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RESEARCH ARTICLE

Analysis of Surface Properties Determining Slip Resistance of Ceramic Tiles

Anita Terjék, *Zsuzsanna* Józsa

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Abstract

Slip resistance tests of pavements form an important part of Construction Products Regulation (CPR) in the EU. Measuring slipperiness is a complex problem. This property is often incomplete or inaccurate. The paper presents new test results of glazed and unglazed ceramic tiles with natural, polished and textured surfaces tested in dry, wet and oily conditions. In the research 3 different methods of slip resistance tests were used providing the average angle of inclination, skid-resistance value and coefficient of friction. The results show that surface roughness was also a significant factor affecting slipperiness. It is necessary to examine the structure of materials that is why measuring cleanability, as an important contributor to slip resistance and surface roughness, is fundamental in this research. Based on the experiments, it was found out that multiple cycles of sodium hypochlorite treatment could modify the surface of ceramic tiles.

Keywords

ceramic tile · slip resistance · roughness · cleanability

Anita Terjék
Material Testing Laboratory, ÉMI Nonprofit Ltd., H-1518 Budapest, P.O.B.69, Hungary
e-mail: aterjek@emi.hu

Zsuzsanna Józsa
Department of Construction Materials and Engineering Geology, Faculty of Civil Engineering, Budapest University of Technology and Economics, Műegyetem rkp. 3, H-1111 Budapest, Hungary
e-mail: jozsa.zsuzsanna@epito.bme.hu

1 Introduction

Floor covering is responsible for ensuring the quality, mechanical properties and also aesthetic appearance of flooring regarding its intended use. In every aspect selecting a product, it is unavoidable to know if it will fit for its purpose, not just only be attractive or uncostly.

There is a wide range of flooring materials available on the market with different appearance (colour, surface texture, decoration, etc.) and several technical characteristics associated with many expected performance levels. Considering that the surface of the floor covering can be a critical component of workplace safety, one has to consider all the tile characteristics that are relevant to a specific application.

The selection of materials is a fundamental step in the design process of flooring, since it can significantly influence the achievement of a satisfactory compliance with the essential requirements of Construction Products Regulation (EU) No 305/2011 (CPR) [1]. Some of the main requirements are sufficient strength and flexibility, fire resistance, volume stability, walking comfort, resistance to abrasion and staining, cleanability and last but not least slip resistance, etc.

Among the various floor covering materials widely used in areas where the above mentioned safety requirements are particularly critical, this article deals with ceramic tiles. These products are the common decoration material for floors and walls of not only residential houses, but shopping malls, business, sport and wellness centers, as well as hospitals or laboratories. Floorings made of this material are subjected to various stresses for both internal and external usage. Ceramic tiles are categorized in numerous ways considering manufacture, surface finish and used raw materials. There have been considerable changes in the manufacturing process in recent times, therefore a wide range are available with different surface characteristics in order to serve various roles in use. Textured surface can be achieved by glazing or patterning in the material, polishing procedure on the other hand creates a smooth surface and makes a tile more popular than ever by its beautiful gloss.

Ceramic tiles, playing a major role in the performance of flooring have to meet many performance requirements. At the same time they also have to be aesthetic in private and public environment. In this case they need to be safe in use and therefore provide sufficient resistance to slipping, chemicals and staining, besides having adequate strength and water absorption.

Among the general requirements for floor coverings according to structural aspects not only the above mentioned characteristics, but also the use of appropriate design and construction technology is significant. In addition to the technological requirements the entire structure of the floor layer also affects the tested characteristics mentioned in this article. For example, insufficient waterproofing of the structure - especially in floors lying on the ground - can cause the separation of the adhesive layer and thus decrease in homogeneity and load bearing capacity. The fragmentation of ceramic tiles affects the safety in use, as well. At the same time, waterproofing deficiencies and defects could induce the wetting of floor structures. In consequence water absorption of ceramic tiles may occur, and increase in the moisture content of the mortar must also strongly affects the cleanability [2].

Obviously from general criteria described in CPR, safety and accessibility in use raises more questions, especially in the subject of slip resistance. National requirements now have a greater emphasis, so threshold levels should be established in relation to any essential characteristic where an intended use requires it. Regarding the research and application of ceramic tiles there is a great importance of defining precisely the interaction and friction between surfaces in order to install the right floor covering for the right environment. While many tiles rapidly lose significant slip resistance if have not been cleaned properly, maintenance is a key factor predicting acceptable long working life. So those properties concerning safety could influence also the sustainable use of natural resources in the viewpoint of durability.

2 Slip resistance, assessment of different methods, tested materials

Slip resistance is one of the key characteristics prescribed by the harmonised standards for the purpose of CE marking of construction products [3]. When designing a floor with a given level of safety for users, it is essential to know the contribution to slip, that results from the surface covering materials.

The risk of slipping depends not only on choice and performance of tiles, but also human and environmental factors. Accidents are affected greatly by the surface structure of floors and working with slippery materials. Therefore slip resistance of ceramic tiling and its negative changing is an important problem, however in some workplaces, there is an increased risk of slipping due to possible contamination; water, oil, grease, soap, dust and sand, etc. Liquid contaminates on floors or subtle changes in elevation may contribute to slips, trips and falls [4].

Our experiences show that multiple testing is essential because of the complexity of defining and measuring slip resistance resulting from surface patterns, fixing, maintenance and cleaning. The nature of slipping and the perception of slipperiness are very subjective, and may depend on the interaction of many variables. Not only is the slip resistance value of a tile taken off from the production line needed to know, but be aware of its reducing ability; simply to say how the surface will behave during its lifetime. The friction-related properties of a pavement depend on its surface texture characteristics [5].

