EXPERIMENTAL ANALYSIS OF SMALL SCALE ROOF PONDS, PROTECTED BY A VARIETY OF MATERIALS IN DIFFERENT POSITIONS IN REGARD TO WATER LEVEL

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ABSTRACT

The experimental analysis aims to investigate ways to protect a water pond, in order to reduce bottom pond temperature. For this purpose, three identical shallow ponds are together recorded in moderate climate. The bottomless ponds are placed on a concrete roof, exposed to the ambient conditions. Water depth is kept constant in 0.10m, while each pond has an area of $1m^2$. A number of alternative materials for water protection are tested: white textile, the textile used in ironing board, aluminum layer, aluminum foil and insulation. Some of the materials are keeping afloat on water level, while other are kept below or above water level. The analysis focus on the devices that give the lowest temperatures, thus the most effective ones. The bottom pond temperatures are analyzed, in regard to the climate. Furthermore, the bottom pond temperatures are also compared to the temperatures below an insulation layer placed on a concrete slab. According to the experiments, protecting water with reflective materials can reduce bottom pond temperature, thus increasing cooling efficiency.

KEYWORDS

Roof Ponds, indirect evaporative cooling

1. INTRODUCTION

Roof ponds represent an effective passive cooling technique, especially in hot and dry climate. The heat losses mechanism is a combination of radiation, conduction and evaporation while the increased thermal capacity of the water reduces the temperature fluctuation of water.

The most investigated roof pond variation is the skytehrm (Raeissi 2008); water is enclosed to plastic bags. During the summer day the pond is protected by insulation panels which are removed during summer night. The function is revised during winter, for passive heating.

In order to overcome the maintenance issues, Tang et al (2004) proposed a roof pond with negligible maintenance, constructed by keeping gunny bags or cloth floating in the surface of water pond. In order to be afloat, the textile is supported by polystyrene strips or other floatable material attached to it underneath. The wet textile dissipates the heat through water evaporation, convection and radiation losses while capturing solar radiation. Moreover water absorbs the heat gains from the building and dissipates them. According to simulations and experiments (Tang et al., 2003 & 2005) the system prove to perform better compared to other passive cooling techniques.

According to a former parametric study of the system (Spanaki et al 2010), the efficiency of the system can be improved by placing a textile with low emissivity. Decreasing textile emissivity by 50% has a sensible effect on water temperature decreasing by 2.6 ^{o}C. The parametric study assumes that low emissivity layer acts the same way as a wet textile, allowing water evaporation through it. On the other hand low emissivity materials are commonly reflective metals. The lack of porous on the reflective layer exhibits evaporation losses.
The aim of the present study is to experimentally investigate ways to protect water pond while encouraging evaporation losses. For this purpose a number of alternative materials are used, in a variety of positions: on, below and above water layer.

2. THE TESTED MATERIALS FOR WATER PROTECTION

The tested materials have high reflectivity. Since the emissivity has proved to be a critical parameter for the bottom pond temperature of the Rood Pond with gunny bags [mine], the emissivity of the tested materials has been recorded with the D&S Emissometer, Model AE1. The emissivity values are listed in Table 1. The ironing board has lower emissivity and higher reflectivity comparing to the white textile. Aluminum foil is a reflective metallic material, differing from textile in terms of the heat dissipation mechanism, since it is not allow evaporative losses through it.

Table 1: The emissivity of the materials tested for water portection

material	White textile	Ironing Board	Aluminium layer	Aluminium foil
Emissivity	0.86	0.44	0.04	0.03

3. EXPERIMENTAL SETUP

The experiments refer to the record on three bottomless shallow ponds of 1.00 m x1.00 m x 0.16 m, constructed by stainless galvanism metal. The perimeter of each pond is externally insulated with 50 mm polystyrene panels. The ponds are filled with water 10cm deep, while a polyurethanes layer (naylon) is internally waterproofs the pond.
Water level is kept constant at 0.10m by floater in each pond, while evaporated water is supplied by a water tank. Three T-Logg 100E (Greisinger electronic GmbH – D -93126) data loggers record the temperatures on the bottom of the examined ponds.
The site where experiments were held is at Vrahokipos (Latitude 35° 19' 60N Longitude 25° 15' 0E, Elevation 25 m), a rural area of Heraklion city, on Crete island in Greece. The meteorological data were also recorded on the site of the experiments.

4. RESULTS AND DISCUSION

Three periods of experiments are analyzed. The temperature records are also referred to three ponds that are together recorded.

