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Introduction
Moisture or dirt may make floor slippery, leading to an increased risk of slipping. For that reason, international requirements apply to the slip resistance of flooring materials such as tiles. This information sheet aims to give as accurate a description as possible of the testing method which is accepted in the United States for determining the anti-slip properties of ceramic tiles as described in ANSI A137.1. In addition, the methods which are conventionally used in Europe will be discussed, which meet European technical specification CEN/TS 16165. Though these are not directly applicable in the United States, they may be relevant for the design and specification of projects outside the US. Mosa tiles are also tested according to these methods when applicable. This information sheet provides insight into the results of the Mosa Ultragres unglazed tile range for flooring applications, including their various surface types and specific areas of use.

For all other characteristics, standards, and tolerances, please refer to the Ultragres porcelain tiles, unglazed technical product sheet.

About ANSI A137.1 section 9.6 - Procedure of Dynamic Coefficient of Friction (DCOF) Testing
Section 9.6 of ANSI A137.1 describes the method for determining the dynamic coefficient of friction using a measuring device called a tribometer, also known under the name DCOF AcuTest. This method applies to level floors in interior applications for the purpose of foot traffic. Other areas of use are outside the scope.
A tribometer is an automated, portable device that measures frictional resistance while moving over the surface. In addition to how the test is performed, there is a description of the requirements placed on:
- the device and auxiliary materials (such as sliders, preparation materials, and a lubricating medium among other things);
- the method of calibrating and preparing the sensor;
- reporting.

According to ANSI A137.1, the preferred device is the BOT 3000, though equivalent devices are also permitted. The standard method is to perform the test under wet conditions, with the aid of a 0.05% sodium lauryl sulfate (SLS) solution in distilled water as a lubricating medium.

Figure 1 - BOT 3000 tribometer

As of January 2014, this method replaces the old method for determining the static coefficient of friction in accordance with ASTM C1028 and is therefore the official method for determining the frictional resistance of hard flooring materials in the United States.

Pursuant to section 6.2.2.1.10 of ANSI A137.1, the ASTM C1028 method can still be used:
- as an alternative to DCOF measurements under dry conditions;
- to enable comparisons with measurements of tiles that were performed in the past based on the C1028 method.

The difference between static and dynamic frictional resistance is that, in the case of static friction, resistance is measured by setting in motion an object of a certain prescribed weight from a stationary position, while in the case of dynamic friction the resistance is measured while an object of a certain prescribed weight moves across the surface at a consistent rate of speed, which is likewise specifically mandated.

The DCOF AcuTest effectively measures the interaction between the sensor, the lubricating medium, and the tile surface under controlled conditions; the surface is therefore the only variable. This makes it possible to compare different surfaces or to measure changes in the surface as a result of wear and tear or soiling, for example.

The minimum value for ceramic tiles used for level interior applications under wet conditions is 0.42. However, section 6.2.2.1.10 of ANSI A137.1 expressly states that the responsibility for using tiles with a value of ≥ 0.42 lies with the specifying party and that the latter must take the following into consideration, among other factors:
- intended use and type of traffic;
- anticipated level of soiling;
- anticipated maintenance and cleaning;
- anticipated degree of wear and tear;
- manufacturer's recommendations.

The above factors also apply to other applications besides level interior applications for foot traffic.

Tiles that achieve a value of less than 0.42 with an SLS solution are suitable for use in dry areas and in areas that may come in contact with water as long as suitable measures are taken to keep them dry, such as (but not limited to):
- absorbent entry mats;
- extra safety measures during cleaning.

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Advantages of the DCOF AcuTest

- Measurement can be performed in a mobile manner, either in a laboratory or on-site.
- The method offers good reproducibility and is less dependent upon the operator than the C1028 method.

Disadvantages of the DCOF AcuTest

- Surfaces with pronounced profiles cannot be measured because they negatively influence the uniform motion of the device.
- Overly smooth surfaces can yield a false reading of high slip resistance due to high friction between the test surface and the sliders.
- The wheels can lose traction (i.e. slip) on surfaces that are wet or highly soiled, which can influence the validity of the measurements.