For the present work different commercial products were chosen; glazed (G) and unglazed (UG) ceramic tiles with 3 possible surface types identified according to the following marking: N for natural (matte finish), T for textured (patterned by glazing) and P for polished (glossy) surface. They all are tiles formed from a finely milled body mixture (clay and/or other inorganic raw materials) and shaped by dry-pressing [6].

For determining friction a precise examination is necessary, which approximately simulates the physical forces and the process of walking, and which can be repeated at any time under the same conditions, therefore a number of test methods have been developed over the years.

During the so-called ramp test based on methods of DIN 51097 [7] for wet and DIN 51130 [8] for oily surface the angle of inclination is measured. These tests involve a person walking back and forth on a contaminated test panel. The angle of inclination of the panel is gradually increased until the person slips. The average angle at which slip occurs is compared to a classification range. This angle is a measure for the coefficient of friction. The value is then corresponded to a classification range giving exact installing requirements.

When surface is contaminated with water, scale runs from A to C (Fig. 1). GUV-I 8527 [9] (former GUV 26.17) gives precise instructions for areas where people walk barefoot, such as swimming pools and spas.

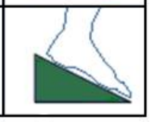
A	12° - 17°	
B	18° - 23°	
C	24° -	

Fig. 1. Classification of barefoot ramp test according to DIN 51097

Testing on oily surface, the scale runs from R9 to R13 (Fig. 2). In Germany BGR-R 181 [10] regulation introduces requirements for different uses in this case.

Skid-resistance tester (SRT), shown in Fig. 3 is a portable device described in the standard EN 13036-4 [11]. Operating by the principle of the Charpy pendulum, on the swinging arm the slider is allowed to fall from a certain angle, and it rubs against the surface that is being tested. The measured pendulum test value (PTV) can vary from 0 to 150 and is proportional to the absorbed potential energy of the slider.

R9	3° - 10°	
R10	11° - 19°	
R11	20° - 27°	
R12	28° - 35°	
R13	36° -	

Fig. 2. Classification of shod ramp test according to DIN 51097

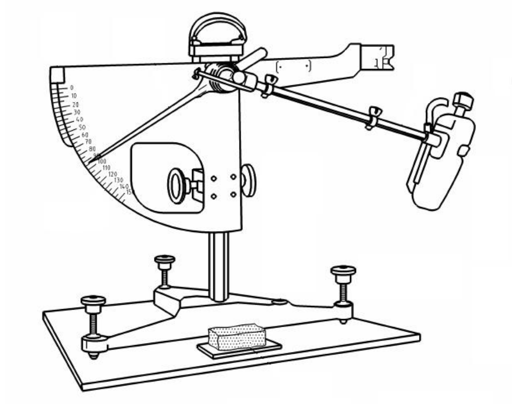


Fig. 3. Skid Resistance Tester (EN 13036-4)

Due to the fact that adhesion between the surface and the slider can be altered when covered with liquids, measurements taken in both wet and dry state are significant in this case.

Floor Slide Control 2000 Print (Fig. 5) is an example of equipments used for floor friction test both in laboratory and on site. It travels across the surface pulling the measuring glider and directly calculates the coefficient of friction (μ).

In Table 1 the results of slip resistance tests mentioned earlier are presented. Fig. 4 shows the images of tested ceramic tiles (all images represent a 4 cm × 4 cm surface).

Regarding the selection of samples we decided to choose numerous different surfaces in order to show diversity in material texture, and thus in the behaviour. It was pointed out that it is difficult to draw correlations for the assessment of the individual test methods because of the difference not only in the design of these equipments, but in the size of various sliders in contact with the surface. These test results can only be interpreted in a combined form due to the unlike units.

For the classification of a ceramic tile or other flooring material, principles of available previous studies, regulations and international standards can be used in this research. The angle of inclination of both ramp tests and PTV can be represented in the form of the friction coefficient [12]. By adapting this information, a new approach of classification was determined presented in Fig. 6 by taking coefficient of friction as the base of conversion.

So a new system of evaluation has been clarified with the combined results of all methods taking into account test results of products distributed in Hungary. On the other hand conversion of a result from one method to another may lead to inaccurate classification. In fact this can be recognised that only the classification of oily ramp test (R9) can correspond to the coefficient of friction at the bottom of the scale.

The CPR requires that flooring products must provide adequate slip resistance during an economically reasonable working life. In Hungary there is no requirement for slip resistance yet. For this reason tests have been performed on ceramic tiles characterised by different surface texture to assess the interaction of slipperiness and cleanability in the function of measuring surface roughness.

3 Surface roughness

Surface roughness, an important contributor to slip resistance [13] and cleaning [14], is significant due to the fact that the surface quality of a flooring material is determined by the production technology. The texture is not only influenced by the way of manufacture, but also wear, abrasion and soiling can contribute to the alteration [15]. However a great majority of the surfaces are not completely flat or smooth, so roughness can be a measure of the texture of a surface, thus it is quantified by the vertical deviations of a real surface from its ideal form. Surface roughness determines the primary texture of the surface, and is normally used for quantification of floor topography [16].

Detecting unevenness of the surface measurements were performed by Surftest SJ-301 surface roughness-meter. A very small (scale of μm) tip radius of diamond stylus (Fig. 7) is moved in contact with a sample for a specified distance and contact force while scanning the surface.

The approach is to measure and analyze the surface texture, so a filtered roughness profile is used for this evaluation. The remaining profile is partitioned into adjacent segments, where height (Z_p) is assumed to be positive in the up direction from the mean line opposite to the depth (Z_v) (Fig. 8).

