

Apply safe flooring in housing environments related to elderly (Evaluating suitability technologies to absorb impact in the event of a fall)

Leila Mashhour^a, Ximena Aguirre Suarez^b, Joan Lluís Zamora i Mestre^b

^a Departament de Tecnologia de l'Arquitectura, Programa de Doctorat Tecnologia de l'Arquitectura, de l'Edificació i de l'Urbanisme, Universitat Politècnica de Catalunya (UPC), Spain.

^b Escuela Técnica Superior de Arquitectura, Master en Estudios Avanzados en Arquitectura, Línea Innovación Tecnología en la Arquitectura, Universitat Politècnica de Catalunya (UPC-ETSAB), Barcelona, Spain.

Leila_mashhour@yahoo.com, Leila.mashhour@upc.edu

Shock absorbing flooring which known as compliant flooring as well is a technology for injury reduction in seniors. It is a type of secure pavement oriented to decrease the hardness of the ground and the impact force applied to the body parts that hit the ground. Consequently such floorings decrease fall-related injury in care homes and play grounds. We investigated 4 types of compliant flooring and 10 types shock absorbing model as they described in their technical sheet, for about one month in a senior home in Barcelona. This research classified in two levels of practical tests directly on floorings in order to compare their housing facility properties and in second level the participants include seniors and staffs of the center were interviewed about the current flooring of the center and proposed compliant floorings. Some of the compliant floorings were collected from gym or sport areas, playground and some vinyl flooring with shock absorption property with different thickness. It is notable to mention that underlay and overlay of the flooring must complete each other. Compliant flooring must be soft in case of fall but stiff enough to not to impair walking.

Keywords: compliant flooring; shock absorption; anti-slip; falls; injury reduction; care homes

1. Introduction

Falls are the second important reason for accidental or inadvertent injury deaths worldwide. With the estimation of 646,000 individuals die annually from falls, making it the second reason for unintentional hurt death, after road traffic injuries. About 37.3 million require medical attention occur each year because of the falls (WHO, 2018). Approximately 50% of old people over 65 falls at least once a year and this rate is about 40% in nursing homes which involves the elderly in long term painful erosive treatment and the high cost of cure. Various methods have been proposed to prevent falls by researchers and investors in this regard. But according to the statistics, these solutions do not seem enough to reduce the number of risks and injuries. Many factors cause a fall and it may happen in any places outdoor or indoor, at any ages and it's an unpredictable issue. For this reason, besides making environment safety to prevent falls, more attention should be paid to reduce the rate of injuries in the event of a fall. **Flooring** is one of the main factors which directly involve injury caused by the fall. This means that the type of flooring has a direct relation to the damage involved. The harder the flooring, the higher rate of the damage, the point is that in this research both factors of slippery and shock absorption properties are the most important factors in order to make a safe area for seniors.

This study focuses on evaluating *Shock absorption floorings* available in today Spanish market, include anti-slippery properties (fig.1). Usually, the shock

absorption floorings are oriented for kids in outdoor playgrounds, for teenagers in gym and sports areas or even applied in industrial zones to control the weight, impacts or vibration of machines, but except some few floorings there is not any shock absorbing flooring specific oriented to seniors in order to protect them. In order to prevent injury, that was an idea from the physicians, several methods have been proposed by the researchers. Most of the researches and proposed products are about the wearable accessories (hip protector), fall detection with sensors embedded in the belt, bracelet, and vest or even under the carpet and monitoring the environment using camera and sensors. Many discussions are still open on which methods and techniques are more practical in any place and time.

There are investigations conducted on the flooring and only a few companies as developer the idea, work on such flooring professionally which specifically addresses the issue of the elderly. Proper flooring can be an effective solution to control and prevent risk injury. A promising intervention way that is exclusively related to the high-risk environment is to increase the shock/impact absorbance of the floor to attenuate energy in the event of a fall. **Novel compliant floors (NCF)** or **Shock Absorbing Flooring (SAF)** are a passive intervention method that may protect an individual for many types of fall-related injuries. However, some evidence suggests that number of floors with low stiffness surfaces could impair balance maintenance, thereby increasing the risk of falls (D. Wright, 2012) but unfortunately according to the

author researches there is not any implemented project with such flooring types in Europe and Spain. There are few companies in US and Canada generates such materials and pavements called compliant flooring which unfortunately some of them are not active now.

