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Absorption characteristics of masjid carpets

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ABSTRACT

This work investigated the absorption characteristics of eight types of carpets that are especially designed and manufactured for masjids and two types of carpets pads. Measurements were carried out in the reverberation room according to ISO 354. Each type was tested three times: first when it was installed directly on the floor, second when it was installed above 5.7 mm of polyurethane foam, and last when it was installed above 10 mm of polyethylene foam. The results showed that the absorption coefficient is directly proportional to frequency and knot density. The results also demonstrated that adding pads of polyurethane or polyethylene foam increased the absorption, principally in the mid-frequency range. The effect of polyurethane foam on absorption was higher than that of polyethylene foam. Finally, the absorption coefficients of the examined carpets were found to be close to those of Muslim worshippers when they are in the position known as “standing in rows”.

1. Introduction

In its essential form, the masjid (mosque) is a right prismatic room with a rectangular base. In contemporary masjids, worshippers and carpets constitute the two main acoustic absorbers. Other room surfaces are typically rendered with reflective materials such as marble, paints, glasses, or ceramics. Thus, knowledge of the absorption characteristics of both carpets and worshippers is essential for the acoustic design/assessment of new or existing masjids.

A carpet is a special type of textile that is used as a floor covering. Carpets are manufactured by attaching pile tufts (or face yarns) to a backing (or backing yarns) either manually (handmade) or using a machine (machine-made). Masjid carpets are machine-made woven carpets. The main reason to use this type of carpet in masjids, according to manufacturers in Egypt and Saudi Arabia, is its durability in comparison to other machine-made carpets. Thus, the following sections will address only this type of woven carpets.

Face yarns can be natural materials such as wool or cotton, or they can be synthetic materials such as acrylic, olefin, nylon, polypropylene, or polyester; blends of wool and nylon can also be used [1]. Backing consists of two threads, which are usually perpendicular, called wefts (or fillings) and warps (or warp chains) [2]. Wefts run widthwise and are made of jute in different diameters. Warps run lengthwise and are made of cotton threads. Warp chains are interlaced with filling and are used to fix face yarns in place and maintain the internal structure of the backing. Additionally, stuffer threads run parallel to the warp chains but are not interlaced with fillings. The main purpose of stuffers is to maintain the dimensional stability, the structure of the backing, and the appropriate backing density required for some types of carpets [1]. In practice, woven carpets are manufactured by a highly complicated technique in which face yarns are weaved through the backing, or simply bent around weft threads, to give the carpet its well-known appearance. The process of weaving uses different methods such as Axminster, Saxony or Wilton. Thus, the structure of the backing may differ widely according to machine and carpet style, and is just as important as the pile itself.

Among the different parameters that indicate the quality of a carpet are knot density (calculated as knots per square inch KPSI, knots per square meter KPSM or knots per square cm KPSC), pile height and type, weight per square meter, pitch, total shots, and backing structure.

Modern acoustic design requires calculating many parameters. One of the most important acoustic parameters is the reverberation time T. To calculate T, the absorption properties of the room boundaries must be known. Many researchers have commented on the lack of data that are especially oriented to masjid acoustics [3–5]. Consequently, the current practice either ignores the acoustics of masjids or depends on approximations that may lead to inaccurate results. The main purpose of this work is to present the measurement results of the absorption characteristics of 8 types of carpets that are specifically designed and manufactured for masjids. Measurements were carried out in the reverberation

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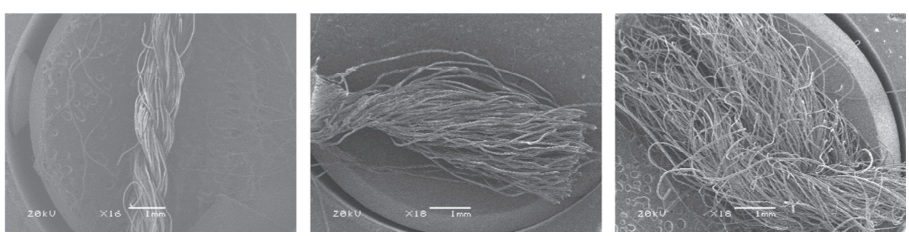
chamber of the Acoustic Research and Tests Unit (ARTU) in the Faculty of Environmental Design, King Abdulaziz University, Jeddah, Saudi Arabia. It is also of interest to relate their absorption characteristics to their technical specifications such as knot density, pile material, pile height, weight per square meter, and backing structure. Finally, the absorption characteristics of masjid carpets will be compared to the absorption characteristics of Muslim worshippers as previously measured [6].

