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3.2: New Directions in Green Roof Research

GREEN ROOF RESEARCH IN BRITISH COLUMBIA- AN OVERVIEW

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Abstract

In 2002 a stakeholder workshop held in Vancouver identified the major barriers to the market penetration of green roofs in BC as the lack of climate-specific performance data, the absence of third party testing and verification of green roof systems, and a lack of demonstrated feasibility. To address these issues the British Columbia Institute of Technology (BCIT), supported by a consortium of regional government organizations, industry associations, and material suppliers, created a green roof research program. In collaboration with the National Research Council of Canada (NRC), a dedicated field test site, the ***Green Roof Research Facility (GRRF)*** was constructed and commissioned in 2003. This presentation will discuss BCIT's educational strategy in green roof technology, design and construction of the facility, instrumentation for data collection, and preliminary data.

BCIT has expanded its capacity to create the ***Centre for the Advancement of Green Roof Technology (CAGRT).*** The Centre's principle functions within the education and research forum are to develop the regional infrastructure network to inventory performance of green roofs; develop a system performance evaluation module, provide a testing and verification facility for the local green roof industry, and improve public awareness of the technology through education and demonstration.

Introduction

BCIT is one of Canada's largest polytechnic institutions with 50,000 students currently enrolled in 200 full-time, part-time, and distance programs. One of BCIT's research objectives is to increase its capacity for innovation at the community, regional, and provincial levels. Strategies to meet this objective focus on increasing research activity and capacity, integrating research into program design, integrating students into research, developing new partnerships, and encouraging entrepreneurship as a tenet of all research activities to assist

Green Roof Research Facility

faculty to develop new ways of working with local businesses and industries to spur innovation and economic growth.

With growing awareness of environmental preservation in the design and construction sector and the Federal government's commitment to the Kyoto Accord and addressing climate change (2004 Throne Speech), a green roof industry is emerging in Canada. The interest in green roof technology is particularly strong in BC due to its favourable climate and regional government environmental commitments. In fact, the City of Vancouver's South East False Creek Policy Statement requires installation of green roofs on at least 25% of roof areas in the City's new sustainable urban development project along the southeast shores of False Creek (1). A stakeholder workshop held in Vancouver in 2002 identified the major barriers to the market penetration of green roofs in BC as being primarily rooted in the lack of climate-specific performance data, the absence of third party testing and verification of green roof systems, and a lack of demonstrated feasibility. The Green Roof Workshop held in Vancouver in March 2002 summarizes this need: Although green roofs have been widely adopted elsewhere in North America and in Europe, more technical research is required to understand the site level performance and regional scale benefit of green roofs specific to our region. Such research is critical to establishing standards, policies and programs to support broader implementation. (2) In 2003, in collaboration with the National Research Council of Canada, a field test site, the Green Roof Research Facility (GRRF), was constructed and commissioned at the Great Northern Way Campus to provide a demonstration site and performance data for the local community. GRRF is a 100 m^2 building dedicated to research and performance data acquisition on stormwater source control and thermal performance of green roofs. The GRRF project schedule is based on a six-year project life span. The project may continue, subject to site availability and research needs. The first year was dedicated primarily to project planning and facility construction, the second year to commissioning, and the third through sixth years to testing, analysis, and reporting.

This research is designed to improve the understanding of the many public and private benefits of green roofs (3). The results will be directly applicable to the future densification in the Lower Mainland. Vancouver has the highest percentage per capita in Canada of individuals living in multi-family housing and the highest population density per square kilometre in Canada (4). This is itself a prerequisite to the concept of sustainable development. While the research facility is a wood frame construction typically used in multi-family housing, the data collected will also be transferable to other building types. This research also has broader environmental implications. At the building scale, a green roof will reduce energy consumption, thereby lowering greenhouse gasses. At the urban scale, the mass adoption of green roofs will reduce the urban heat island effect (5). Through energy efficiency and reduction in the urban heat island, green roofs can become a part of the solution and an action response to the Kyoto Protocol. The data obtained will also be useful in determining cost benefits of green roofs based on reduced energy consumption. The green roof plants and soils absorb rainwater, reducing stormwater runoff into the city system. This research will quantify the ability of green roofs to reduce the total volume of stormwater and delay runoff in this climatic region. The data collected will contribute to the calibration of a development scenario modeling tool developed for the restoration and protection of the regional watersheds, which are under continual pressure due to rapid density increase and infrastructure growth in the region (6,7).