It is possible to represent the surface roughness by using many different parameters. In this study 2 roughness parameters were chosen for the evaluation according to standard EN ISO 4287 [17]; arithmetical mean deviation Eq. (1) and the maximum height of the assessed profile Eq. (2) are calculated based on the roughness profile shown in Fig. 8.

$$R_a = \frac{1}{\ell} \int_0^{\ell} |Z(x)| dx \quad (1)$$

and

$$R_z = \frac{1}{5} \sum_{i=1}^{5} Z_p + \frac{1}{5} \sum_{i=1}^{5} Z_v \quad (2)$$

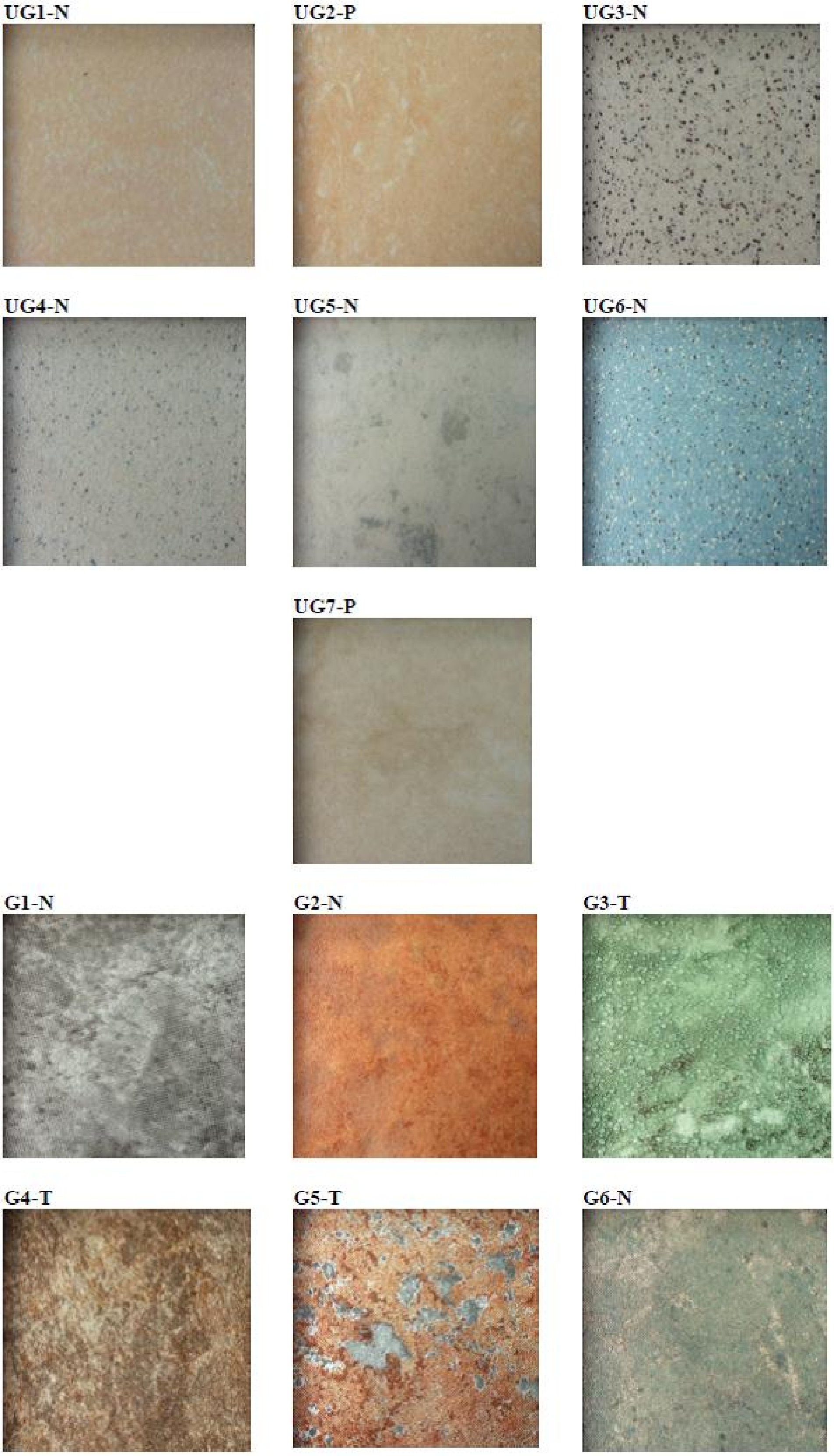


Fig. 4. Images of tested ceramic tiles

Fig. 5. Floor Slide Control 2000 Print

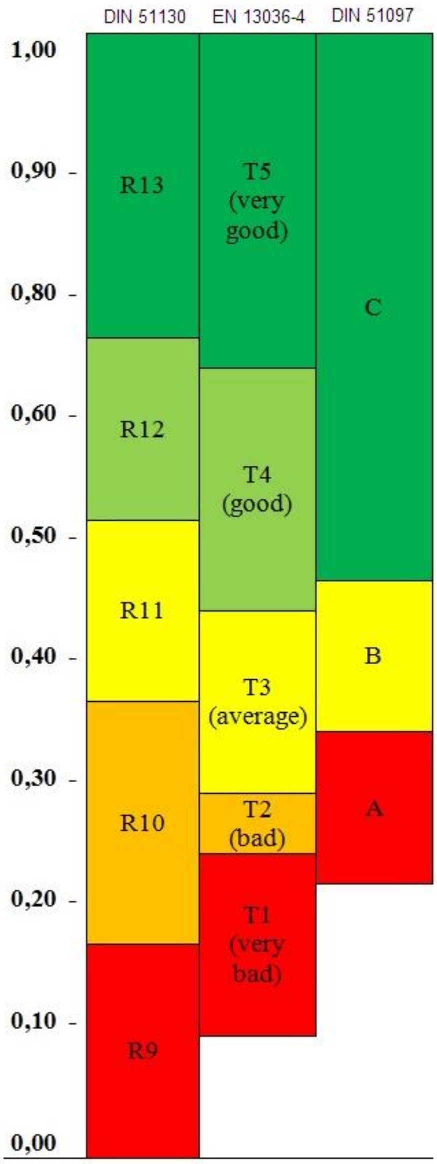


Fig. 6. Classification of slip resistance using combined test methods

The above mentioned two parameters were measured on the surface of each samples and Table 2 shows the average of 5 measurements.