Because carpets are widely applied as floor coverings in different rooms and have a noticeable acoustic effect, their absorption characteristics have been investigated in many prior research studies. Harris [7] measured the normal absorption coefficient and flow resistance for several hundred carpet samples in order to investigate which variables in carpet construction have a direct effect on the acoustic absorption. Based on the data obtained, certain samples were examined in the reverberation chamber at the National Bureau of Standards for comparison with the tube measurement. Results showed that pile density is one of the fundamental variables that can affect carpet absorption. Shoshani and Rosenhouse [8], investigated the relationship between the absorption coefficients of a cover made of woven fabric and its main parameters, including fibre content, yarn count, cover factor, the air gap behind the fabric, the frequency of the impinging sound wave, and the influence of washing on sound absorption. Results showed that Noise Reduction Coefficients (NRCs, the arithmetic average, rounded to the nearest multiple of 0.05, of the absorption coefficients at 250, 500, 1000 and 2000 Hz [9]) for the examined samples ranged between 0.09 and 0.22; the absorption coefficient was much higher at higher frequencies. Shoshani [10] measured absorption coefficients of tufted carpets backed by several layers of stitch-bonded nonwovens using an impedance tube. Results indicated that the absorption coefficients of backed carpets were significantly higher than those of un-backed carpets between 250 and 1000 Hz. The increase in the absorption of backed carpets depends primarily on the thickness of the backing, whereas the effect of fibre content is only marginal. Finally, Shoshani and Wilding [11] examined the effect of pile characteristics on the absorption of tufted carpets in the frequency range 125–4000 Hz using an impedance tube. The parameters considered were fibre content and denier, pile density, and average pile height. During measurements, only one pile parameter in the examined samples was varied. One of the important results was the significant increase in the absorption coefficient in the low and medium frequency range, 250–1000 Hz, when there was an air gap behind tufted carpet used as a wall covering.

1.1. Description of the selected samples

After a comprehensive survey, masjid carpet manufacturers in the west of Saudi Arabia were identified. Visits and meetings with those manufacturers revealed that there are 8 types of masjid carpets in production. These carpets can be classified into 3 categories on the basis of their face yarn materials: 3 are made of acrylic, 4 are made of heat-stabilised polypropylene (PPHS) and one is made of an 80/20 blend of wool and acrylic. However, the first two are the most common because of their low prices. Masjid carpets have a standard width of about 3.99 m and a length of 25 m. This width fits 3 rows of worshippers, which is the customary grouping during prayer according to the Islamic faith [12,13]. In Saudi Arabia, it is a common practice to install masjid carpets above paddings of either polyurethane foam (PUF) or polyethylene foam (PEF). The former is an open-cell foam (synthetic rubber) adhered to thin solid backing,



(a) Acrylic fibres (b) Polypropylene fibres (c) Wool fibres

Fig. 1. Tuft fibres as seen by the electron microscope.

Table 1
Technical specifications of the tested samples.

#	Sample code	Pile material	Total shots	Weight		Thickness			# of fibres per tuft	Backing structure	Knot density			Pitch	Row	Filling
				Per m^2	Per pile	Pile height	Backing	Overall			KPSM	KPSC	KPSI			
				kg	mg	mm										
1	PAZ/1	Acrylic	Single	4.275	5.5	12	2.17	14.17	200–210	Wilton	235,800	24[d]	152	11	14	Jute
2	DIA/7		Single	2.60	7.0	10.5	2.65	13.15	200–210	TR[a]	250,000	25	161	13	12	Jute
3	KAN/2		Single	3.27	6.3	11	2.68	13.68	165–180	STAG[b]	275,100	28	177	11	16	Jute
4	PRI/6	Polypro-pylene HS	Double	2.19	6.8	10.5	2.92	13.42	180–185	STAG[b]	137,550	14	89	11	8	Jute
5	LOU/3		Single	3.84	7.2	10.5	2.45	12.95	105	STAG[b]	176,850	17[d]	114	11	10	Jute
6	CRY/5		Double	2.33	5.6	9.5	2.00	11.50	175–180	STAG[b]	189,000	19	122	9	14	Jute
7	MAD/4		Double	2.75	6.4	10.5	2.07	12.57	170–175	Wilton	235,800	24	152	11	14	Jute
8	XMIN-7/9	Wool	Triple	2.845	17.3	8.5	2.64	11.14	Uncountable	AXMI[c]	97,520	10	63	7	9	Jute
9	PUF	Polyurethane foam		1.50	–	–	–	5.70	–	–	–	–	–	–	–	–
10	PEF	Polyethylene foam		0.28	–	–	–	10.00	–	–	–	–	–	–	–	–

[a] Triple row.
[b] Double row staggered.
[c] Axminster.
[d] Each knot contains double pile.