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The Effect of Construction Factors on Static Electricity Resistance Properties of Floor Mats Produced on Jacquard Fur Weft Knitting Machines

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ABSTRACT: Since floor coverings are laid across large areas of interiors, they can be a serious source of contamination in buildings. Alongside functional and decorative aspects, environmental and health concerns are becoming increasingly important. If refined, a carpeted flooring gains additional characteristics such as antistatic resistant properties. At best the occurrence of static electricity can be reduced by choosing appropriate materials but it cannot be prevented entirely. However, ensuring that all electric charges are discharged immediately and smoothly, prevents any danger to people or objects. If static electricity is continually discharged when it occurs, the charge cannot become large enough to cause an electrical discharge (electric shock). Floor coverings are antistatic when they generally do not allow any disturbing electrostatic charges to develop; the charge needs to be less than or equal to 2.0 kV during the walking test. This research describes how static electricity is generated and can give rise to shocks to personnel walking on a floor covering. The link between floor electrical resistance and static charge build-up, and the role of construction factors (thickness, weight, materials type, structure and pile height), is explained. Methods of reducing static electricity by use of various artificial fibers are described, and the requirements and application of static electricity reduction are discussed. The work was further extended to include testing, characterization and evaluation of the various jacquard fur weft knitting floor mats obtained, in order to clarify their performance and verify the feasibility of the design that has been devised for the manufacture of these knitting floor mats.

KEY WORDS: Electrostatic propensity; Floor coverings; Fur; Jacquard weft knitting fabric, Mats; Pile knit machine; static electricity

I.INTRODUCTION

The phenomena of static electricity have existed since antiquity. More than 2000 years ago, Thales discovered that rubbing amber on silk allowed him to pick up small pieces of paper. Understanding of the phenomenon, of course, came much later, with the discovery of the electron in the twentieth century leading to the understanding of electrical charge. [1]

Since the usage of polymers in shoes, furniture, and floor covering materials like carpets and mats has grown commonplace, static electricity has become especially important in the context of flooring materials. When a person contacts a door handle after only a few steps on a dry, insulated carpet, static electricity can inflict an unpleasant but generally safe shock. Static electricity was the earliest form of electric process discovered by man [2] [3]. Static shocks can occur from a variety of materials, not just polymer ones; natural materials like wool can also cause them. [4]

Friction-induced static energy can be transferred to textiles and other materials. People walking on floor coverings can build high-voltage electrical charge, which can be a big hazard. The release of accumulated static charge may cause pain to individuals, impact, or harm electronic devices, or provide a fire risk, as in the case of a gas station [5]

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All materials experience static electricity due to electrical charges, which can pose issues in many contexts and necessitates properly grounding objects. An atom's center is its positively charged nucleus, which is surrounded by negatively charged electrons. The static electrical effect is caused by a substance accumulating excessive positive or negative charges due to various forces like movement or friction. The explanation for this is that a tiny quantity of electrons can be transferred between two materials when they come into contact due to friction or contact separation. Both materials thus acquire a charge, with one showing an excessive positive charge (caused by an electron deficit) and the other showing the same negative charge (caused by an electron surplus). [1] [6][7]

When an excess of similar charges builds up on a surface, the material will rebalance to a neutral state by letting electrons flow through the earth and any adjacent local materials, which both permit electron flow. This event is referred to as electrostatic discharge. Only when there is more static electric charge created than can escape from the surface can static electricity begin to build up. Because of this, insulating and dissipative materials with lower electrical conductivity experience an accumulation of static electricity more quickly than materials with higher electrical conductivity. Dissipative materials allow charges to travel very slowly because they have higher resistance between 105 and 1011 Ω. Positive or negative static charges develop on the surface of textile polymers due to their higher resistivity and when the triboelectric effect occurs due to their interaction with other materials. [1][8][9]

The mechanism of charge accumulation on the body is depicted in Figure (1). The main cause of the accumulation of body charge is the interaction between footwear and floor coverings. [1].
An example of how charges accumulate on the human body and how they are released to the ground device as following:
The person is electrically neutral when they first enter the room.
As a result of the floor coverings' charge separation, the person's body acquires charges; in this case, we assume positive charges.
Discharging: Whenever an electric device or other earthed body approaches, a spark discharge takes place. Consequences: The gadget may sustain harm from a shock reaction. d) The floor coverings stay charged and gradually realign themselves in a new manner over time. [10] [11]