<u>BCIT's Green Roof Research Program Phase 1</u>

Knowledge Transfer and Curriculum Integration


Student Design Project

Advancement of green roof technology cannot solely be driven from the design and planning process, success, as with all emerging building technologies, hinges on successful construction implementation. In the project's initial year, BCIT faculty and students, along with consultants, contractors, and industry support, designed and constructed the building, installed instrumentation for data collection, and created a resource centre for green roof technology. Fifteen faculty and over 200 students in BCIT's polytechnic trades programs have now had first hand experience in the construction of a green roof project. To provide this sector of the construction industry with the base knowledge and confidence of green roof technology provides fundamental support to the advancement of successful green roof implementation in the region. The carpentry apprentice program produces 114 graduates each year. Based on career demographics, these students will become the leading general contractors and construction managers that will advance the British Columbia construction sector over the next 20 years. Additional trade apprenticeship students involved in the green roof program included steel fabrication, mechanical, electrical, millwork, painting, and finishing students.

In each application, the trade students were introduced to green roof technology through a lecture/seminar session(s) and then spent 14 to 40 hours on construction. Phase 1 of the green roof initiative included a curriculum integration project assessing the viability of interfacing green roof technology learning outcomes into a wide spectrum of courses and programs in BCIT's School of Construction and the Environment. Previous to 2002 none of the technology or polytechnic trades programs incorporated green roof specific learning outcomes. Program and course offerings were assessed to determine if and where green roof technology could be integrated into the existing curriculum. As the facility was originally developed with resources from the department of Architectural and Building Engineering Technology, the integration of green roof technology has spontaneously occurred within courses of that department, namely those pertaining to planning, architectural, materials and processes, construction, specifications, building science, civil and structural engineering, and systems synthesis. Further curriculum integration must occur in many areas of construction technology: estimating, and project and construction management, land use planning, environmental issues in construction and urban ecology as examples.

Students from BCIT, Emily Carr Institute of Design (ECID), and the University of British Columbia (UBC) are now involved in various green roof research projects at the GRRF. Projects include green roof water quality studies (BCIT), assessing data collection methodology (BCIT), prototype development of a vegetative tile for slope roof applications (ECID), and urban agriculture application (UBC).

Green Roof Research Facility

In 2002 a 40-acre light industrial land track was donated to BCIT, ECID, Simon Fraser University, and UBC for the formation of an inter-institutional academic campus. The new Great Northern Way Campus site was selected for the green roof project for three reasons. First, it provided sufficient area to erect a 5.94 m (20') high structure with a level roof free of shading obstruction from adjacent building or trees, which would have compromised the data collection. Second, the site location is 5 meters above sea level and in a micro climatic location that receives rainfall levels close to the average rainfall level throughout the Lower Mainland. Third, during the time frame of planning, the City of Vancouver released five strategic plans for the southeast False Creek sustainable community sited 2 km to the west (8). Subsequent to the GRRF construction, the 2010 Olympic Village and the GNW campus have been included as key components of the City of Vancouver's Sustainability Precinct. The building was located aligned with geodetic coordinates, this was not for purposes of green roof research but with a potential for future vegetated wall systems.

Site Location, City of Vancouver

Design and Construction

Demonstrating green roof technology with a dimensional wood frame structural system exposes and diminishes the myth of the inappropriateness of green roofs on wood frame multi-family housing. General population concerns include rotting of the wood deck, with the misunderstanding that a concrete deck is required to secure a waterproof system. At the outset two students on an educational co-op through the Architectural and Building Engineering Diploma program designed and produced the drawings and models of the GRRF. This was supported by the consulting services of Earth Tech Consulting Engineers for structural, electrical, and mechanical systems.