By comparing the obtained test results, a linear relationship (3) was found between the two parameters that can be described by

$$R_z \approx R_a \times 6 \qquad (3)$$

The higher the value of R_a the smaller the ratio of the two parameters (R_z/R_a). Based on the evaluation of these correlations, it was pointed out that the surface roughness depends on the value of the measurement range.

For polished surface we also evaluated that average roughness (R_a) is usually smaller than $1\,\mu$m, while textured surface has significantly high mean deviation observed in its profile.

The parameter R_z represents the sum of the height of the largest peak height and the largest valley depth in the profile. So it can be assumed by observing the graphical representation that possible contamination may gather in the valleys eventuating to a discoloration of the unglazed tile. This phenomenon could partially related to the way of cleaning parallel to the surface.

4 Cleanability

Risk of slipping on flooring is mostly affected by the presence of contamination. Slip resistance of ceramic tiling can change with use. Different material behave adversely against various chemicals, they also vary in tendency of staining and cleanability [12]. The resistance of chemicals and to staining of ceramic tiles is also a property that shall be declared according to EN 14411 [6]. During the determination of chemical resistance by using test method described in EN ISO 10545-13 [18] ceramic tiles are subjected to the action of test solutions (household chemicals, swimming pool salts, acids and alkalis at low and high concentrations) at ambient temperature, and the attack is visually evaluated after a set period of time.

Categories of chemical resistance are established for the result of the test:

- Class A, when the tile has undergone no apparent surface changes
- Class B, when the effects of the aggression are not very noticeable
- Class C, when there are evident effects of the attack, with total or partial loss of the original surface

The test method for evaluating the stain resistance according to EN ISO 10545-14 [19] is similar to the above mentioned process. The face of a tile is maintained in contact with various test staining agents (green and red solution, iodine in alcohol solution and olive oil) for a sufficient period of time.

The surface is then subjected to fixed cleaning methods and finally, is examined to detect any irreversible changes in ap-

Tab. 1. Result of slip resistance tests measured on ceramic tiles

Sample ID.	Average angle of inclination (wet)	Average angle of inclination (oily)	Skid-resistance value (PTV wet)	Skid-resistance value (PTV dry)	Coefficient of friction (μ)
UG1-N	21	13	8	59	0,70
UG2-P	24	15	23	57	0,64
UG3-N	23	18	21	45	0,42
UG4-N	27	19	29	87	0,56
UG5-N	20	18	29	96	0,37
UG6-N	26	18	24	86	0,79
UG7-P	23	7	7	83	0,44
G1-N	12	15	15	53	0,17
G2-N	27	26	40	62	0,23
G3-T	19	16	14	73	0,53
G4-T	28	19	25	71	0,49
G5-T	29	24	33	89	0,40
G6-N	23	16	22	89	0,45

Tab. 2. Result of surface roughness of ceramic tiles

Sample ID.	Arithmetical mean deviation (R_a) (μm)	Maximum height of the assessed profile (R_z) (μm)
UG1-N	1.62	8.26
UG2-P	0.61	10.67
UG3-N	1.74	13.05
UG4-N	5.19	22.35
UG5-N	2.99	18.40
UG6-N	1.93	12.66
UG7-P	0.04	0.28
G1-N	1.00	6.41
G2-N	4.00	20.85
G3-T	3.54	14.84
G4-T	2.18	12.85
G5-T	3.87	20.53
G6-N	2.19	12.40

pearance. Categories for stain resistance vary through cleaning agents:

- Class 5.: stain is removed by hot water
- Class 4.: stain is removed by hand cleaning with weak commercial product
- Class 3.: stain is removed by mechanical cleaning with strong commercial product
- Class 2.: stain is removed after immersion for 24 hours in a solvent
- Class 1.: stain is not removed

Table 3 shows the classification of the resistance of chemicals and to staining performed for the same samples mentioned before.

Group of UA, GA means that there is no visible effect on the surface after treating with household or swimming pool chemicals. In addition all of the glazed products chosen are resistant to high concentration chemicals, belonging to the GHA group. 3 of the 7 unglazed tiles could not withstand this concentration without damage, so they are classified as ULA, while the other 4 are in the group of UHA. Most of the samples are stain resistant, only one surface needed mechanical cleaning.

As a matter of fact, required or specified slip resistance can be maintained by frequent effective cleaning with appropriate detergent and cleaning tools. Therefore surfaces of these tiles need further examination in order to get adequate correlation between the evolution of slip resistance and changing in surface roughness during continuous cleaning practice.

The type of contamination, that the floor is exposed to, will influence the treatment, the cleaning frequency and the used material. Although ceramic tiles are very easy to clean and maintain, it is important that an effective cleaning is established for each regime.

In most domestic and commercial applications a daily procedure involves the removal of contamination by sweeping and then washing with well-tried detergent. Sodium hypochlorite (NaOCl) is frequently used in Hungary as a disinfectant dissolved in water. Because of its destaining properties, it is often a choice in household cleaning and in hospitals. Even so it was not chosen for test solution in EN ISO 10545-13 [18] standard.

In this article we report the impact of multiple cycles of sodium hypochlorite treatment on ceramic tile samples by using concentrate and diluted solution. Thus we would like to show if these treatments could modify the surface therefore surface roughness was measured as an indicator of the behavior of the different texture.