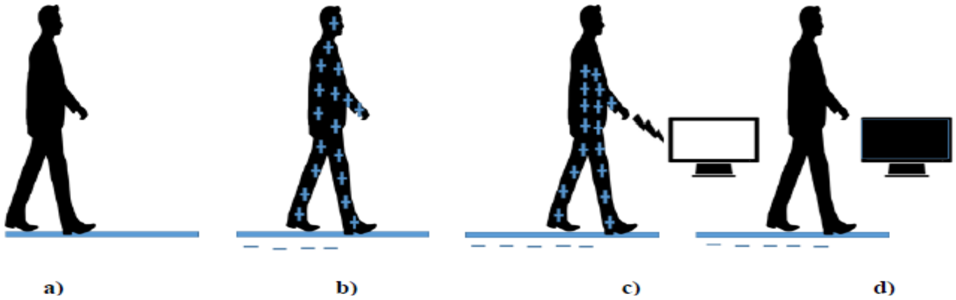

Fig 1: Charge Build-up Mechanism [11]

Elastic floor coverings are also antistatic if they are conductive. Floor coverings are antistatic when they generally do not allow any disturbing electrostatic charges to develop; the charge needs to be less than or equal to 2.0 kV during the walking test. [12]

A carpet or mat is a type of textile floor covering consisting of a pile's top layer attached to a support. Wool used to be the primary material for piles, but in the 20th century, less costly synthetic fibers like polyester, nylon, and polypropylene gained popularity. The most often used textile covering flooring options are broadlooms and carpet tiles due to their superior dimensional stability and elasticity. [13]

The floor covering looks luxurious, is easy to maintain, and is a pleasure to walk on. Typically, it has a backing attached to the top layer of pile. It is made of both natural and synthetic fibers and comes in a variety of shapes, patterns, and hues. Carpets in a house help to reduce noise and heat loss through the floor. In addition, they are more comfortable to sit or rest on than solid wood floors. Carpets are frequently categorized based on the kind of fiber used to create the surface strands. [13] [14]

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Carpet manufacturers can incorporate both synthetic and natural fibers into their blends. In terms of fiber properties, carpet yarns differ from yarns used in clothing and home textiles. This study concentrated on two synthetic fibers, acrylic and polyester and their blends. Charge generation is affected by the types of materials in contact. A guide to this is given in a triboelectric series (Table 1) where materials are ranked according to how they have been experimentally found to charge against each other. [6]

Table1. A Triboelectric Series of Materials

Rabbit fur	More positive
Glass	↑
Human hair	
Polyamide (nylon)	
Wool	
Fur	
Silk	
Aluminium	
Paper	
Cotton	
Steel	
Wood	
Rubber	
Acetate rayon	
Polyethylene (PE) and polypropylene (PP)	
PET	
PVC	
Polyurethane (PU)	↓
PTFE	More negative

Acrylic fiber and acrylic carpet fiber is more expensive than polyester, it is not more expensive than wool and has the same appearance and feel. The carpet fiber made of acrylic is resistant to moisture and mildew and has a low static charge. It is widely used for bath and scatter carpets, as well as velvet and level loop designs.[15] There are two main ways to make acrylic fibers: wet spinning and dry spinning. Melt spinning is unable to produce acrylic fibers because the fibers degrade at temperatures close to melting.

Polyester fiber when used in thick, cut pile textures, polyester carpet fiber is known for its rich soft "hand." It offers outstanding color clarity and retention. Polyester is easy to clean and repels water-soluble stains. [14] Although there are many other kinds of polyester, polyethylene terephthalate-based materials are typically referred to as polyester. Polyester has a propensity to retain electrical charge and is extremely combustible. Most synthetic materials naturally can hold an electric charge for a long time. [16]

Classification of carpet types based on the method of manufacture can be classified according to the process of their manufacturing and textures, as shown in Figure (2).