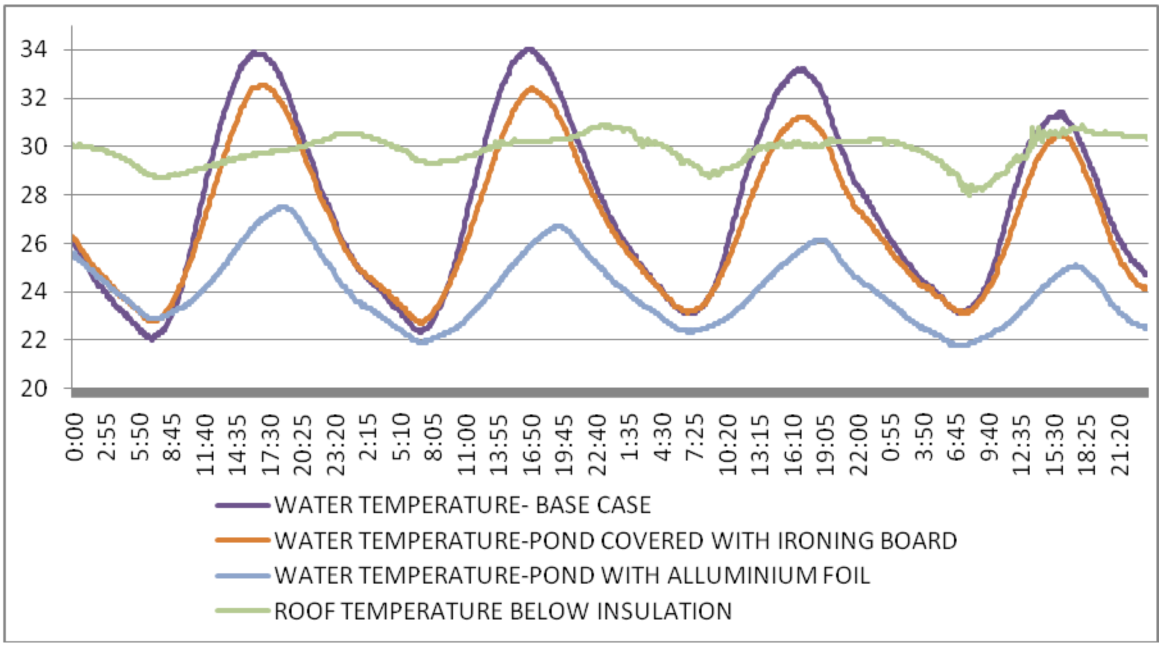

Figure 1: Bottom pond temperatures of three ponds protected with a variety of materials, placed on water level. The records are referred to the period between 2nd and 5th of July 2010.

4.1 The effect of the protection material properties to the bottom pond temperature

The first period of experiments refers, from the 2nd to the 5th of July 2010, aims to compare three ponds protected by different materials, placed on water level, as listed on Figure 1. According to the experimental records, roof temperature below insulation has lower temperatures during daytime compared to the bottom pond temperature of the base case scenario (Roof pond with white textile floating on water level). The mean daily maximum temperature of the bottom pond temperature in the Base case Scenario is 33.13°C, thus 2.63°C higher comparing to the corresponding mean maximum of the roof below insulation. The fluctuation of the temperatures of the roof below insulation is low. The mean daily minimum is 28.6°C, while the corresponding temperature of water in the Base Case scenario is 6.0°C lower.

The total thermal performance of pond with aluminum foil seems to be better compared to the other tested devices, since the daily minimum and maximum bottom pond temperatures are lower. The mean daily maximum water temperature reaches, 26.35°C, the mean daily minimum reaches 22.23°C, while the overall mean daily bottom pond temperature is 24,07°C. Concluding, the fluctuation for the roof above insulation panel and the corresponding value of bottom pond temperatures are 7.61°C and 5,27°C respectively.