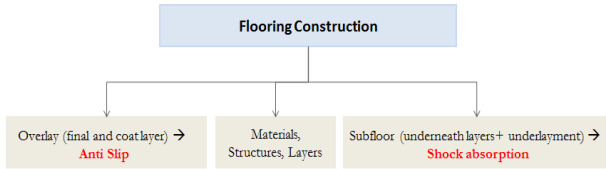


Figure 1. Compliant flooring construction-By author

Biomechanical efficacy evidence shows compliant flooring may reduce fall-related impact forces with the lowest effects on standing and walking equivalent. Clinical effectiveness records indicate that compliant flooring may decrease the severity of injuries, but may increase the number and the risk for falls. Early information suggests that compliant flooring may be a cost-effective method, but may also affect physical requirements for the healthcare staff (Chantelle C. Lachance, 2017).

Aim of this research:

Main Objectives

- The main goal of this research is to **reduce the injury** caused by falling in older adults. It is important to detect and identify the factors that lead to falls.
- To find a standard features as an appropriate material in order to decrease the impact shock. To gain this goal, it is need to evaluate all capabilities of the selected floorings products and desired factors. It is expected that the desired flooring has both stiff surface to avoid disturbing the balance while walking and also has the flexibility and resiliency enough to absorb and reduce the impact force.

Specific Objectives

- Generalizability of the final results on different flooring with regard to function;
- The compare study between flooring types and evaluate different data, help us to extract needed information about the final results;
- By comparing the flooring, we can evaluate the position and quality level of Spanish flooring standards with other countries;
- Provide the proper features of flooring material to manufacturers and companies by compare the usability of different flooring types and make it easier for architects, designers and customers to select;

- Propose a flooring system based on shock-absorption;
- Propose a material to reduce the risk of injury caused by falling and promoting safety and environmental security;
- Reducing the cost of healthcare services and health insurance system for the family;
- Search about similar compliant flooring in Spanish current market which has the capability of using in care homes.

2. Materials and Methodology

Partners

- Flooring manufacturers or distributors
- Real site of elderly housing as a case study
- Devices, tools and methods in order to perform test and the companies that provide us such tools.
- Questionnaires and interview asked from nurses, staffs, seniors, directors, architects, etc.
- International and local Norms and standards (fig. 2-fig. 5).

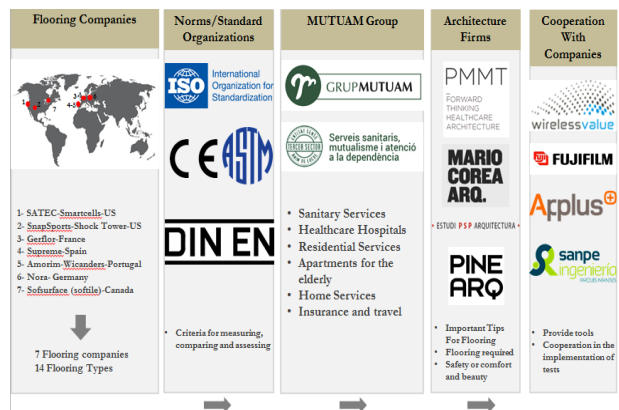


Figure 2. Partners of the research- By author

In this research, some of such shock absorbing and compliant floorings from different countries will be evaluated. The novelty of this research is the focuses on time range with the most probability risk of fall, areas with high risk of fall, activities and users in seniors centers. In the first level we studied the statistical information of falls in one care home (MUTUAM, 2019). In second level the elderly and the staffs were interviewed. The questions were categorized into two groups of current and proposed flooring. In third level the 14 types of floorings from different companies with shock absorption property were tested by different methods in order to detect the best one as shock absorbing flooring system, safety and comfort while walking (fig. 3, fig. 4). The flooring types selected from different application and materials include caocho, rubber and cork. They

were installed in Mutuam de Collserola for about one month in an area in order to test and consultations with the elderly and staff of the Collserola center. Because of the final surface of some of the pavements we covered them with a very thin vinyl in order to avoid focusing and confusing participants with the different flooring surfaces. Because flooring surfaces like nursing homes and health centers will never be used roughly. All technical information of each flooring type were analyzed.