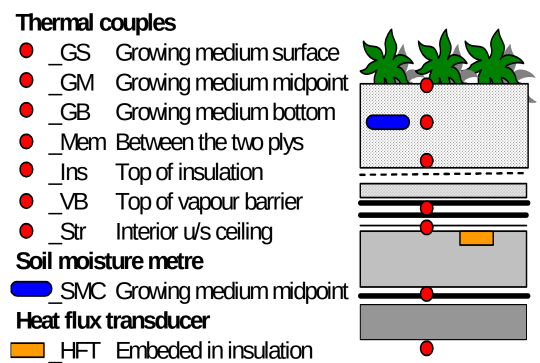
The GRRF has short spans of 3.6 m (12'); the 38 x 300 mm (2" x 12" nominal) roof framing can support up to 356 mm (14") of fully saturated growing medium. For reduced load, 38 x 254mm (2" x 10" nominal) framing is required to support 150 mm (6") of growing medium and 38 x 204 mm (2" x 8" nominal) to support 75 mm (3"). The GRRF demonstrates the performance of the installed membrane and drainage system. However, students constructed models of several different green roof systems, and each, identified by supplier, are exhibited on site. This demonstration role of GRRF is directed toward the immediate concerns and issues regarding the implementation of green roofs to the building owner, the building design team, and the local authorities having jurisdiction.

Research opportunities and the options for the profiles for the green roof systems were selected by the research partners, BCIT/NRC, and the funding consortium. The consortium was comprised of regional government organizations, industry associations, and material suppliers. In order to maximize data collection and analysis of comparable data sets from two extremely varied climatic conditions within Canada, the same generic system was installed at the GRRF as was installed at the Field Roofing Facility (FRF) at the National Research Council in Ottawa. Three, 33 m^2 research roofs are separated by demising parapets 355 mm (14") high. The reference roof without a green roof system is located in the center, with a green roof to the east and west. The west roof has 150 mm (6") of growing medium, as per the FRF at the IRC/NRC Ottawa (9). Priority established at the first meeting of the funding consortium was to trail and collect performance data from the most economical roof profile thought to be compatible with the coastal climate and applicable to big box retailers and industrial building. Therefore, the east green roof has the same generic system as the west green roof but with 75 mm (3") of growing medium. This provides comparable data on both the thermal performance and stormwater mitigation potential of two depths of growing medium from two climatic zones. It is expected that a shallow growing medium depth might be sufficient in moderating the heat transfer between the building and the environment through the roofing system during the mild Vancouver climate. However, the shallow depth may not be sufficient for stormwater mitigation in the rain season of the coastal climate.

Members of the staff, executive, and board of the Roofing Contractors Association of British Columbia (RCABC) donated their time and expertise to install the two-ply SBS modified bituminous membrane system. Before roofing, a plywood slope was installed above the structural deck to provide consistent 2% slope to drain. This was the selected alternative to sloped insulation in order to provide a consistency in insulation depth throughout the measurement areas. The application of the roof above the sloped plywood deck consists of the following layers: kraft laminate vapour barrier, polyisocyanurate insulation with cellulose facers (R28), 4mm rigid asphalt protection board, a 180 gram polyester reinforced thermal fusible base and a 250 gram polyester reinforced SBS cap sheet. The cap sheet contains root repellant in its formulation to prevent damage from roots.