Successive cycles of normal (1:5 dilution) and concentrated treatment was done on the samples, after this the surface of tiles was washed with potable water, then dried and analyzed. Each value of R_a and R_z corresponds to the average of 5 measurements in 5 different locations of the sample. In Table 4 and Table 5,

Fig. 7. Detector unit of SJ-301 surface roughness-meter

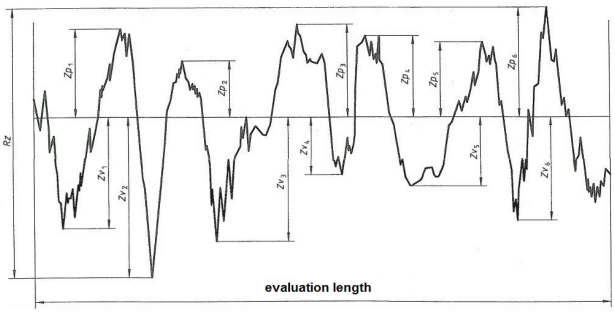


Fig. 8. Roughness profile

Tab. 3. Classification of chemical resistance and resistance to staining of ceramic tiles

Sample ID.	Chemical resistance	Resistance to stains
UG1-N	UA, UHA	5.
UG2-P	UA, UHA	5.
UG3-N	UA, UHA	3.
UG4-N	UA, ULA	4.
UG5-N	UA, ULA	5.
UG6-N	UA, UHA	4.
UG7-P	UA, ULA	4.
G1-N	GA, GHA	5.
G2-N	GA, GHA	5.
G3-T	GA, GHA	4.
G4-T	GA, GHA	4.
G5-T	GA, GHA	5.
G6-N	GA, GHA	5.

the results of surface roughness measurements are reported after diluted and concentrated NaOCl treatment.

As seen in Fig. 9-12 regarding both parameters there is a revolving change in the surface. After consecutive cycles peaks in the roughness profile appear that is likely to be eliminated in the next stage by treating additional amount of detergent.

This experiment suggests that there is not only an increase in the roughness but also deterioration in the surface that would affect the life and the surface quality of ceramic tiles. This alteration also plays an important role in the uncertainty of slip resistance and show a direct relationship between these properties. Test results measured on dry surface were also influenced by the effect of modification in roughness, seen in Table 6-7.

As can be seen in Fig. 13-16 in the presence of water, curves of PTV, measured on samples on original surface and after each treatment represent the change, mostly decrease in slipperiness.

Cleanability of a tile or a surface may vary dramatically depending on its roughness properties resulting in the contribution to slipperiness of floor covering materials. In addition to this Fig. 17-20 show the values of slip resistance test performed by using SRT measured on dry samples in each state.

Slipping mostly happens on flooring contaminated by water. Based on the evaluation of the test results of wet PTV, it is examined that the way of cleaning can influence the primary surface roughness of ceramic tiles; even so this property can change during the lifetime of the installed product. Interaction between these factors were also significant regarding the quantification of slipperiness and furthermore the classification of flooring material in different stages. Determination of the irregular alteration in PTV results after each treatment phase requires additional research. Table 8 and 9 show the PTV measured under all experimental conditions and give a qualitative comparison to the assessment of correlations.

5 Conclusions

According to the surface roughness test and PTV results tendency of slipperiness and efficiency of applicable cleaning detergent can be determined. Evaluating those test results, understanding of material properties such as texture, grain size and in addition detecting the changes in surface roughness, equally help in the selection of proper cleaning techniques.

It was examined that after different solution of sodium hypochlorite treatment in this cleaning experiment changes in the surface occurred. Results of the measured roughness parameters show that cleanability of both glazed and unglazed ceramic tiles could modify the surface. This might lead to a change in the slip resistance of the tile.

Polished surface of ceramic tiles has lower coefficient of friction, therefore dangerous in term of slip resistance. On the contrary roughening of a surface has positive effect on slip resistance, but at the same time prevents the easy removal of dirt. Consequently slip resistance, cleanability and surface roughness are the interrelated properties of the flooring.