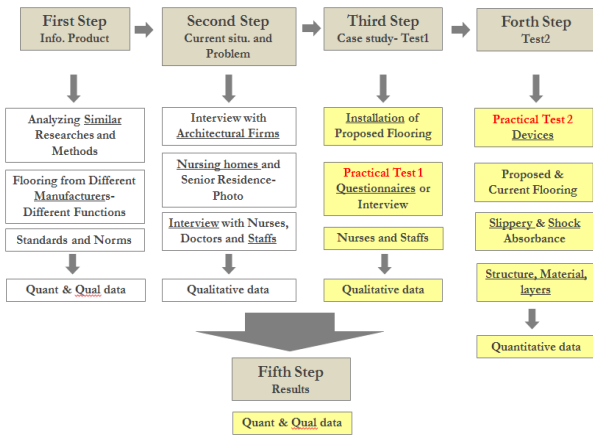


Figure 3. steps of the research- By author

One day activities of seniors were monitored and the traffic path, shoes, walking styles were evaluated. In addition we analyzed current flooring in different areas of the center to check their slippery according to DB-SUA (Documento de Apoyo al Documento Básico-Código Técnico de la Edificación) Section SUA 1 security against the risk of falls. 1. slipperiness which use as a norm UNE ENV 12633: 2003 (CTE, 2015) in Spain.

Data

We have 3 main data groups:

- Qualitative data is gained by the questionnaire and interviews with different carriers of nurses, staffs, doctors and architects in one of the Mutuam’s centers.
- The quantitative data is obtained by practical tests will be executed on pavements.
- Standards and norms defined by international or local organizations .

Two types of questionnaire were defined about the current situation of the pavement and the proposed pavements. Rest of the questions are about general information and statistical data in resent three years of center. The participants in our interviews are older adults, nurses, auxiliaries, cleaning staff and architectural offices with good experiences in designing such areas (fig. 5).

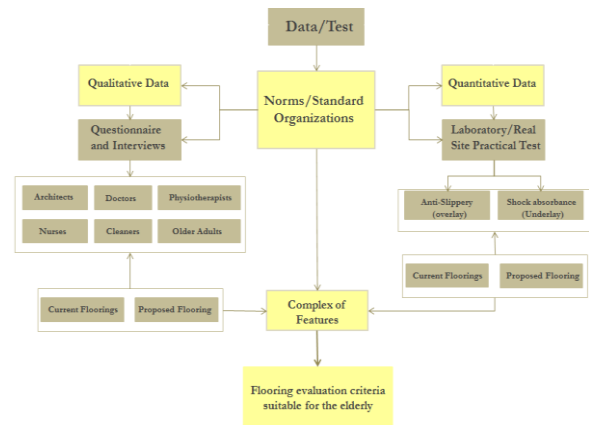


Figure 4. Types of data of the research- By author



Figure 5. 14 flooring types with name and code- By author

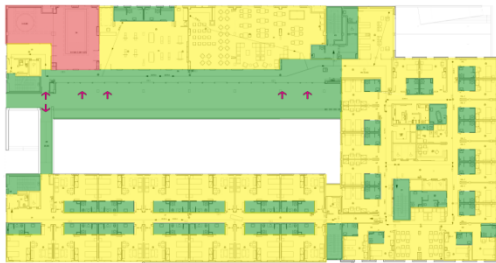
• **Tests on current and proposed floorings**

1. Slip_resistance_testing-UNE ENV 12633: 2003 (tab. 1)

Slip resistance test performed on current flooring of the center by specific pendulum device (fig. 6) demonstrated that, except the vinyl flooring in gym, parquete in one of the dining room in the first floor the rest of the interior floorings did not pass the standard test and they are not a safe environment for seniors interms of anti-slip.

