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Engineering Performance of Garden Roofs in North (Canadian) Climate - 5 Years of Field Data[1]

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Garden Roof Systems (GRS) are specialized roof systems that support vegetation growth on rooftops. Industry claims that the GRS offer a number of benefits such as longer service life for the waterproofing membrane, reduction in the heating/cooling needs of a building, thereby lowering the energy demands and associated greenhouse gas emissions. It is also expected that GRS can reduce storm water runoff and improve water quality. Technical advances in roofing membranes and components offer techniques to install GRS in different climatic conditions. To quantify the engineering performance of the GRS in cold climates, National Research Council Canada instrumented and monitored the field performance of a generic GRS at its Ottawa campus. The instrumented building is 9 m (30 ft) long, 8 m (26 ft) wide, and 5 m (16 ft) high. It has an experimental roof area of 70 m^2 (800 ft^2) and can represent a low-slope industrial roof. The roof was divided into two equal sections separated by a 1 m (3 ft) median. On one section, a generic garden roof was installed and on the other section, a conventional roofing assembly with a modified bituminous membrane was installed as a Reference Roof System (RRS). Based on five years (2001 to 2005) of field monitored data, one can conclude the following:

Roof membrane temperature

Observation

- Figures 1 to 3 provide the engineering statistics (minimum, mean, and maximum) of the membrane surface temperature of the RRS and GRS. Ambient temperature data are also presented for comparison purposes. Bar charts represent monthly averages of the minimum, mean, and maximum values for a five-year duration.
- Mean temperature values (Figure 1) of the GRS's membrane surface are similar to that of the ambient conditions with the exception of the winter months (November to March), during which the membrane temperature of the GRS is higher than the ambient conditions. Note that in the case of GRS,

[1] *To respect the space limitation of the conference proceeding, this paper presents the data in an executive summary form. Details of the field monitoring program (photographs and figures of the field location, construction, and instrumentation) and figures showing yearly data in the form of monthly bar charts for three characteristic parameters: temperature, heat flow, and rain runoff data are available upon request from the authors.*

membrane temperatures are measured below the growing media and vegetation and thus the membrane is protected.

- Mean temperatures of the RRS membrane, in general, are relatively warmer than the ambient conditions throughout the year. In the summer months, mean temperatures are about 10ºC higher than the ambient due to reflective characteristics of the RRS's membrane.
- Minimum temperature values (Figure 2) of the GRS membrane are higher than the ambient temperature conditions. This may be due to the fact that the thermal mass of the growing media prevents heat loss. The respective temperature values of the RRS are always lower than the ambient conditions.
- An opposite trend is observed for the measured maximum temperature values (Figure 3). In the case of the RRS, the membrane temperatures are higher than the ambient conditions throughout the year, which may be due to the type of membrane used in the RRS.

Implications For Durability Testing

- For durability evaluation, membranes are exposed to accelerated weathering process to simulate thermal stresses. Membranes to be used in the GRS can be conditioned at a constant temperature for a long period of time (duration not specified) representative of the ambient conditions. Whereas for the RRS's membrane, cyclic temperature conditions can be considered for a shorter period.

Practical Limitations

- Observation of the RRS's membrane temperature can differ significantly depending on the reflective characteristics of the membrane surface and material composition. Thus, one should not generalize these observations to other roof assemblies such as reflective roofs and protected membrane roofs that are used in the roofing industry.

Energy Performance

Observations

- Figures 4 and 5 respectively summarize the heat flow into and out of the RRS and GRS. Negative values indicate heat flow out of the roof system (heat leaving from the building interior). Positive values indicate heat flow into the roof system (building interior is heated).
- GRS and RRS have similar performance in the colder months (November to February). This indicates there should not be change in the space-heating requirement of the building due to the type of roofing system in place.
- During the months of April to September, the RRS (Figure 4) has a heat flow into the building higher than the heat out to the building, which can increase the cooling load requirement of the building.
- In summer, the cooling energy requirement due to the GRS (Figure 5) is kept to a minimum.

Design Implication

- When designing the air conditioning systems of buildings with GRS, with given climatic conditions, provisions can be made to reduce the cooling load requirement. Alternatively, an insulation thickness trade off could be considered to achieve the same energy performance.

Practical Limitations

- GRS growing media thickness and plant types will have an impact on shading thermal mass and thus can alter the system energy performance.