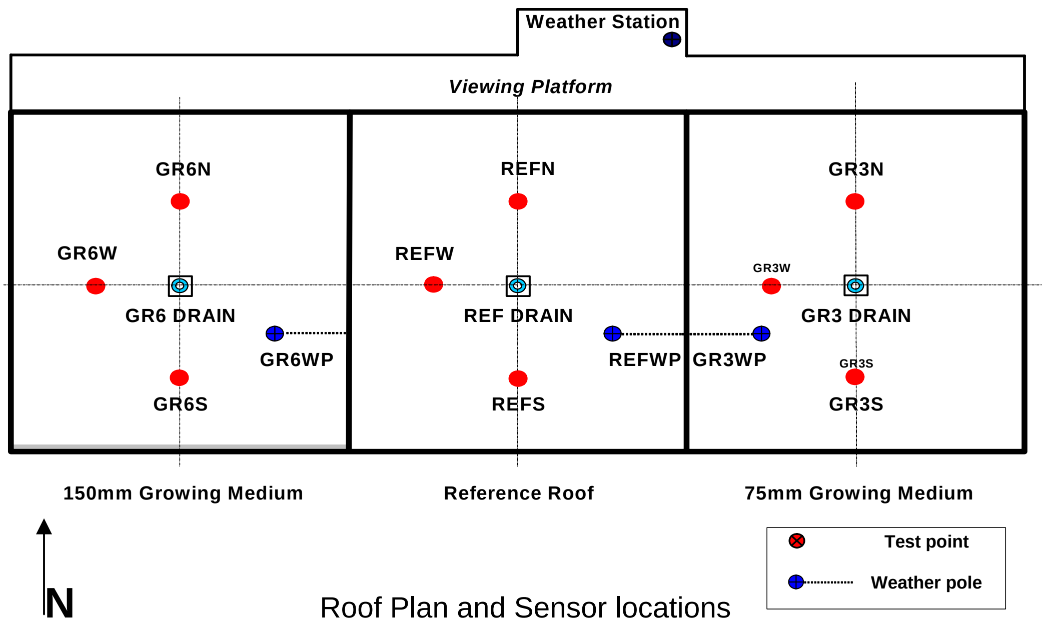
Instrumentation and Sensor Location

The data collection methodology recognizes the vegetative roofing as an engineered building envelope system. Therefore, the performance of green roofs is being evaluated as an integral part of the building envelope. The instrumentation was located, secured, and documented as each layer of the roof was installed. For data collection on thermal performance each roof has three test points with a vertical series of thermal couples connected to the multiplexers of the data acquisition system. The thermo couples were installed between each layer of the roofing system: the underside of the plywood deck (underside of open ceiling), on top of the vapour barrier, on top of insulation, and between the base and cap sheet of the SBS membrane. The diurnal temperature range measured in the two-ply membrane provides critical data on the ability of the green roofs to reduce heat aging and thermal stresses in the roof membrane. A heat flux transducer (HFT) is located in plane with the top surface of the insulation. The HFT measures the amount and direction of energy flow through the roof. These measurements will provide the data required to determine the contribution of the green roofs to reducing the amount of energy required to maintain a desired interior temperature at GRRF. Cost savings for heating and cooling due to the implementation of the green roofs will be calculated based on data generated. The two green roofs have the addition of a soil moisture meter at mid point of the growing medium and thermal couples at the base level, mid level, and top of the growing medium.



Test Point Sensor Location

The BCIT Technology Centre designed and manufactured three specialized flow meters to measure the extreme range of runoff from the test roof sections. These flow meters were built on the same working principle of tipping bucket rain gauges used for hydrological measurements. Runoff volume tips the calibrated bucket, which passes the magnetic sensor sending a pulse to the data logger. The runoff gauges are encased in a rectangular glass container. If an audience is at the research facility during a rain event they are provided with real-time visual evidence of the performance of a green roof in stormwater mitigation. The



Roof Plan and Sensor locations

resolution is 10 times greater than the standard hydrological rain gauge used on the GGRF weather station, providing increased accuracy in runoff measurements.

The weather station located on the rooftop monitors air temperature and relative humidity, solar radiation, rainfall, wind speed and direction. Each of the three test roofs has an independent weather pole to monitor reflected solar radiation, ambient temperature, relative humidity, and temperature profiles above the roof with thermal couples located at 50 mm (2”), 125 mm (5”), and 225 mm (9”) above the cap sheet or growing medium. The 93 sensors are connected to the data acquisition system. Data is transferred to an onsite CPU and backup locations over the BCIT backbone network. Data can be accessed locally and remotely for analysis.