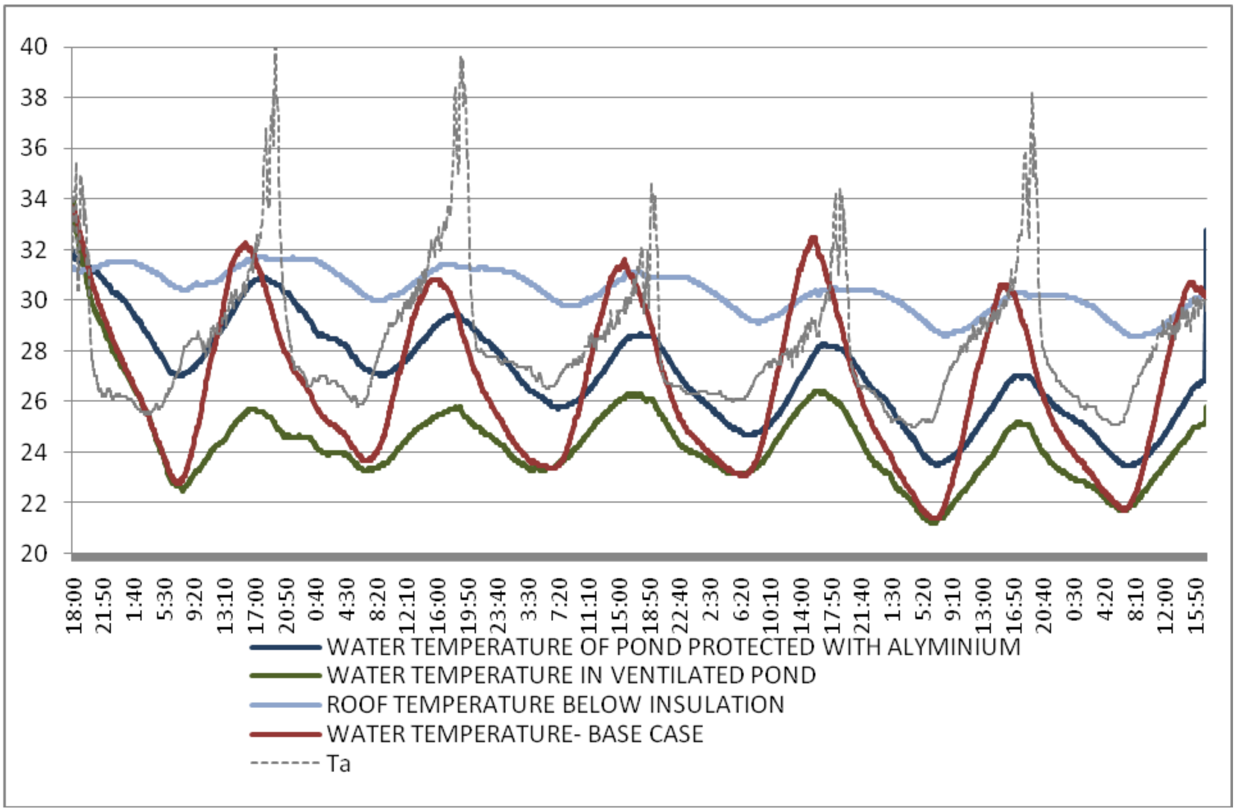

Figure 2: Bottom pond temperatures of three ponds. The aluminium foil is placed on water level, while the ventilated pond is protected by an aluminium layer above water level. The base case represents the pond with floating white textile. The records are referred to the period between 13th and 19th of July 2010.

4.2 The effect of the positions (below and above water level) of protective layer to the bottom pond temperature

The second period of experiments refers to the period between the 13th and the 19th of July 2010, as listed in Figure 3. An aluminum layer 5mm thick is placed above water level, representing a ventilated pond. The other pond has an aluminum foil, floating on water level. The third recorded pond, representing the Base Case Scenario is protected by a white textile floating on water level. Water depth is kept constant to 0.10m. Figure 2 shows the record temperatures for the second period of experiments.

Bottom pond temperature of the ventilated pond is represented by a curve that is almost parallel to the pond with a floating aluminum foil; the temperature difference between daily mean maximum is 2.68^{o}C (=28,88-31,56) while the corresponding value for the mean daily minimum values is 2,7^{o}C (=25,58-22,88). The daily minimum water temperature of the ventilated pond, is equal to the corresponding value of the Base case Scenario.

Bottom pond temperature of the ventilated pond has low fluctuation. The mean temperature for the ventilated pond is 24.32^{o}C, while the corresponding value for the roof below insulation is 6^{o}C higher. Placing an aluminum foil on water surface results daily decreased maximum water temperatures and increased minimum comparing to the corresponding values of the Base Case scenario. Concluding, the ventilated pond results a remarkable bottom pond temperature reduction, compared to the other investigated ponds.