Rain Water Run Off

Observation

- Figure 6 summarizes the rainfall and runoff data. Each bar represents the cumulative data for the respective month averaged over a period of four years.
- Rain runoff of the RRS is less than the total rainfall due to evaporation.
- During the summer months, run off from the GRS is significantly less than the total rainfall due to the retention capacity and the evaporation potential of the growing media and plants.

Design Implication

- In the summer months, the GRS can be treated as buffer zone to retain rain and offer advantages in the storm water management process.

Practical Limitations

- Saturation of the growing media can occur depending on the growing media and rainfall intensity, which can lead to ineffectiveness in the retention process.
- Increases in design live loads of the building structure are necessary with the GRS due to growing media saturation.

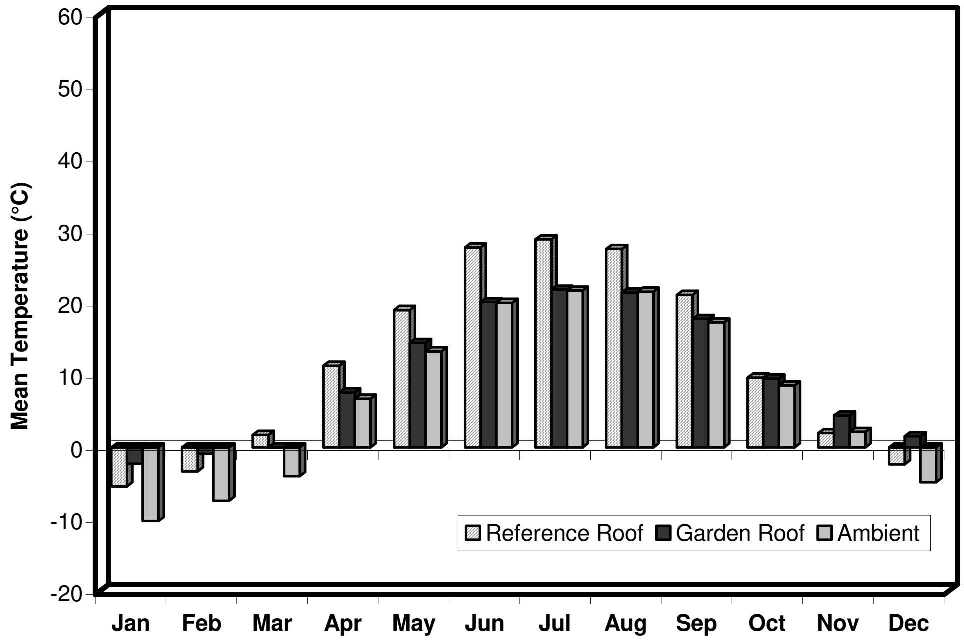

Figure 1. Measured mean temperature at the membrane surface, averaged over a five-year period (2001-2005).

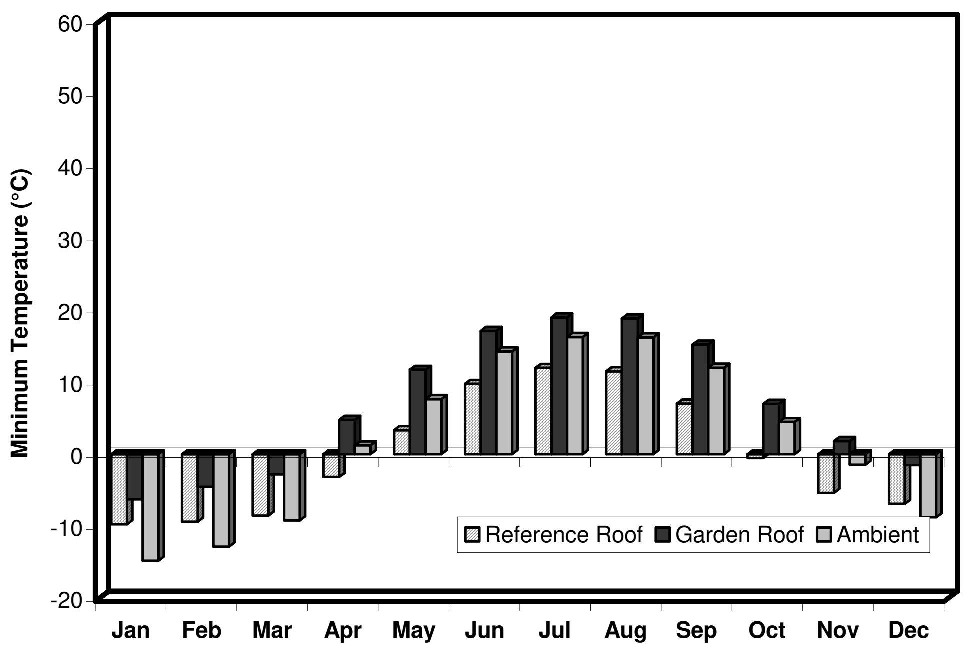

Figure 2. Measured minimum temperature at the membrane surface, averaged over a five-year period (2001-2005).