Table 1. classification of floors according to their slipperiness-ENV 12633:2003- By author

Classification of floors according to their slipperiness	
Slip resistance Rd	Class
$Rd \leq 15$	0
$15 < Rd \leq 35$	1
$35 < Rd \leq 45$	2
$Rd > 45$	3



All the areas in all levels of the center were classified according to the defined norm. Here is the second floor of the Mutuam de collserola which classified all the areas with three colors of yellow, green and the red color which respectively described as class one, two and three according to the probability of slipperiness in these areas(Tab. 1).

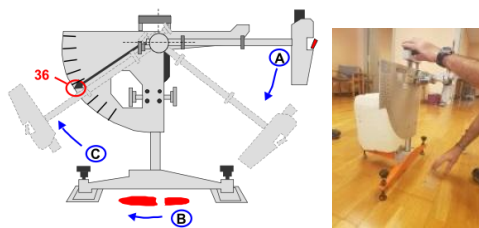


Figure 6. Slip resistance pendulum testing

All areas include stairs, rooms, corridors, bathrooms, lobby, diningroom, gym and, etc.

2. Impact resistance by coefficient of restitution test-ISO 10545-5

The ISO 10545-5: 1998 standard establishes a method for determining the impact resistance of ceramic tiles by measuring the restitution coefficient, we use the evaluation process established in the standard as a guide (fig. 4).

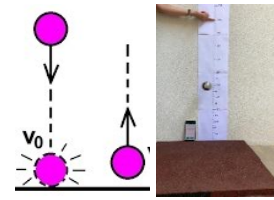


Figure 7. Impact resistance by coefficient of restitution test with metal ball

For the test, a metal ball is dropped from a height h_0 , after hitting a ground without friction, the value of the restitution coefficient CR or e can be estimated knowing the maximum height h_1 after the first rebound. Presumably, h_0 must be greater than h_1 due to the loss of energy during the rebound process.

$$e = \sqrt{\frac{h_2}{h_1}} \quad (1)$$

with the previous images that have a higher rebound height compared to the others. This rebound means the initial potential energy has been transformed into kinetic energy after the impact, without losing the energy by the friction of the air.

3. Visual verification of pressure distribution test- FujiFilms

Prescale films_presented by Fujifilm, with different levels of sensitivities and functions can precisely measure pressure, pressure distribution, and pressure balance visually by the color density.

This specific technology is normally used in industrial sectors such as measuring Impact pressure on bumpers, airbags and water jets, Functional testing of equipment for baseball, golf (fig. 8).

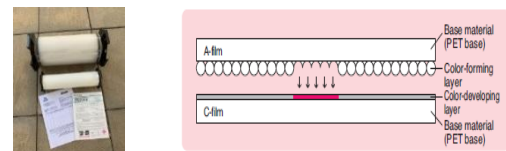


Figure 8. Visual verification of pressure distribution test with metal ball and prescale Fujifilm-4LW

With this test we try to use a different method which can be visually distinguished the same result (Fujifilm, 2019) . the final sheet will be scanned and analyzed by specific software called FPD-8010E (fig. 9).

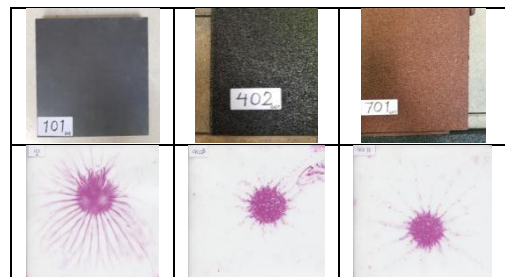


Figure 9. Result of prescale Fujifilm pressure distribution- By author

- **A-film:** Base material (PET base) coated with a color-forming material (microcapsules)
 - **C-film:** Base material (PET base) coated with a color-developing material (fig. 8)
4. HIC meter Wireless Impact Test-1177-2018 Norm

This European standard specifies a method to determine the impact attenuation of the playing surface. It defines a "Head injury criterion -HIC" for the surface, which represents the upper limit of its effectiveness in reducing head injuries when game equipment is used in accordance with EN 1176 (Sanpeingenieria, 2019).