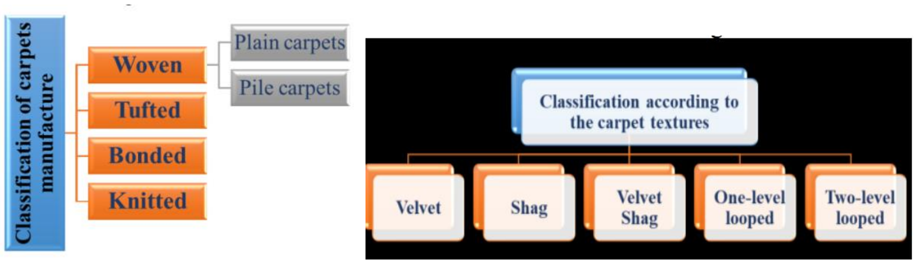

Fig 2: Classification of Carpets According to Their Manufacture and Textures

Knitted Carpets

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Knitted carpets, like woven carpets, can be classified as either flat or pile. Flat carpets are knitted and do not feature a pile-producing yarn system. Pile carpets, on the other hand, are made up of a ground knit fabric and a pile that are both generated at the same time. On top of the carpet, piles are one or more thread systems or fiber bands. They are firmly attached to the ground layer. The pile yarn is either tied in the ground or made into a stitch in the ground. Knitted carpets are distinguishable from cut-and-loop pile carpets. The ground layer is the layer between the pile layer and the back side of the carpet. Furthermore, warp-knitted carpets are among the carpets made using the knitwear manufacturing concept. They are textiles with pile threads tied in a ground material as a pile thread end or a pile loop.[16]

Pile yarns are inserted with needles or sewn into a textile fabric. For the carpet backing, the woven fabric needs to have good tenacity, uniformity, and shape stability. The density of the backing fabric has to be such that the sewn, loose pile naps are stable during finishing, as they are inserted without loop formation. Suitable materials for this are jute as well as many other natural and synthetic materials such as polypropylene (PP) bands or spun bonds.[15]

Compared to domestic use, commercial carpet backing systems come in a wider range of varieties. Three components can make up a backing system as following:

The main backing,
The bonding glue that is applied
The secondary backing, also known as the cushion/hard back. In the most popular approach, a secondary backing, often known as a cushion, is connected to offer additional pile-yarn stability and to add dimensional stability to the carpet structure. The yarn is fastened into the primary backing by synthetic latex or vinyl. The main backing for tufted carpets is typically woven, slit film polypropylene fabric, while certain nonwovens made of polyester and polypropylene are also utilized in certain situations. It is possible to use woven scrim polypropylene as a secondary fabric backing. Backings made of synthetic materials do not shrink when wet.

Unitary backings are carpet backings that are tufted and comprise just of a chemical backing, without the need for an additional secondary backing. They should only be used in glue-down installations. The most common backing and laminating material is styrene butadiene latex, while other materials are also utilized, including polyvinyl chloride, amorphous resin, ethylene vinyl acetate, polyethylene, and polyurethane. For tiny, machine-washable rugs only, natural latex is utilized.

Numerous physical characteristics of the carpet, such as dimensional stability, tuft-bind, little pilling, and fuzz, secondary backing adherence, robustness, and defense against edge ravel.
The aim of this research is to design jacquard fur weft knitting floor mats that can be used for static control. To achieve the goal, the construction of the anti-static floor covering and the parameters associated with are studied.

II. EXPRIMANTAL

Seven weft knitted pile mats were produced on jialong JL12 Jacquard Fur Double Jersey Circular Weft Knitting Machine (Diameter 32"- Gauge.20) with different raw material. The raw materials used were synthetic yarns (polyester & acrylic) or mixed yarns which should be taken to reduce or eliminate the build up of electrical charges . Table (2) shows the properties of the synthetic yarns which were used to produce weft knitted pile mats.

