

MEASUREMENT OF THE SOUND ABSORPTION CHARACTERISTICS OF VEGETATIVE ROOFS

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1. INTRODUCTION

Vegetative roofs have the potential to provide excellent external/internal sound isolation due to their high mass, low stiffness and their damping effect, and to provide a high level of sound absorption due to the low impedance of the vegetative substrate layer. The acoustical characteristics of vegetative roofs provide ecological contributions to the urban environment through a reduction of noise pollution from aircraft, elevated transit systems, and industrial noise. Vegetative roofs can reduce sound transmission into the interior of buildings, contributing to improved room acoustics through a reduction in noise and hence a reduction in distraction and stress (Connelly & Hodgson 2008). Through surface absorption, vegetative roofs will affect the propagation and build-up of positive and negative sounds and reduce reverberation in enclosed rooftop areas, altering the quality of the soundscape and the habitability of rooftops.

Vegetative roofs can be comprised of various material layers: root barrier, water reservoir/drainage layer, filter fabric, substrates and plants. The layer thought to have the most significant effect on the vegetative roof's acoustical characteristics is the layer of the vegetation and substrate. The vegetative substrate is complex to characterize; it varies in terms of the depth of substrate, the substrate constituents and physical properties, the plant's aerial biomass and root structure, as well as the dynamic in-situ microclimatic and conditions which vary over season and time.

2. METHOD

2.1 Laboratory Measurements of Vegetative-Roof Substrates Using an Impedance Tube

In order to understand the sound absorption characteristics of an established vegetative roof system it is first of interest to examine the absorption characteristics of the substrate independent of vegetation, before the vegetative substrate layer is investigated as a complex layer.

The most direct method to evaluate the absorption potential of vegetative-roof substrates is to measure the complex reflection coefficient in an idealized incident sound field using an impedance tube [1]. From the measured complex reflection coefficient, the normal-incidence sound-absorption coefficients and normal specific acoustic impedance ratios are calculated. A parametric experimental study was developed to determine the physical characteristics and properties of vegetative-roof substrates which contribute most significantly to the absorption of

sound energy. The substrate characteristics of interest include: particle density, bulk density, total porosity, percentage organic matter, particle-size distribution. The properties which are a function of the micro-climate and site conditions of interest include volumetric water content and compaction.

Six vegetative-roof substrates and the primary three constituents – sand, compost and pumice – were measured in an impedance tube at three levels of volumetric water content: oven-dry (0%), wilting capacity and field capacity, and at two states of compaction. The permanent wilting capacity and the field capacity are percent by volume quantities which define the minimum and maximum available water content required for plant viability, and hence defined the limits of volumetric water content. The substrates were measured when either non-compacted or compacted to approximate in-situ conditions.

2.1 In-Situ Measurements of Vegetative Roofs Using the Spherical-Decoupling Method

The spherical-decoupling method has been used to measure sound-reflection properties and deduce the sound-absorption potential of locally-reactive surfaces and grounds, such as playing fields and forest floors [2,3]. This study first investigated the application of the spherical-decoupling method to vegetative roofs where the substrate surface particles and the plants of the vegetative roof do not provide a perfectly homogeneous and specular reflecting surface (i.e. no diffusion); surface properties which are inherent assumptions in the theory supporting the spherical-decoupling method. The overall objective is to understand the impact of substrate depth and plant species type and coverage on the absorption potential of vegetative roofs, so that vegetative roofs could be optimized for sound absorption.

The primary investigation was completed inside the controlled environment of an anechoic chamber with which a 1.68 m x 1.68 m test plot was constructed with material layers representational of the common vegetative-roof systems of the Pacific Northwest of North America. The less than ideal surface conditions have been accommodated in measurement methods through the determination of an appropriate geometric configuration of the sound source, the microphones and the surface plane, and through repeated measurements at multiple surface locations. The measurement method was subsequently utilized to complete in-situ measurements of 25 rooftop test plots. The test plots ranged in substrate depth in 25 mm increments from 50 mm to 200 mm; 7 test plots contained the substrate only. 18 test

plots were planted with three structurally-distinct plant species: sedums, a coastal-meadows community and grasses.



Fig.1. Set-up of instrumentation and vegetative roof test plot constructed in UBC Anechoic Chamber

3. RESULTS

3.1 Vegetative Roof Substrates

Figure 2 shows test results from the impedance tube measurements. These results suggest that within the octave bands 250 to 2000 Hz the percentage organic matter and volumetric water content are the most significant substrate characteristics relative to sound absorption. The absorption coefficient of the evaluated substrates correlated positively with percentage organic matter and negatively with moisture content and increased compaction. The state of compaction is significant in the 500 to 2000 Hz octave bands.

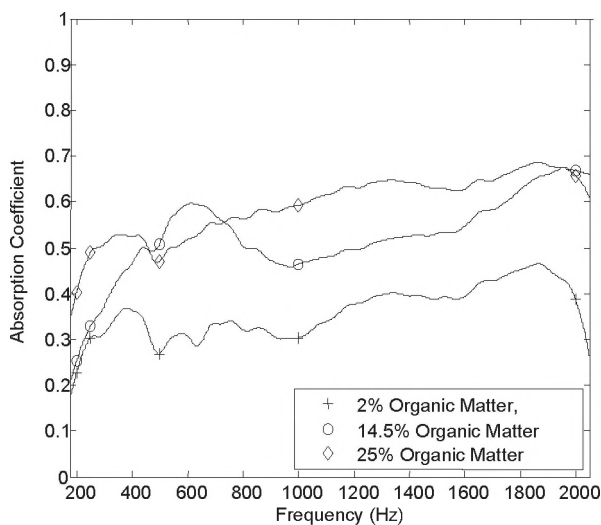


Fig.2. Absorption coefficients of Vegetative Roof substrate

3.2 Vegetative Roof Test Plots

In the anechoic chamber the absorption coefficient of the 130 mm substrate increased with frequency from 0.6 to 0.8 over the frequency range 686 Hz to 5489 Hz. Preliminary measurements of the vegetative-roof test plots – with moisture content at field capacity, plant coverage not yet fully established – indicated that the absorption coefficient of the substrate plots increased with frequency up to 3000Hz. The expectation was that the depth of substrate would increase the absorption of the vegetative roof; a positive correlation was observed - the difference between the minimum and maximum absorption coefficients was 0.15. A positive correlation was observed between absorption and total plant coverage.

4. DISCUSSION

The non-specular characteristics of the vegetative roof test plots provided additional challenges to the testing method developed in the anechoic chamber. A number of factors may have caused this disruption; this may include microclimatic conditions; wind and temperature and surface conditions..

An increase in total coverage, providing more consistency over the surface, will occur over the next several months of the spring and summer growing season. Additional investigations will focus on: validating and increasing the frequency limits; the height of the microphone above the surface and aerial biomass and the distance between the two microphones for specific plant structures.

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