Figure 10. HIC meter Wireless Impact Test-1177-2018- By author

For each flooring new data (temperature, material, weight ...) must be added in Ludometer software (fig. 10). The floorings under test was hit with the metal head provided with the instruments of the test equipment from different drop heights. Signals emitted by the accelerometers of the test head are processed during each impact, to determine the severity derived from the measured impact measure, defined as the head injury criterion (HIC), and to determine the acceleration peak of (g_{max}) experienced.

For our case study (nursing homes, residences, hospitals) the application of these floors is not adequate, so we must cover them with other material that can guarantee the properties of easy cleaning, anti stains, which allows moving wheelchairs easily, etc. This may affect the result of the test.

3. Conclusions

- There are many methods in order to fall detection and fall protection in elderly. But each has weaknesses that make the elderly unwilling to use them;
- Many of the care homes are interested in this research in order to using such compliant flooring to make their centers more secure and comfortable for older adults and staff as well;
- There are many manufacturers that produce and provide compliant floorings but many few of

them oriented directly to the elderly which some of them have been out of the cycle of production and no longer operate in the market;

- It is possible to find tests and technologies applied to this situation;
- As an architect we believe that in order to satisfy and secure the elderly, laboratory tests or simulating methods are not enough and we must know about older people opinion directly about their demands of the environment.

4. Acknowledgment

The authors would like to express gratitude to the MUTUAM group and Collserola center for their invaluable consultations and engagement with the research project who provides the access to some of its buildings to develop the campaign of tests. Thanks of Josep Ballester - Health Area Director of Mutuam, Rafael Angel- Head of Mutuam maintenance and supply service of Mutuam, Ezequiel Martinez-Director of Collserola center, Noemi Sech (Coordinator of Nursing) and, Merce Quintana. Thanks to the flooring companies that offered their products to carry out research. The manufacturers include SATECH(Samartcells), Sofsurfaces(softile), Supreme floors, Wicanders, Snapspots, Nora, Gerflor. Here we have to thank those companies that provided us with their professional technology and devices include APPLUS with pendulum device specifically Manuel Luque (Technical Responsible), Sanple company with the HIC meter wireless, specially David Santos (Director Técnico - Ingeniero Civil), Josep Riera (QBM - Quality by Measurement) who patiently support us in using and analyzing the prescale method of fujifilm.

Bibliography

- Chantelle C. Lachance, M. P. (2017, February 6). Compliant flooring to prevent fall-related injuries in older adults: A scoping review of biomechanical efficacy, clinical effectiveness, cost-effectiveness, and workplace safety. *PLOS ONE*, 1-23. doi:10.1371/journal.pone.0171652
- CTE, C. T. (2015). *codigotecnico*. Retrieved 08 2019, from <http://www.codigotecnico.org>, <http://www.arquitectura-tecnica.com/hit/Hit2015-1/DccDBSUA.pdf>
- D. Wright, A. &. (2012). The influence of novel compliant floors on balance control in elderly women—A biomechanical study. *CIHR IRSC*, 43(4), 1480-1487. Retrieved from <https://www.ncbi.nlm.nih.gov/pubmed/21545881>

II Jornada de doctorado del programa TAEU. 2019

- Fujifilm. (2019). *Prescale*. Retrieved from Fujifilm:
<https://www.fujifilm.com/products/prescale/prescalefilm/>
- MUTUAM. (2019). *serveis-residencials-Centre Residencial Mutuam Collserola*. Retrieved 08 2019, from mutuam.cat:
<https://www.mutuam.cat/serveis-residencials/residencies-gent-gran/centre-assistencial-mutuam-collserola>
- Sanpeingenieria. (2019, May 06). Retrieved September 2019, from Sanpe Ingeniería | Parques Infantiles:
<https://www.sanpeingenieria.es/> ,
<https://www.sanpeingenieria.es/sanpe-es-acreditada-por-enac-para-el-uso-de-la-nueva-normativa-de-parques-infantiles/>
- WHO. (2018, January 16). *World Health-Falls*. Retrieved September 05, 2018, from <http://www.who.int/mediacentre/factsheets/fs344/en/>