Rainfall Pattern



As a sample the climate graphs of Colombo is given in fig 6

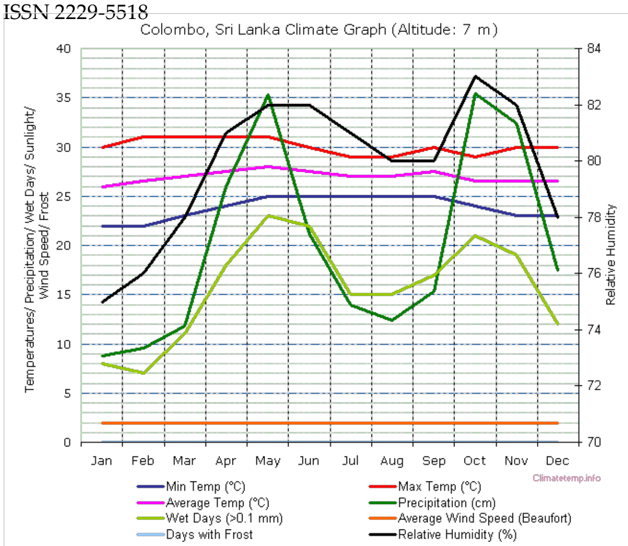


Fig. 6 Climate graphs of Colombo

The seasons are slightly complicated by having two monsoons. From May to August the Yala monsoon brings rain to the island's south western half, while the dry season here lasts from December to March. The south west has the highest rainfall – up to 4000mm a year. The Maha monsoon blows from October to January, bringing rain to the dry zones of Sri Lanka, while the dry season is from May to September. The dry zones are comparatively dry, with around 1000mm of rain annually. There is also an inter-monsoonal period in October and November when rain can occur in many parts of the island.

3 Water Surface Evaporation Cooling

Water on the surface of a building has a tendency to evaporate. Roughly 2.5kilo jule of heat energy is consumed for every gram of water that evaporates,. Wetting a building is therefore helping to remove heat in a process that is analogous to body sweating of human [2].

Historically, water has been used in the form of cascades, fountains and traditional methods like Khas Khas mats, to improve the thermal comfort of buildings and surroundings. Evaporation of water helps to passively cool buildings, reducing the energy needed for air conditioning. When combined with other passive design techniques, adequate thermal comfort might be achieved without air conditioning.

Indirect Evaporation Cooling

When surface evaporation processes are used to cool any portion of building, which then acts as a heat sink, this is known as indirect evaporation cooling. Cooling is provided whilst keeping the evaporation process outside, which avoids elevating the indoor humidity level. Direct evaporation cooling cools outside air through evaporation, and brings this air into the building. The drawback of this method is that indoor humidity levels are increased so direct evaporative cooling techniques should be discounted.

Methods of evaporation cooling include roof pond systems, which can also lose heat by radiation and convection and water spraying is another form of evaporation cooling..

Roof Ponds

In the simplest form, this involves placing a pond on the building roof. As water evaporates from the pond, heat is consumed. This cools the roof, which acts as a heat sink and absorbs heat from the interior of the building.
A more refined method involves insulating the pond during the daytime, to prevent solar gain. During the day water in the pond absorbs heat, cooling the ceiling below. At night, water is circulated over the insulation. Heat is then removed by means of evaporation, convection and radiation. Such systems have been successfully trialled in the hot, humid climate areas, where cooling of 10^{0}C to 13^{0}C below outside air has been reported [2].
Obviously, roof ponds require additional structural support and there may be public health concerns associated with standing water

Water Spraying

Spraying of water is a simple and economic way of reducing the solar heat gain of buildings in the tropics [3]. Water is typically sprayed onto roofs for 40 seconds every five minutes. A small amount of external power is required to pump the water up to the roof, but the energy required for this is minimal compared with the additional cooling that is attained [4]. While roof spraying has some potential for cooling in hot humid climates, the effect is relatively small. A reduction of indoor air temperature of 1^{0}C to 4^{0}C has been reported. Studies show that roof spraying is a less effective cooling method under cloudy conditions and rainy season. [2], [3].

Continued efforts in finding economical, effective and natural way of cooling. Traditional methods like Khas Khas mats, water fountains, etc. were also analyzed along with the evaporation cooling [5].

The feeling of comfort after taking bath as a result of utilization of body heat for the evaporation of water was also looked into. This lead to the efforts of creating comfortable living and working conditions in buildings by evaporation of water a process was accordingly developed utilizing the concept

4 Cooling Buildings by Water Surface Evaporation

Cooling of buildings by roof surface evaporation requires a mat made of double layered empty jute bags or 6 mm thick coir, laid in close contact with the roof. And water is sprinkled uniformly over it. The bags/coir matting remains soaked in water throughout the days and nights during summer. Water may be sprayed manually or with the help of sprayers [6].

