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ScienceDirect

Energy Procedia 78 (2015) 489 – 494

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Analysis of the Acoustic Conditions in a Tent Structures

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Abstract

Shape variability and material diversity belong to the modern trends in architecture and civil engineering. A significant progress can be seen in the usage of woven, non-woven and foil membranes, so called architextiles. Textile membranes find their applications as both interior and exterior structures offering interdisciplinary challenges for architects, artists, engineers, chemists, physicists, textile designers and material scientists. Lots of ongoing research is done in terms of their durability, thermal physics properties, tension from wind, weather and also in terms of the energy aspects. In the field of acoustics, most of the studies relate to the sound insulation and absorption properties influenced by the mass changes, structure perforation, tension in the membrane etc. In general, there is much less information on acoustic comfort available in comparison with the thermal comfort. Nevertheless, the physical properties of membranes allow for building of large-span tents, suitable for variety of cultural events and concerts, where the acoustic quality inside the hall and sound insulation properties of its exterior structure are one of the main building physics requirements. This article brings a literature overview on room acoustic problems in halls built out of woven and non-woven membranes, and shows an example of a measurement and analysis inside a temporary tent structure built for a cultural event.

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

Keywords: Acoustics, textile membranes;

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Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.712

1. Introduction

Modern textile structural skins are definitely a interesting component in a modern architectural design. They have many, for an architect, attractive properties, such as good flexibility, low weight, high tensile strength, sufficient penetration of daylight into building interior. Many different types of textile membranes already exist and probably the most interesting from the acoustical point of view are multilayer membranes, micro perforated absorbers and double-leaf absorbers [1, 2]. Different kinds of textile membranes exist, but the most common are woven, non-woven, knitted structures and their combinations. Their acoustic properties are typically considered from both, room acoustics (e.g. sound absorption) and building acoustics, (e.g. sound insulation) point of view. In the architectural design, both, room acoustic and building acoustic aspects contribute to the overall acoustic comfort.

If we look at the state of the art we will see, that quite some research has been done in the field of material research [3-15], but only little information can be found in literature about the acoustic comfort in the tent structures [16, 17].

Sound engineers often indicate occurrence of flutter echoes and uncomfortably high degree of reflectivity at middle and high frequencies in tent structures. The basic impermeable textile membranes have typically higher reflection properties at high frequencies then in low frequencies, where the membrane effect might play a role. Logically, the sound in a tent structure is coloured by sound reflections, enhancing high frequencies and causing so called “sharp sound”. If we look at the reverberation time in a large tents in frequency domain, we should typically observe a kind of “inverse” situation in comparison with ordinary rooms built out of hard walls (with quasi flat sound absorption) where a “boomy” sound will be present due to low absorption at low frequencies. (Note that flat sound absorption coefficient at room surfaces will not result in a flat reverberation time over all frequency range. Low frequencies will reverberate longer due to significantly lower air absorption at f < 1000 Hz). From the sound insulation point of view, the penetration of sound waves through the boundary walls will be obviously higher in a tent structures in comparison with classical “stone-based” buildings.

In this article we aim at the assessment of the acoustic condition in a temporary tent structure used for music performance. This pilot study compares measurements *in situ* with simulations in ray-based algorithm and discusses the way the input data for these kinds of simulations should be considered. In ray-based room acoustic simulations, typically the sound absorption properties α (-) together with scattering coefficient is given. In case of the textile membrane we rather speak about the reflection and penetration of sound than about sound absorption. In this article we will illustrate how it is possible to simulate “room” that is built out of textile membrane.

2. Description of the experiment

2.1. Description of the case study

The tent space analyzed in this article has a floor dimension of 10 x 30 m and height varying from 2,2 to 3,7m. The description of the tent, together with measurement and simulation setup is shown in the Figure 2. A total surface area of interior surfaces is S = 801 m^2 and the volume of the room is V = 880 m^3. On the floor there was a light carpet. Other surfaces are made out of PVC tarpaulin textile material. The mentioned tent–space was built up for a music event in the castle park of Merode in Germany.

To understand the acoustic conditions in the given space better, and to confirm or reject the general hypothesis, the room acoustic measurements were performed in situ, followed by simulations in Odeon software. Because measurements were performed only few hours before the music festival, some acoustic treatment have been already made in a room, such as relatively heavy curtains (ordinary wedding drapes, with typical absorption coefficient α_{1000} = 0,57~0,75) have been placed on the ceiling and walls in the tent. As a matter of fact, we had no opportunity to measure the effect of curtains on a ceiling in situ and only the situation with opened and closed curtains on walls were performed. However, simulations with and without curtains were performed later on.

In this article we show the comparison of three different variants.

Variant 1: “open” curtains (walls are only partially covered by folded curtains), measured and simulated;

Variant 2: “closed” curtains (walls completely covered by curtain), measured and simulated;

Variant 3: “without” (without covering), only simulations were performed;