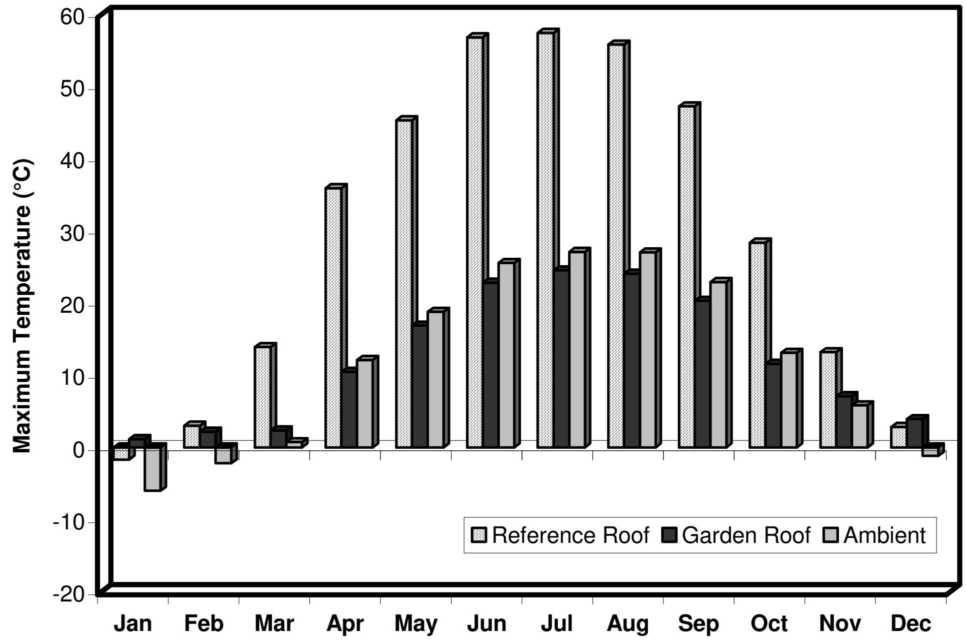

Figure 3. Measured maximum temperature at the membrane surface, averaged over a five-year period (2001-2005).

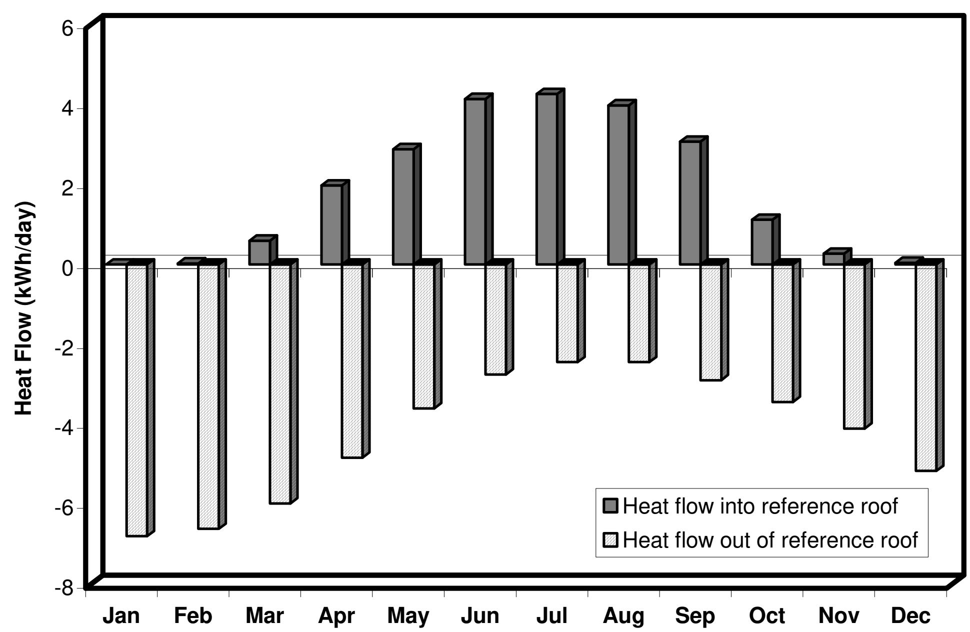

Figure 4. Monthly heat flow through the reference roof, averaged over a five-year period (2001-2005).