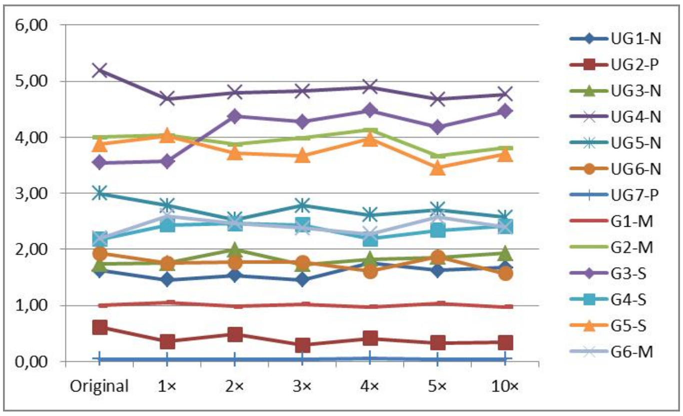


Fig. 9. Change in R_a measured on ceramic tiles after diluted NaOCl treatment

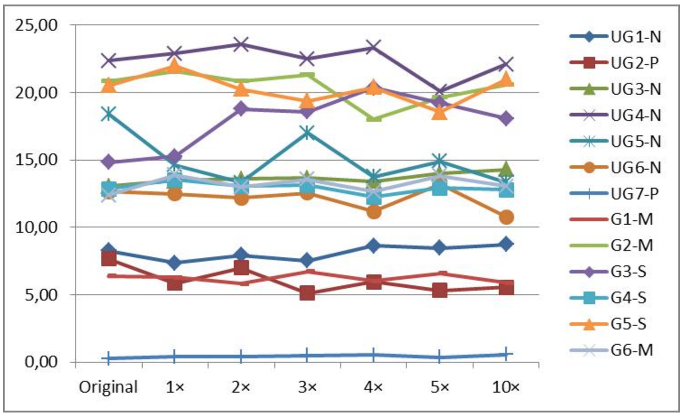


Fig. 10. Change in R_z measured on ceramic tiles after diluted NaOCl treatment

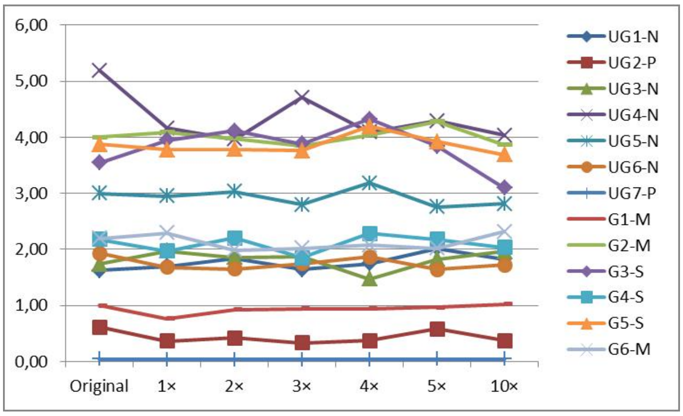


Fig. 11. Change in R_a measured on ceramic tiles after concentrated NaOCl treatment

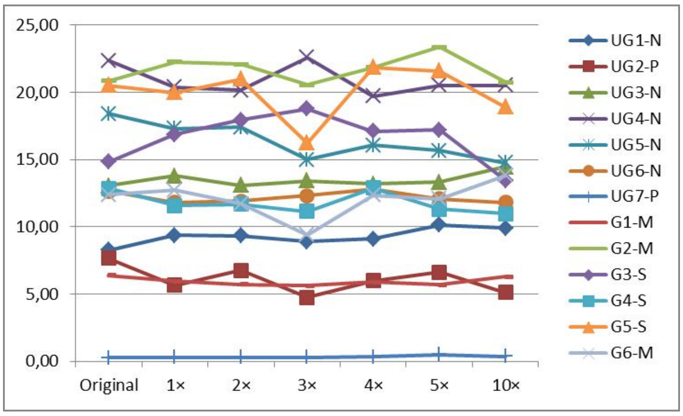


Fig. 12. Change in R_z measured on ceramic tiles after concentrated NaOCl treatment

Tab. 4. Results of surface roughness measured on ceramic tiles after diluted NaOCl treatment

Sample ID.	Original		5×treated		10×treated	
	R_a (μm)	R_z (μm)	R_a (μm)	R_z (μm)	R_a (μm)	R_z (μm)
UG1-N	1.62	8.26	1.62	8.46	1.67	8.73
UG2-P	0.61	7.67	0.33	5.34	0.34	5.56
UG3-N	1.74	13.05	1.86	13.99	1.93	14.28
UG4-N	5.19	22.35	4.68	20.08	4.77	22.11
UG5-N	2.99	18.40	2.71	14.89	2.57	13.35
UG6-N	1.93	12.66	1.86	13.21	1.57	10.80
UG7-P	0.04	0.28	0.04	0.39	0.04	0.58
G1-N	1.00	6.41	1.04	6.60	0.97	5.89
G2-N	4.00	20.85	3.67	19.67	3.81	20.59
G3-T	3.54	14.84	4.18	19.21	4.46	18.09
G4-T	2.18	12.85	2.34	12.94	2.41	12.78
G5-T	3.87	20.53	3.45	18.55	3.70	21.01
G6-N	2.19	12.40	2.57	13.81	2.40	13.07

Tab. 5. Results of surface roughness measured on ceramic tiles after concentrated NaOCl treatment

Sample ID.	Original		5×treated		10×treated	
	R_a (μm)	R_z (μm)	R_a (μm)	R_z (μm)	R_a (μm)	R_z (μm)
UG1-N	1.62	8.26	2.02	10.15	1.82	9.90
UG2-P	0.61	7.67	0.58	6.65	0.37	5.13
UG3-N	1.74	13.05	1.83	13.33	1.96	14.48
UG4-N	5.19	22.35	4.29	20.51	4.04	20.52
UG5-N	2.99	18.40	2.76	15.66	2.82	14.77
UG6-N	1.93	12.66	1.64	12.09	1.72	11.81
UG7-P	0.04	0.28	0.04	0.52	0.04	0.37
G1-N	1.00	6.41	0.96	5.71	1.02	6.31
G2-N	4.00	20.85	4.28	23.36	3.86	20.76
G3-T	3.54	14.84	3.84	17.22	3.09	13.48
G4-T	2.18	12.85	2.18	11.31	2.03	10.99
G5-T	3.87	20.53	3.92	21.60	3.69	18.91
G6-N	2.19	12.40	2.02	12.10	2.31	13.84

Tab. 6. Results of skid-resistance value (PTV) measured on ceramic tiles after normal treatment

Sample ID.	Original		5×treated		10×treated	
	PTV wet	PTV dry	PTV wet	PTV dry	PTV wet	PTV dry
UG1-N	8	59	14	44	15	45
UG2-P	23	57	15	69	13	48
UG3-N	21	45	24	100	23	83
UG4-N	29	87	31	91	30	95
UG5-N	29	96	24	96	21	55
UG6-N	24	86	37	83	30	74
UG7-P	7	83	6	70	8	69
G1-N	15	53	16	49	11	49
G2-N	40	62	43	91	42	93
G3-T	14	73	24	81	20	81
G4-T	25	71	27	76	25	69
G5-T	33	89	49	89	43	86
G6-N	22	89	50	79	31	77

Tab. 7. Results of skid-resistance value (PTV) measured on ceramic tiles after concentrated treatment