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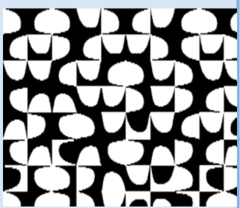
Table2. The Properties of Used Synthetic Yarns

YARN TYPE	Color	Yarn Count	Tensile Strength	Elongation %	Rkm	Number of twists
Virgin polyester	black	300 Denier	810	30%	35	-
Virgin polyester	black	150*2 Denier	830	34%	36	-
Polyester	white	70 Denier		29%	32	-
Recycle Polyester	white	300 Denier	789	25%	29	-
Acrylic	white	28|1 Metric	500	22%	14	360
Acrylic	black	28|1 Metric	575	27%	16	370
70% acrylic 30%virgin polyester	white	28|1 Metric	360	22%	14	360
70% acrylic 30%recycled polyester	black	28|1 Metric	525	22%	14.7	340

The specifications of the seven samples which were produced on Fur Double Jersey Circular Weft Knitting Machine could be seen in Table (3). The difference between them depends on the various fabric's constructions and binding shape.

Table3. The Specifications of Produced fur Knitted Fabrics

<table>
<tr><th rowspan="2">Samples No.</th><th rowspan="2">Design</th><th colspan="3">High pile Material</th><th colspan="3">Low pile material</th><th>binding shape</th><th>Binding yarn</th></tr>
<tr><td>Yarn Type</td><td>color</td><td>Yarn Count</td><td>Yarn Type</td><td>color</td><td>Yarn Count</td><td rowspan="8">w</td><td rowspan="8">Polyester white 70 Denier</td></tr>
<tr><td>A1</td><td rowspan="7"></td><td>Virgin polyester</td><td rowspan="7">black</td><td>150*2 Denier</td><td>Virgin polyester</td><td rowspan="7">White</td><td>150*2 Denier</td></tr>
<tr><td>A2</td><td>Virgin polyester</td><td>300 Denier</td><td>Polyester Virgin</td><td>300 Denier</td></tr>
<tr><td>A3</td><td>Acrylic</td><td>28|1 Metric</td><td>Acrylic</td><td>28|1 Metric</td></tr>
<tr><td>A4</td><td>blend 70% acrylic 30%recycled polyester</td><td>28|1 Metric</td><td>blend 70% acrylic 30% virgin polyester</td><td>28|1 Metric</td></tr>
<tr><td>A5</td><td>blend 70% acrylic 30%recycled polyester</td><td>28|1 Metric</td><td>Recycled Polyester</td><td>300 Denier</td></tr>
<tr><td>A6</td><td>Acrylic</td><td>28|1 Metric</td><td>Recycled Polyester</td><td>300 Denier</td></tr>
<tr><td>A7</td><td>blend 70% acrylic 30%virgin polyester</td><td>28|1 Metric</td><td>Recycled Polyester</td><td>300 Denier</td></tr>
</table>

To investigate the effect of fabric constructions on its functional behavior, different tests were done including:

1. Thickness test, this test was carried out according to the ASTM D1777- 96(2011) e1. [17]

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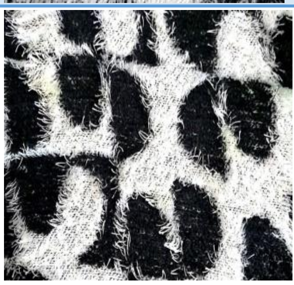
2. Weight test, this test was carried out according to the ASTM D3776 / D3776M - 09a [18]
3. Electrostatic propensity of textiles test, this test was carried out according to the ASTM D4238-90 (Withdrawn 1996). [19]

III. RESULT AND DISSECTION

Since the main objective of this research is to study the effect of major factors associated with fabric structure on electrical characteristics of fabrics produced thereof this is done in order to optimize the fabric design, different fabric types with various structure parameters were made. Results obtained along with their appropriate discussion are given below. Table (4) shows the tests results for all weft knitted pile mats.