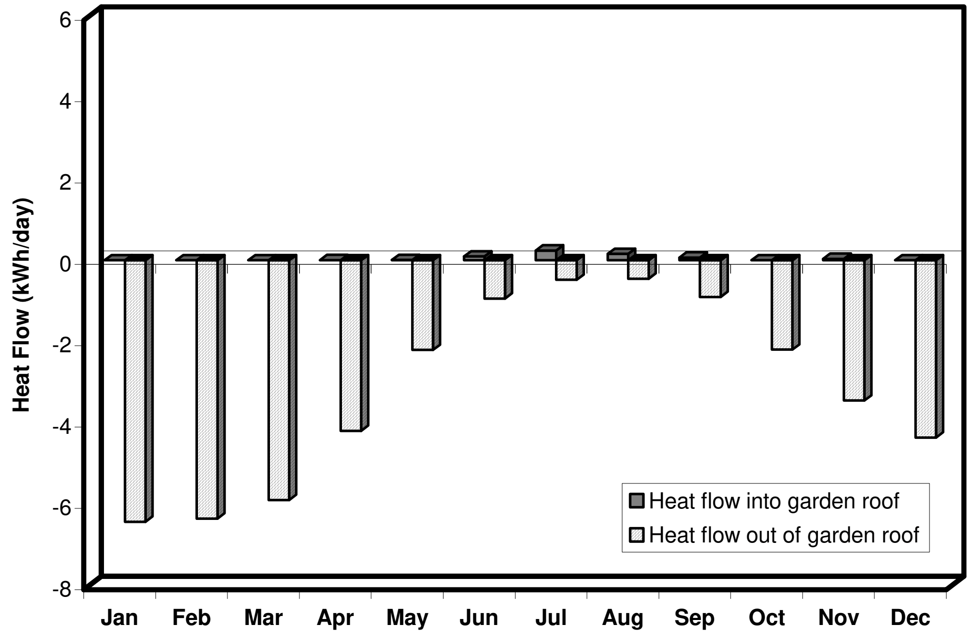

Figure 5. Monthly heat flow through the garden roof, averaged over a five-year period (2001-2005).

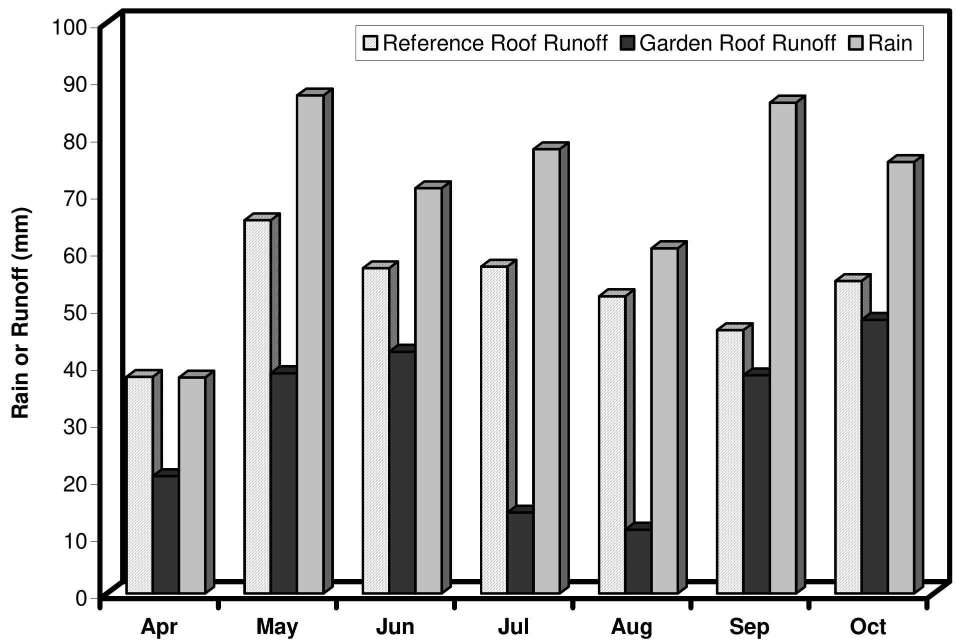

Figure 6. Cumulative monthly rainfall and runoff from the reference and garden roofs (averaged from 2002 to 2005).