Soil and Plants

Planting 2003

Cornelia Hahn Oberlander, the landscape architect consultant to the project, specified the soil mixture and plant species. The generic soil mixture consisted of 1/3 sand, 1/3 white pumice, and 1/3 organic matter. The plants were grown for mid June installation; however, they were not planted until middle of August due to a construction delay. Irrigation was provided from planting and for one full year. Despite the untimely planting, five of the species survived the summer drought and wintered well with significant root development. The Sedum Lydium was replaced in the spring 2004 with Sedum Sexangulare. The exact cause of the Sedum Lydium failure was not determined. 30% of the Festuca Scoparia plugs were pulled within the first month of planting by black crows. In the spring the most developed Festucas Scoparia were divided and replanted to continue the planting pattern. Additionally, Hart Fescue was seeded with the three grasses. The decision to inter-seed was made based on the goals of the research plan in which fully established coverage was required for data collection.

19 to 20 per Row Fetuca scoparia Bearskin Fescue	10 Rows		15 per Row Sedum acre Mountain Moss Sedum	8 Rows
23 per Row Bouteloua graclis Blue Gramma Grass	12 Rows		14 per Row Floriferum Weinstephaner Gold	6 Rows
20 per Row Carex glauca Blue Sedge	10 Rows	NO PLANTING	14 per Row Sedum Lydium* Lydian Stonecrop	8 Rows
GR6 150 mm Growing Medium		REFERENCE ROOF	GR3 75mm Growing Medium *Replanted with Sedum Sexangulare	

Planting Schedule

Preliminary Data from Green roof Research Facility

The data and discussion are provided as a summary of the first 30 days of observation of the fully establish green roof systems at the Green Roof Research Facility. The inclusion of this preliminary data is to indicate scope of data collection and methodology. The data and summary are based on the collection of 112,320 pieces of data every 24 hours over the 30-day observation period. Included in this summary are analysis of climate, stormwater retention and delay, temperature profiles, and heat flux. October 5, 2004 is highlighted in graphs for a detailed description of defined rainfall event after several days without rainfall. Even though the diurnal temperature range on October 5 is less than the average within this observation period, the data provides a clear description of the effects of the green roof system in terms of the temperature profiles and heat flux through the three monitored roofs.

Rainfall and Runoff

Rainfall reached 100 mm over the first 30 days measured. Seven defined rain events accounted for 60% of the 30-day rainfall. An event is defined as a discrete period of precipitation separated in time from other recorded precipitation by at least 6 hours before the start of the event and by at least 6 hours after. Runoff is defined from start of runoff to 6 hours after the end of event or until the start of the next defined event. Delay is defined as the time difference from the reference roof runoff start and the green roof runoff start. Event categories by volume only are as follows: Light, L <= 2 mm; Medium, M = 2 to 10 mm; Heavy, H > 10 mm.

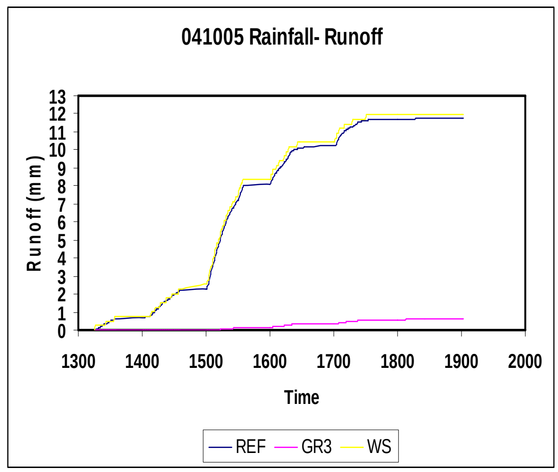


Figure 1 Event 3 Cumulative Runoff

The graph in Figure 1 illustrates the period of heavy rainfall observed on Day 12 of the observation period. During this event, 12.19 mm of rain fell over the duration of 4 hours and 23 minutes. No rainfall was recorded in the previous 11 days. The green roof with 75 mm (3") of growing medium (GR3) mitigated 95% of rainfall runoff (see Figure 1). This event clearly exemplifies the potential of green roofs to mitigate stormwater runoff but is tempered through

