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Time-depending performance of resilient layers under floating floors

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HIGHLIGHTS

- Three mechanical tests were performed for 20 resilient layers.
- Mutual correlations among these three parameters were investigated.
- No general rule can be defined between different parameters.
- The effect of service time was evaluated and a preliminary relationship have been proposed.
- Density seems not to influence final performance, on the contrary the contact shape does.

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ABSTRACT

In the floating floor system the performance of resilient layers, in terms of impact sound pressure level reduction, is of paramount importance. In the present study in order to evaluate the time-depending performances, a comprehensive characterization of twenty different layers was carried out, evaluating dynamic stiffness, compressibility and compressive creep. The aim of this work was to find out a possible correlation among these parameters and the effect of service time on mechanical and acoustical properties. Results indicated that a general rule couldn't be defined. Furthermore, the presence of a coating, as well as different density and/or contact shape, has proved to influence the final acoustical performances.

1. Introduction

At these days, buildings are complex constructions within several engineered materials, layers and structures. For the indoor comfort, several parameters have to be taken into account: thermal distribution, air quality, radiated energy and sound insulation. The latter issue include both airborne and impact sound pressure level.

In multi-story buildings, the resident activities could produce impact sound pressure inside the apartment of the floor below. Many building technologies can be employed to reduce this problem such as resilient covering (i.e. fitted carpet), supported ceilings and floating floors.

Floating floors is one of the most effective solutions to cut the impact sound pressure level by decoupling the upper level (slab) from the structural construction. This mass-spring-mass system is able to moderate effectively sound transmission through walls [1–3].

Adopting floor structures such as concrete, beam and pot, timber frame etc. direct and flanking transmissions could affect the acoustic comfort of different dwelling in the same building. To avoid this problem a reduction system, such as the abovementioned floating floor, should be designed and laid [4,5].

Recently, many resilient materials (such as natural or synthetic wools, felts, foams and various recycled products) have been produced and tested for the reduction of the impact sound pressure level in buildings [6,7], even if the number of resilient layer's studies is still limited.

For these material types, due to their peculiar roles, the "spring" behaviour, time resistance under constant stress and the response when subjected to unexpected loads are important and must be evaluated. As a consequence, the main parameters characterizing their mechanical properties are three: (i) dynamic stiffness, (ii) compressive creep and (iii) compressibility.

As mentioned above, floating floor technology is based on the mass-spring-mass effect as shown in Fig. 1: m_1, called "infinite

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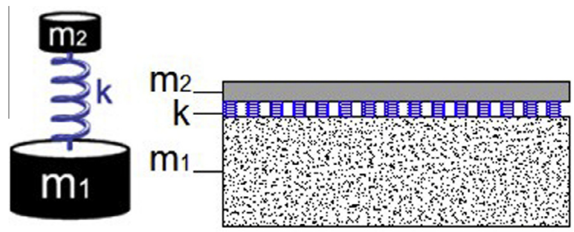

Fig. 1. Floating floor representative scheme.

mass" is the structural and static mass; the spring effect is ensured by the resilient layer (where k is the elastic constant) acting with m_2 as a "resonant system". The whole system decreases the impact sound pressure transmission emitted by footsteps, object fall, etc.

Dynamic stiffness determination is essential to choose the mass and thickness of all floating floor components: in particular this parameter defines the ability of a system to damp vibration transmission. The impact sound pressure level reduction can be evaluated applying Cremer's equation [8]:

$$\Delta L = 30\ log(f/f_0) \tag{1}$$

where ΔL is the impact sound pressure level reduction (dB), f is the frequency [Hz] and f_0 is the resonance frequency [Hz] of the spring-mass system expressed by

$$F_0 = (1/2\tau)sqr(s'/m') \tag{2}$$

where s' is the apparent dynamic stiffness per unit area [MN/m^3] and m' is the mass of m_2 per unit area [kg/m^2].

This property is correlated to the stiffness of a single layer and it depends on density, shape, thickness and static load [7]. It supplies the needed design value to estimate how much the floating floor can reduce the impact sound pressure level.

The **compressibility** is referred to the dynamic load that a layer can tolerate maintaining its elasticity, without non-reversible strain occurs.

The **compressive creep** is related to resistance under static load in the time domain.

The identification of the proper resilient layer is possible only if all these three parameters are measured.

Dynamic stiffness and compressive creep tests are strictly related to real-use conditions. The spring-mass effect and the static load are achieved placing a 200 kg/m^2 mass upon the resilient layer, that simulates a real slab (bed mortar). The former test provides the parameter to calculate impact sound pressure level reduction (ΔL) while the latter evaluates if the layer could withstand static load and guarantee the spring-mass effect over time.