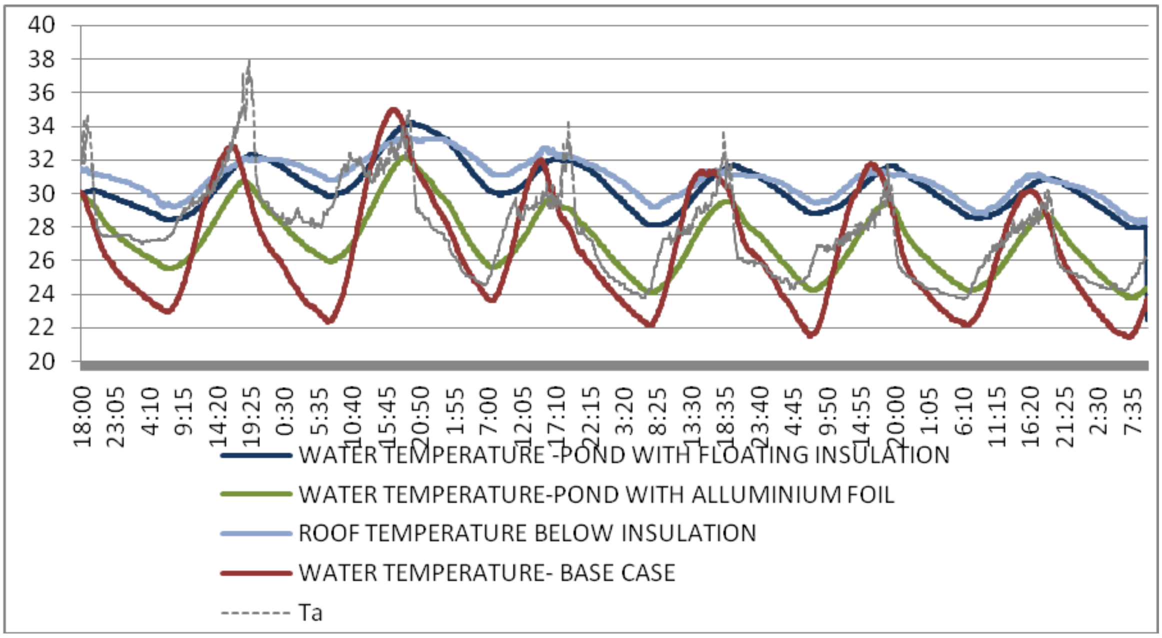

Figure 3: Bottom pond temperatures of three ponds. The aluminium foil is placed on water level, an insulating panel flows on water level. The base case represents the pond with floating white textile. The records are referred to the period between 23th and 30th of July 2010.

4.3 Comparing a roof pond with floating insulation to another one with floating aluminum foil.

An insulated panel of extruded polystyrene 3cm thick is floating on the water level of the pond. The insulating panel is covered externally to an aluminum foil, in order to reflect direct solar radiation. The other pond has an aluminum foil floating on water level, while the third one has a while textile representing the Base Case scenario. Water level is kept constant to the 10cm. The records of the period between 23rd and 30th July 2010 are listed in Figure 3.

The thermal performance of the pond with aluminum foil floating on water level has been described on the previous experimental period; the daily minimum temperatures of water are higher compared to the corresponding values of the Base Case scenario. On the other hand, the daily maximum temperatures of the pond with aluminum floating on water level are lower compared to the Base Case scenario.

The pond with the floating insulating panel, has reduced temperature fluctuations, similar to the ones of the roof avove insulation. As a result, the water below it, does not contibutes to the heat loss mechanism, since it does not encourage evaporative losses. As a result, this pond is not worth to be further investigated.

5. CONCLUSION

Roof pond with gunny bugs, is a roof pond variation proposed about a decade ago. The open pond is protected by a textile that is kept afloat on water surface. One of the advantages of the system is that it does not demand any daily operation or maintenance. The emissivity of the protective layer proved to be a critical parameter, affecting bottom pond temperature according to a parametric study.

The present study investigated a number of alternative materials for roof ponds protection in a variety of positions, thus above water level and floating on water level. The tested materials were the white textile, ironing board, and aluminum foil and aluminum layer. The pond with the white textile floating on water level represents the Base Case scenario, thus the other tested devices are being compared to that.

The experimental analysis showed that the use of reflective materials for water protection together with encouraging evaporative losses, can lead to bottom pond temperature reduction, compared to the Base case scenario. The ventilated pond, protected with an aluminum layer gave lower daily maximum temperatures, while the minimum ones are practically equal to the corresponding values of the Base case scenario (pond with floating white textile).

Further investigation should focus to a number of issues related to large scale application of the investigated system. Further analysis can propose the materials strong enough to be exposed in ambient conditions, the accomplishment to specific building regulations, and aesthetic issues. Furthermore, the performance of the system in regard to the climatic conditions could be also being investigated.

6 ACKNOWLEDGEMENTS

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