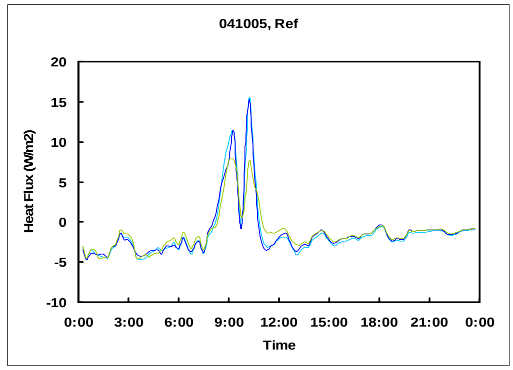
		Daily data			Event data			WS	Ref	GR3	
	Date	WS mm	Ref mm	GR3 mm	Event # *	Category	Duration	mm	mm	mm	Delay
Day 11	04-Oct-04	0	0	0	-	-	-	-	-	-	-
Day 12	05-Oct-04	12.5	12.5	0.6	3	H	4h23	12.2	12.0	0.6	1h46
Day 13	06-Oct-04	7.1	7.4	3.8	4	M	4h09	4.3	1.7	2.4	0h30
					5	M	1h07	2.8	1.4	1.3	0h22
Day 14	07-Oct-04	0.0	0.2	0.1	-	-	-	-	-	-	-
Day 15	08-Oct-04	27.7	26.8	22.8	6	H	16h20	27.7	26.8	22.8	1h54
Day 16	09-Oct-04	10.4	10.3	8.3	7	H	18h17	10.4	10.3	8.3	0h30
	10-Oct-04	0.0	0.3	0.7	-	-	-	-	-	-	-

Figure 2 Excerpts Prelim[illegible]mmary for Stormwater retention

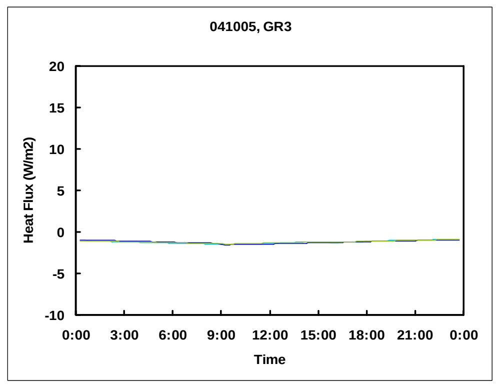
the examination of the following four events in which the growing medium is close to fully saturated. On Day 13 two medium events occurred, and GR3 had a retention rate of 44% and 52% respectively. On Days 14 and 15, retention decreased to 17% and 20% in the next two rain events in which over 30 mm of rainfall was measured over two long duration events (16h 20min, 18h17min respectively). GR3 retained of 67% of rainfall over the 30 measured days. Stormwater data for GR6 has not been included in this initial assessment (see Figure 2).

Thermal Performance

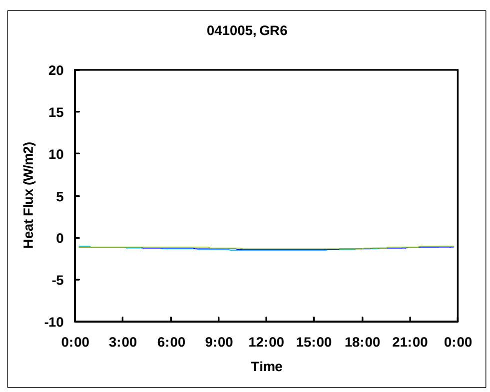
The first 30 days of measured events fell within an expected temperature range for the British Columbia west coast, with a seasonal range from 9°C to 21°C with overall average of 14°C. Regardless of this temperate range the diurnal temperature range at the measured point between the two-ply SBS membrane of the non-green reference roof (REF) reached 50°C in one 24-hour period on October 2. On October 5, Day 12, when the first of three rain events occurred, the diurnal range decreased to 25°C. The average diurnal temperature range over the first 30 days of measurement for the REF, GR3, and GR6 were 32°C, 3°C, 1.5°C respectively. Over the 30-day observation period in which the maximum daily air temperature peaked above 20°C on only two days, the green roofs clearly reduced the diurnal temperature range experienced by the roofing membrane significantly.