The compressive creep analysis is a direct examination. For relevant thickness reduction, the resilient layer is not able to preserve its original configuration in time domain, inducing significant difference between predicted and measured ΔL. If the thickness reduction is not so evident, the material could have some internal rearrangements with a consequent dynamic stiffness increase.

On the other hand, the compressibility test is not related to any particular *in situ* case. Even if this value is not used in any predictive or design calculation, it supplies very important information, such as the resilient layer capability to maintain its peculiar acoustic and mechanical properties under unexpected dynamic loads. A complete thickness and shape recovery indicates good elastic properties, otherwise an incomplete restoration, caused for example by poor inner aggregation (i.e. ceramic fibre layers [9]), limits the spring effect (poor compressibility level).

Calculated and measured ΔL values can be sometimes very different [10–12], due to: (i) the same material of prediction study has not been used for *in situ* realization; (ii) human errors have been occurred during installation, or (iii) resilient layer mechanical properties have changed due to loading-time or loads. While conditions (i) and (ii) can be easily overcome choosing the proper material and increasing the quality control during installation, the third situation needs a comprehensive study of material properties. Compressibility and compressive creep are of paramount importance and must be measured in laboratory to evaluate if the selected resilient layer is suitable for building's expected lifetime. In many countries (e.g. Italy and France) this service life is at least 10 years.

Compressibility is a short-time test (about 1 h), on the contrary, the compressive creep takes at least three months in order to estimate resilient layer behaviour for 7.5 years and up to five months for a 10 years forecast, as expressed by Findley equation [13,14]. Since compressive creep is a long-lasting measurement, it is not usually studied, tested or certified at all.

Considering the aforementioned point, in the last few years, the main purpose of researchers [15–18] and suppliers is focused on the survey of a relationship between compressive creep and other parameters, in order avoid the creep test implementation.

Schiavi et al. [15] have tested 6 types of material with different densities, that could be classified as: (i) rubber or recycled tyres, (ii) wood or cork, (iii) textiles, (iv) polyurethane, (v) glass or rock wool, (vi) synthetic fibres. A method has been proposed to evaluate the long-term behaviour under continuous compressive load and the acoustical performance of resilient layers. For the before-mentioned materials compressibility and 10 years extrapolated compressive creep show quite comparable values. Dikavicius et al. [16] have examined stone and glass wool (open cell material) and elastic polystyrene (closed cell material) showing a decrease in the dynamic stiffness values after compressibility test. Gnip et al. [17] have studied long-term (about 5 years) compressive creep effect on expanded polystyrene proposing a predicting law for the behaviour up to 50 years. Cho [18], has identified a method to determine dynamic stiffness variation induced by creep, by means of quasi-static mechanical analysis, with the assumption that the modification of the resilient material structure caused by creep does not depend on time and stress. The investigated materials have been expanded polypropylene, expanded polystyrene and polyester felt single layer.

The scope of the present study is to verify (i) if there exist a correlation between compressibility and compressive creep for different resilient layer types, (ii) if their mechanical and acoustical properties are affected by service time and (iii) if density, shape and surface coating may influence their performance.

In this paper, instead of "material", the term "resilient layer" will be used, because layers are not always composed of a single bulk material.

2. Materials and methods

Twenty resilient layers (Table 1) were tested in order to evaluate dynamic stiffness, compressibility and compressive creep as specified in the following paragraphs. In compliance with standards, all tests were performed in a chamber under controlled temperature (20 ± 3 °C) and relative humidity (50 ± 10%).

2.1. Dynamic stiffness

Dynamic stiffness for unit area was determined in compliance with UNI EN 29052-1 [19], three specimens for each layer. The apparent dynamic stiffness per unit area s'_t [MN/m^3] is related to the extrapolated resonant frequency f_r of the fundamental vertical vibration of the resilient layer, as given by the Eq. (3):

$$s'_t = 4\tau^2 m'_t (f_r)^2 \tag{3}$$

where m'_t [kg/m^2] is the total mass per unit area used during the test (a steel load plate size 200 × 200 mm and weight of 8 ± 0.5 kg).

For porous materials, if the lateral airflow resistivity, measured in accordance to ISO 9053 [20], is in the range 100 kPa s/m^2 ÷ 10 kPa s/m^2, the contribution of the enclosed air s'_a has to be considered Eq. (4):