Table4. The Tests Results for All Produced Pile Mats

Samples	Samples Design with Various Materials	Fabric Thickness Mm	Fabric Weight gm/m^2	Electrostatic propensity (volt)
A1		**2.293**	**305.2**	**0.8**
A2		**2.131**	**279.89**	**3**
A3		**2.048**	**263.48**	**17**
A4		**2.19**	**286.87**	**13**

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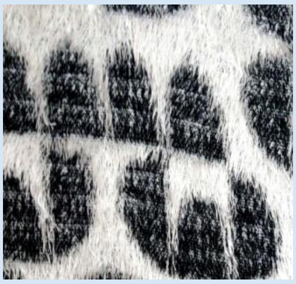
A5		2.329	276.37	7
A6		1.973	270.97	10
A7		2.34	282	6.5

Electrostatic propensity is the capacity of a nonconducting material to acquire and hold an electrical charge by induction (via corona discharge) or by triboelectric means (rubbing with another material). Electrostatic propensity of textiles test covers the determination of the relative electrostatic propensity of fibers, yarns, and fabrics by a corona discharge, this includes the measurement of the maximum charge voltage and the decay half-life. Test result can be used to predict propensity of fibers, yarns, and fabrics. This test method is useful for quality control, research, and characterization of the static propensity of textiles. [19]
Figure (3) shows the electrostatic propensity values for polyester (100%) mats (volt).

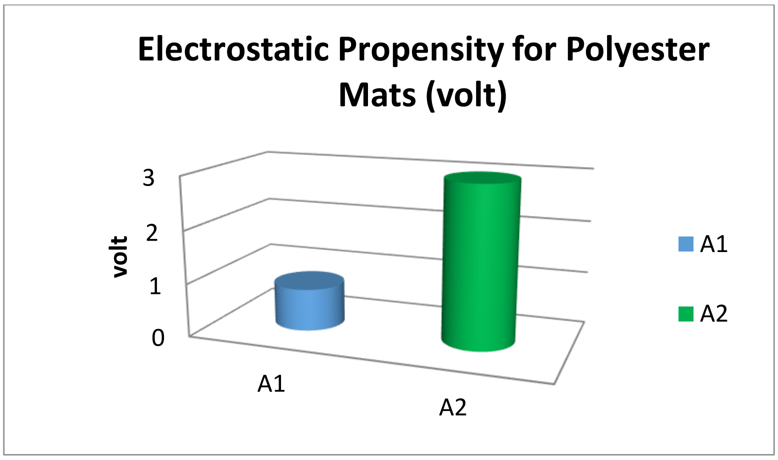


Fig 3. Electrostatic Propensity Values for Polyester Mats (volt)

As shown in Figure (3), the results indicate that the amount of generated static charges differs according to the yarn pile type. The twisted plied yarn (from two yarn 150 Denier Virgin polyester) in sample No (A1) has a higher electrostatic resistance than single yarn (300 diner Virgin polyester) in sample No (A2), because of the twisted plied yarn make more air buckets than the single one which acts as an insulator between the surface and the ground of fabric.
Figure (4) shows the electrostatic propensity values for various materials type (volt).

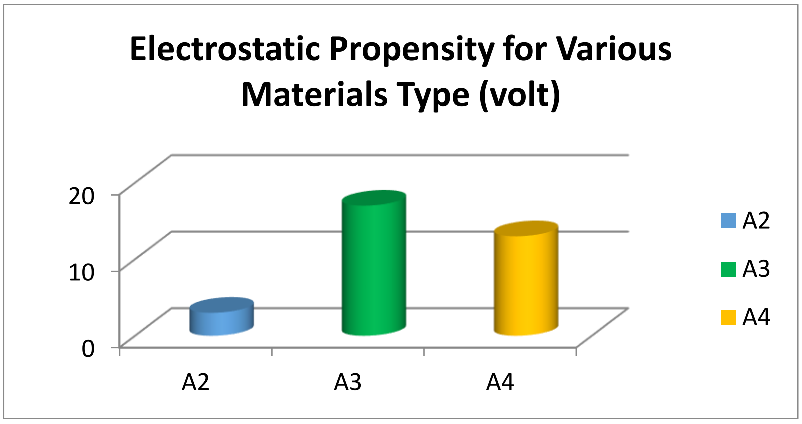


Fig 4. Electrostatic Propensity Values for Various Materials Type (volt)

As shown in Figure (4), the results indicate that the amount of generated static charges showed great variance according to the type of used material. The maximum static charges values belong to sample No.(A3) 100% Acrylic, while sample No.(A2)100% polyester and sample No. (A4) blended of 70% acrylic & 30% virgin polyester recorded fewer static charges. This behavior can be interpreted on the fact that synthetics are so hydrophobic, so they are easy to accumulate electrostatic charges. Since polyester is above acrylic in the electrostatic series [20], none of these compositions would be expected to be neutral to polyester. Indeed, it was found that they were all negative to polyester. From this collection of data, it is possible to conclude that staple blending based on the electrostatic series is one way of reducing static in certain cases.
Figure (5) shows the electrostatic propensity values for various high pile materials type (volt).