Reference Roof



GR3, 75mm Growing medium



GR6, 150mm Growing Medium

N North test Point
W West test Point
S South test Point

Figure 3 - Heat Flux

The heat flux transducer (HFT) were calibrated to register a negative number for heat flow out of the building through the roofs and positive number to show heat flow in through the roofs. The heat flux through the reference roof in this 30-day observation period shows a total negative heat flow of -1.603 kWh/m^2 through the roof during the night and a total positive heat flow of 1.031 kWh/m^2 in the daytime. No heat gain was observed through the two green roofs over the 30-day observation period. The total heat loss recorded for GR3 and GR6 were 0.701 kWh/m^2 and 0.715 kWh/m^2, respectively. Note that although GR6 contains twice the amount of growing medium as GR3, its thermal performance was practically the same as GR3 during this observation period – a relatively warm fall month. The slightly higher negative heat flow through GR6 over GR3 may be attributed to the doubling of the mass of wet growing medium drawing energy through the roof. Further analysis of temperature profiles may provide supporting evidence. The total heat flow through reference roof was 2.634 kWh/m^2 over the 30-day observation period. The green roofs reduced the heat flow to 0.701 kWh/m^2 and 0.715 kWh/m^2, a significant reduction of over 70% (see Figure 3).

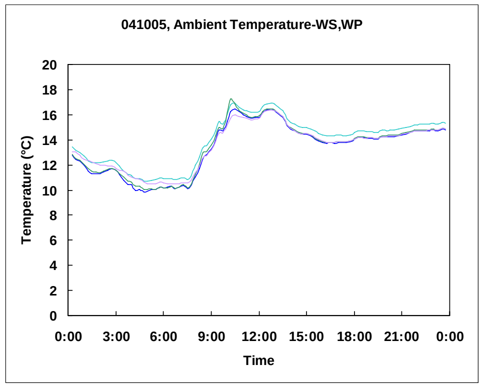


Figure 4, October 5, 2004
Ambient Temperature
(WS- Weather Station, WP- Weather Pole)

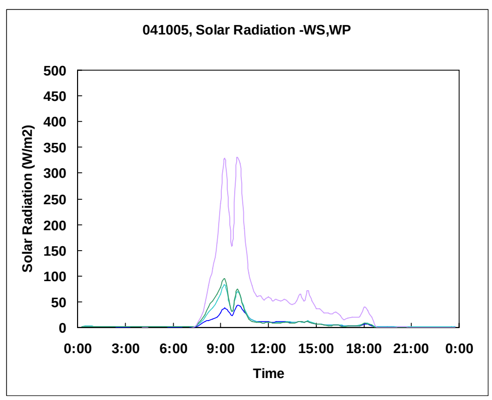
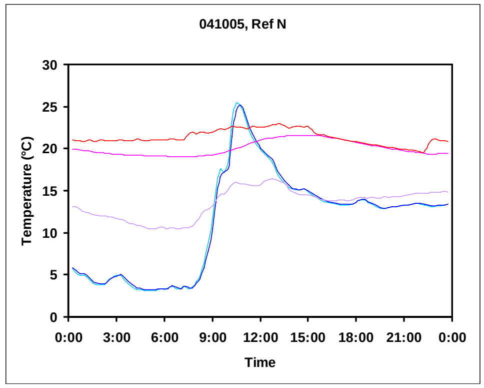


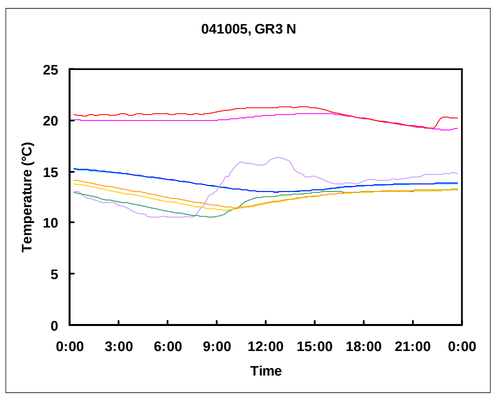
Figure 5, October 5, 2004
Solar Radiation
(WS- Weather Station, WP- Weather Pole)