Sample ID.	Original		5×treated		10×treated	
	PTV wet	PTV dry	PTV wet	PTV dry	PTV wet	PTV dry
UG1-N	8	59	13	76	13	45
UG2-P	23	57	15	50	11	51
UG3-N	21	45	26	84	25	84
UG4-N	29	87	34	51	33	93
UG5-N	29	96	25	96	22	60
UG6-N	24	86	38	77	29	70
UG7-P	7	83	7	69	9	71
G1-N	15	53	16	83	12	49
G2-N	40	62	45	80	46	95
G3-T	14	73	24	96	21	85
G4-T	25	71	33	99	27	74
G5-T	33	89	51	90	45	85
G6-N	22	89	51	94	33	79

Tab. 8. Results of wet PTV measured on ceramic tiles after diluted NaOCl treatment and classification

Sample ID.	Original		5×treated		10×treated	
	PTV wet	Class	PTV wet	Class	PTV wet	Class
UG1-N	8	T1	14	T1	15	T1
UG2-P	23	T1	15	T1	13	T1
UG3-N	21	T1	24	T1	23	T1
UG4-N	29	T2	31	T2	30	T2
UG5-N	29	T2	24	T1	21	T1
UG6-N	24	T1	37	T3	30	T2
UG7-P	7	T1	6	T1	8	T1
G1-N	15	T1	16	T1	11	T1
G2-N	40	T3	43	T3	42	T3
G3-T	14	T1	24	T1	20	T1
G4-T	25	T2	27	T2	25	T2
G5-T	33	T2	49	T4	43	T3
G6-N	22	T1	50	T4	31	T2

Tab. 9. Results of wet PTV measured on ceramic tiles after concentrated NaOCl treatment and classification

Sample ID.	Original		5×treated		10×treated	
	PTV wet	Class	PTV wet	Class	PTV wet	Class
UG1-N	8	T1	13	T1	13	T1
UG2-P	23	T1	15	T1	11	T1
UG3-N	21	T1	26	T2	25	T2
UG4-N	29	T2	34	T2	33	T2
UG5-N	29	T2	25	T2	22	T1
UG6-N	24	T1	38	T3	29	T2
UG7-P	7	T1	7	T1	9	T1
G1-N	15	T1	16	T1	12	T1
G2-N	40	T3	45	T4	46	T4
G3-T	14	T1	24	T1	21	T1
G4-T	25	T2	33	T2	27	T2
G5-T	33	T2	51	T4	45	T4
G6-N	22	T1	51	T4	33	T2

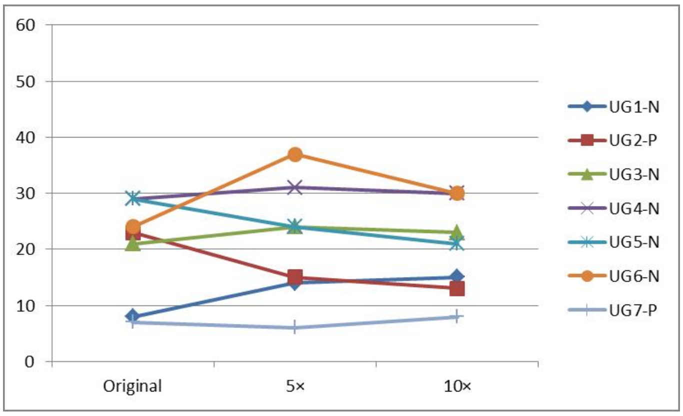


Fig. 13. Change in wet PTV measured on unglazed ceramic tiles after diluted NaOCl treatment

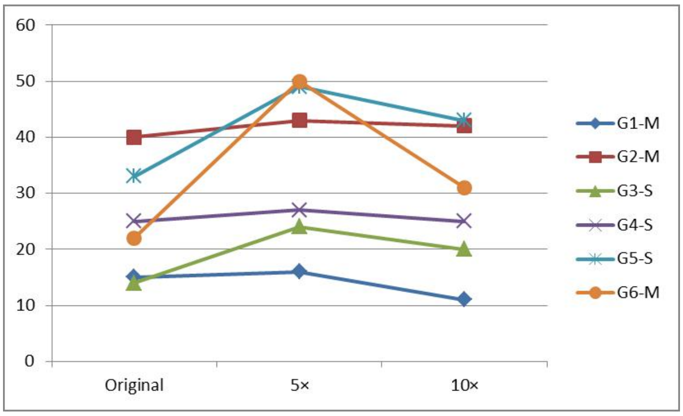


Fig. 14. Change in wet PTV measured on glazed ceramic tiles after diluted NaOCl treatment

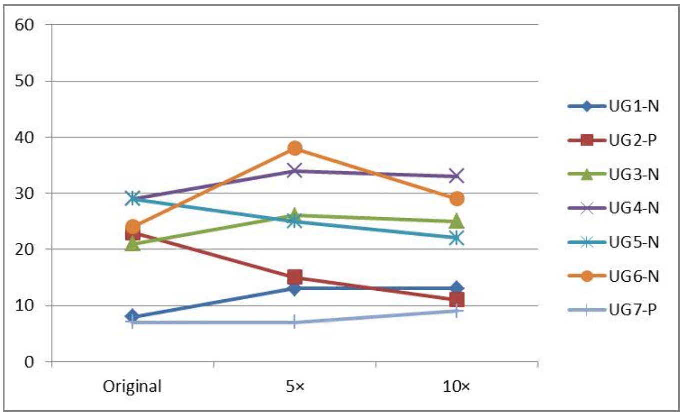


Fig. 15. Change in wet PTV measured on unglazed ceramic tiles after concentrated NaOCl treatment