For an average sized room, specially designed sprayer works for about 25 minutes in 24 hours to spray water intermittently for nearly 5 times a day.

Water trapped in jute bags/coir mattings evaporates continuously at all temperatures. This is due to heat received by the roof and the air movement. The incident heat due to sun's rays on roof is also consumed for the evaporation of water present in wet mattings and therefore cannot add to the heat content of the roof. Higher the sun's heat and wind speed higher will be the quantity of water evaporated, and higher will be the cooling effect. At low temperature, heat required for evaporation is more. The heat from other elements of the building wills also more towards the roof due to its lower temperature as compared to other building elements. Thus the roof also extracts out heat from the structure as a whole, attempting to cool it up to the temperatures of wet bags nearly to outdoor wet-bulb temperatures. The cycle of alternate wetting and partial drying of bags continues to extract heat from the buildings and this extraction of heat depends on the thermal design of building envelope i.e., its heat content and indoor thermal conditions.

The wet condition of the bags/coir matting could be accomplished using either a simple stop cock, mechanically or manually operated pump or electronically controlled electric water lifting pump and a moisture sensor unit. Size of the pump, water storage tank, G I. pipe grid layout, number and type of sprayers and automatic electronic control device with the sensor will, however, depend on the area of the roof, height of the building, discharge rate &coverage of sprayers and water supply conditions. Water requirements vary from building to building depending on the actual heat content and also on climatic conditions. The average requirement for a normal single storey building is 6 to 9 litres per sq. m. of roof surface area per day under hot humid to hot dry climates. In case of industrial and multi storied buildings, the average requirements may be two to three times more depending on their heat content and intensity of sun's radiation. The average time required for cooling a single storied building is nearly 72 hrs, where as in the case of industrial shed with galvanized or asbestose sheet roofs, it may take only few hours but for a 4 to 5 storied building it will be about seven days[8].

5 Recomendations

Based on the research, the following recommendations and precautions need to be adopted before installation and operation of a roof top water evaporation cooling system in topical country like Sri Lanka

- Check the roofs for proper slope and drainage and make necessary repairs to avoid any chance of leakage, seepage and accumulation of water.
- Spread a layer of coir matting or a mat made of empty jute bags thoroughly cleaned and washed. Do not split them to make single layer as double layer is recommended. The bags should be sewn together without overlapping to make a uniform mat, large enough to cover the roof terrace, but leaving a gap of 10 cm all along the parapet walls.
- Install specially designed water sprayer at the rate of one sprayer for 4m x 3m roof or part thereof. Water should be sprayed uniformly five times a day to keep the entire mat continuously in water soaked condition.
- Sprayers may be connected to water supply line if water is available at sufficient pressure at the roof top. A stop-cock may be provided at suitable place in the pipe line to manually control the sprayer.
- If sufficient water pressure is not available at the roof level, a hand operated or electrically operated water lifting pump may be used to lift water from a water tank /container at the ground level to sprayers
- A 1/8 H.P. centrifugal mono block pump is normally enough for supplying water to one sprayer fixed at about 4m height from a water tank at ground level. A 1/4 H.P. pump is preferred for a double storied building for two sprayers.
- An economical and simple automatic control system utilizing a matching pump, electronic switch actuated by water and sensor has also been designed to automatically start the pump when the mat gels dried, and stop the pump, when it gets wet.
- Initially it takes about 72 hours for the existing heavy roofs to cool down indoors but once the cooling has started and the process is continued the system's performance gets stabilized. The thin Galvanised Iron or Asbestose sheet roofs hardly take few hours to produce cooling indoors.
- For building complexes and large roofs, specially designed nozzles, automatic controlling and fault indicating systems can be designed.
- The process may be useful till monsoon rain begins in Sri Lanka. The matting needs to be dried, removed and stored at a suitable place for its reuse and to avoid discomfort by extra cooling during rainy days.

4 Conclusion

Roof top water evaporation cooling system can be used to provide cooling for one to two storeyed buildings. Continuous evaporation from a thin film of water over the roof lowers the temperature of the roof which in turn cools the living space below it. Solar radiation intensity and wind velocity over the roof, affect the rate of evaporation of water but not the temperature of the roof. For this method to be effective, the roof slab should be water proof and made as thin as possible. Roof top water evaporation cooling system are inexpensive to purchase, maintain and operate, and are as readily retrofitted to existing structures as designed into new. Final evaluation of the alternatives should take a life cycle look at all of the assumptions of cost and benefit, energy savings and roof life.

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