Ref
GR3
GR6
WS

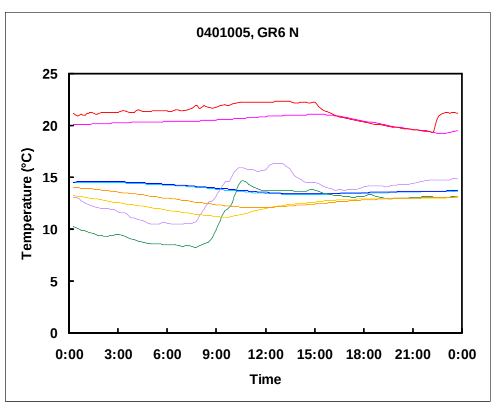
Figure 6, Temperature Profiles, October 5, 2004
These curves are plotted from thermal couples readings located at the north test point., Str- under side of structure, Vap- vapour barrier, Ins- Insulation, GB base of growing medium, GM midpoint of growing medium, GS surface of growing medium, WS- weather station temperature



Reference Roof



GR3, 75mm Growing medium



GR6, 150mm Growing Medium

Str — GB
Vap — GM
Ins — GS
Mem — WS Temp

Figure 6 Temperate Range

Previous Home Next

<u>Future of Green Roof Research for BCIT/BC Industry</u>

In response to growing demand from industry on product development and testing, BCIT was awarded NSERC funding to expand its current capacity and create the Centre for the Advancement of Green Roof Technology (CAGRT). The main goal of CAGRT is to support process and technology innovation within the growing regional green roof industry. These efforts are aimed at providing support to the design community and entrepreneurs who are endeavouring to bring new products, processes, services, and technology into the BC marketplace. CAGRT is also furthering BCIT's educational mandate and currently developing a regional infrastructure network and a system performance evaluation module.

Education Programming

In the fall of 2005, the first course offering of Green Roof Technology, ARSC 8210, is to be incorporated into BCIT's Bachelor of Technology in Architectural Science program. CAGRT will provide a practical learning environment for students in various disciplines, such as building science, architecture, environmental science, engineering technology, and trades programs. Specific involvement will depend on students' disciplines and interests and may include data collection and analysis, new product testing and development, system evaluation and validation, manufacture, quality analysis of runoff, and maintenance and operation of green roofs. As BCIT does not have a landscape or horticultural program, the institute will collaborate with other regional academic institutions in programming and research development in these areas.

Development of a Regional Infrastructure Network

The demonstration role of CAGRT is extremely important in accelerating the adoption of green roof technology by the entire local community. Demonstration aspects revolve around an infrastructure network incorporating the now commissioned GRRF and four significant green roof projects in planning stages in the Lower Mainland of BC. CAGRT will augment these green roofs with instrumentation and data acquisition systems for the collection of real-time data on stormwater runoff, quality of water for rain water harvesting, and thermal performance. Between the four projects identified, variables for analysis include deviations of slopes, exposures, drainage systems, light-weight growing media, and irrigation. Included in the regional infrastructure network is the Elevated Research Platform at the BCIT Burnaby Campus, the Motion Caption Building at Electronic Arts, and the Seymour-Capilano Water Filtration Plant.

System Performance Evaluation Module

The system performance evaluation module (SPEM) will consist of a complete roof installation with a controlled indoor environment. The module will monitor and collect real-time data for evaluation of stormwater runoff and thermal performance of new green roof products and systems. The modules can be located at BCIT, a manufacturing facility, or insitu at a demonstration site. Multiple modules can be used for comparative system evaluations and for predictive performance of green roofs in different geographical locations and climatic conditions. The module's monitoring instrumentation will include a data logger with battery backup and wireless communication, thermal couples, heat flow sensor, soil moisture sensor, temperature and humidity sensor, and rain water flow meter. The module will be constructed to simulate controlled indoor temperature below the green roof system. CAGRT will develop a test protocol to be used with the module for evaluation of green roof systems. Green roof products and systems suitable for evaluation include drainage mats, water retention (reservoir) systems, vegetation support mats, light-weight growing media and drought-resistant vegetation (as independent planting or as ready grown sedum mats), modular systems, and green roof maintenance programs. Small- and medium-sized enterprises as well as design consulting firms in landscape and architecture have already expressed interest in engaging in collaborative research programs facilitated by the SPEM.

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