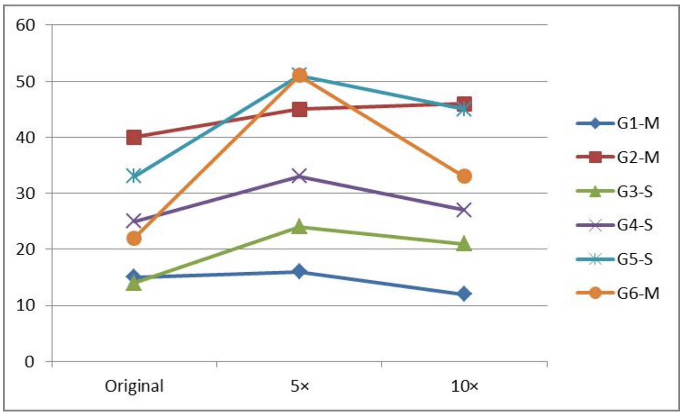


Fig. 16. Change in wet PTV measured on glazed ceramic tiles after concentrated NaOCl treatment

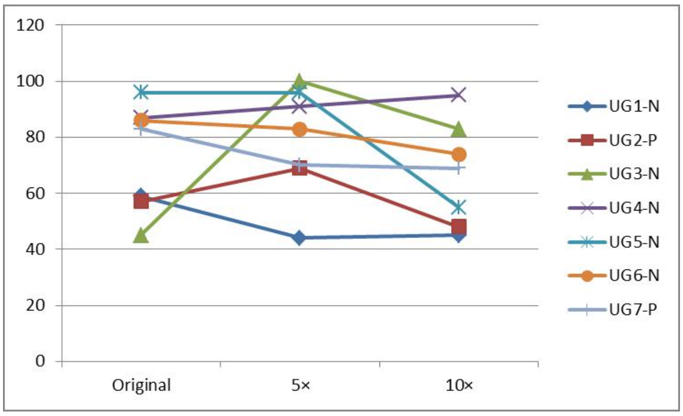


Fig. 17. Change in dry PTV measured on unglazed ceramic tiles after diluted NaOCl treatment

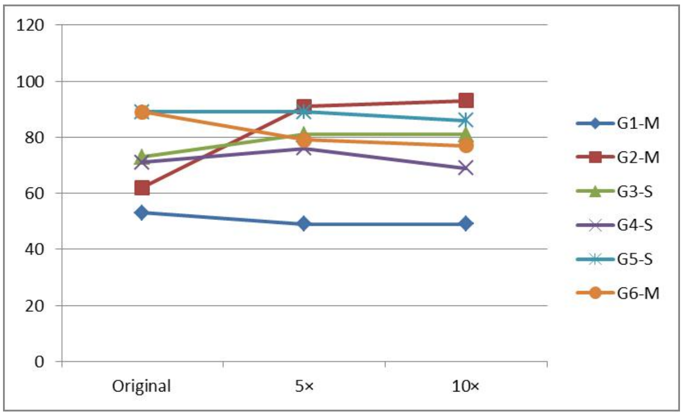


Fig. 18. Change in dry PTV measured on glazed ceramic tiles after diluted NaOCl treatment

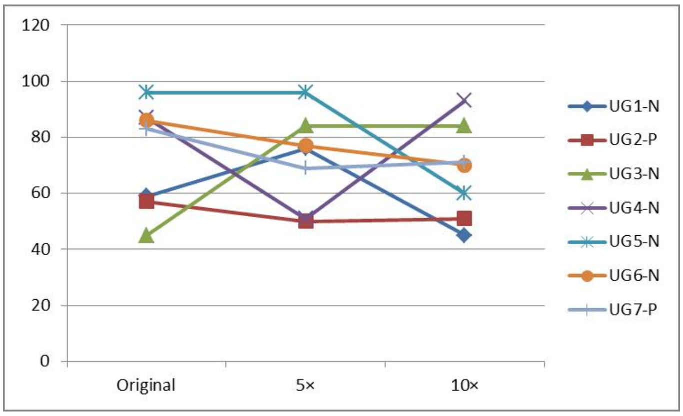


Fig. 19. Change in dry PTV measured on unglazed ceramic tiles after concentrated NaOCl treatment

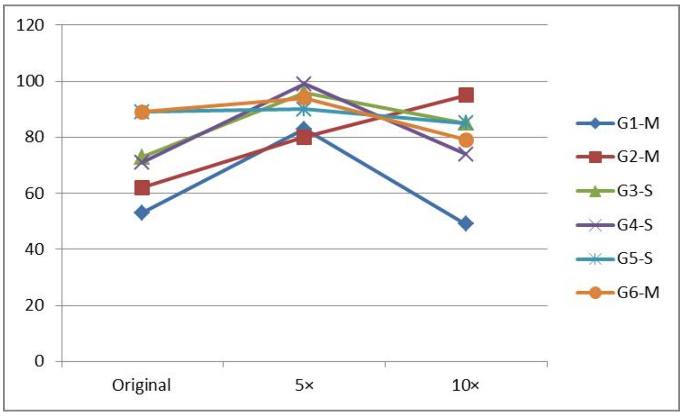


Fig. 20. Change in dry PTV measured on glazed ceramic tiles after concentrated NaOCl treatment

As a result determining if a tile is safe or not regarding the influence of its surface is not adequate, because slip resistance of a ceramic floor in service depends on its characteristics and these may change over the lifetime. Placing more emphasis on the quantification of slip resistance would allow customers to make comparisons and help them to select the most appropriate product for their needs.

Consequently to satisfy the requirements of the regulations, manufacturers shall take responsibility for the conformity of their product with its declared performance, so that would require a risk assessment to be carried out on the intended use of flooring, which however will have an impact on the type of surface finish.

In order to maintain the surface quality of tiles it is important that a strict cleaning regime is implemented using appropriate products specifically designed for cleaning ceramic tiles. Depending on the texture of the tile consideration should be given to the type of cleaning (material, way).

In conclusion to give satisfactory service for ceramic tiles, it is necessary to be selected and installed competently, and to receive appropriate initial treatment, protection and maintenance.

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