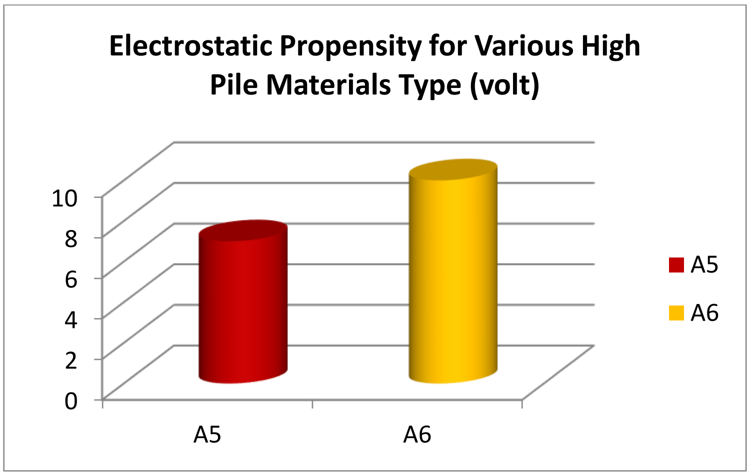


Fig 5. Electrostatic Propensity Values for Various High Pile Materials Type (volt)

As shown in Figure (5), the results indicate that the amount of generated static charges showed great variance according to the high pile materials, blended 30% recycled polyester with 70% acrylic in sample No (A5) gives better results in resisting static electricity than 100% acrylic in sample No (A6) because of polyester is above acrylic in the electrostatic series.
Figure (6) shows the electrostatic propensity values for various low pile materials type (volt).

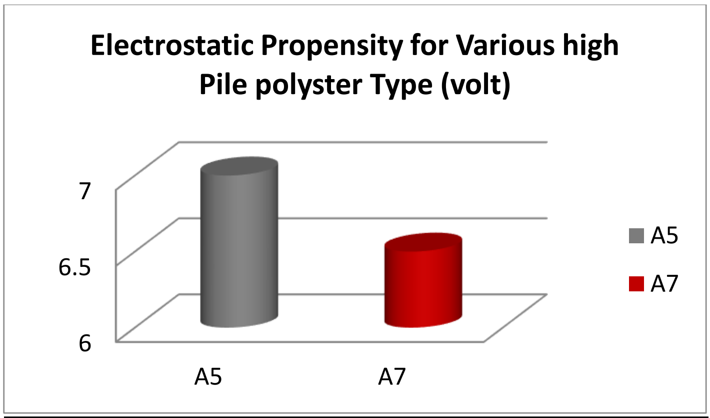


Fig 6. Electrostatic Propensity Values for Various High Pile Polyester Type (volt)

As shown in Figure (6), the results indicate that the amount of generated static charges showed great variance according to the low pile materials, blended 30% virgin polyester with 70% acrylic in sample No (A7) gives better results in resisting static electricity than blended 30% recycled polyester with 70% acrylic in sample No (A5) because of the different natural form virgin polyester compared to the recycled polyester

IV. CONCLUSOINS

Static electricity can be reduced by choosing appropriate materials but it cannot be prevented entirely. However, ensuring that all electric charges are discharged immediately and smoothly, prevents any danger to people or objects. Results of current work indicate that the value of the static electricity resistance obtained for fur knitted mats could be achieved by controlling some constructions parameters. In this context following findings are cited:

- The amount of generated static charges differs according to the yarn pile type.
- Twisted plied yarn make more air buckets than the single one which acts as an insulator between the surface and the ground of fabric.
- it is possible to conclude that staple blending based on the electrostatic series is one way of reducing static in certain cases.

All these results can be used to predict propensity of fibers, yarns, and fabrics. This is useful for quality control, research, and characterization of the static propensity of floor covering

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