Correlation between DCOF and SCOF

Based on multiple studies performed by TCNA, in which over 300 different tile surfaces were tested and evaluated under wet conditions, it was determined that a SCOF of 0.60 correlates with a DCOF of 0.38 on average.

However, no rights may be derived from any DCOF value which is estimated on the basis of a SCOF value, since there is no direct connection between the two methods.

You will find an overview of Mosa series and surface types below, along with the typical values measured in accordance with both methods.

Table 1 - Overview of Mosa measurements

Surface type	Available size (in inches)	DCOF (AcuTest) Wet	SCOF (ASTM C1028) Dry*	SCOF (ASTM C1028) Wet*
AS	6 x 6, 12 x 12	≥ 0.63		
CR	12 x 24, 24 x 24, 36 x 36	≥ 0.58		
LS	6 x 6, 12 x 12	≥ 0.74		
MR	6 x 6, 24 x 24	≥ 0.51		
MZVR, MZVV	12 x 12	≥ 0.53	≥ 0.78	≥ 0.63
RL	12 x 12, 12 x 24, 18 x 18, 24 x 24, 24 x 48, 36 x 36	≥ 0.73	≥ 0.95	≥ 0.81
RM	6 x 6	≥ 0.64	≥ 0.95	≥ 0.75
RQ	12 x 24, 18 x 36, 24 x 24, 36 x 36	≥ 0.62	≥ 0.91	≥ 0.87
TS, WS, XS	6 x 6			
V	4 x 4, 12 x 12, 12 x 24, 18 x 18, 18 x 36, 24 x 24, 24 x 48, 36 x 36, 40 x 40	≥ 0.70 (except for the color numbers 200 and 210: ≥ 0.57)	≥ 0.83	≥ 0.64
VV	6 x 6	≥ 0.70	≥ 0.83	≥ 0.64

* Please note that all test reports are from before 2014.

About CEN/TS 16165 - Determination of slip resistance of pedestrian surfaces

The European Technical Specification CEN/TS 16165 describes in separate annexes the four accepted and most widely used methods for determining the slip resistance of pedestrian surfaces* in Europe. These four methods are:

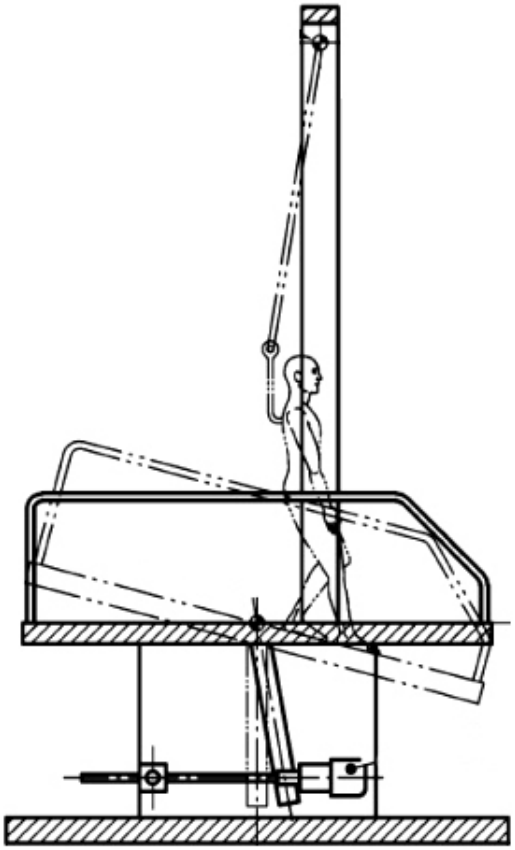
- Annex A - Ramp method, for floors that are walked on barefoot, tested with water and soap as the medium;
- Annex B - Ramp method, for floors in public spaces and the working environment, tested with footwear and with oil as the medium;
- Annex C - Pendulum friction method, for wet and dry applications with specific rubber sliders;
- Annex D - Tribometer method, for wet and dry applications with specific rubber sliders.

Methods A and B can only be performed in the laboratory. Methods C and D can be used for measuring on-site.

Annex A - Ramp method, for floors that are walked on barefoot

In this, two test persons, secured in a safety harness, walk barefoot over the surface to be tested, which is continuously wettened with a soap and water solution. The test subjects walk up and down the ramp, facing downwards. The angle of the ramp is gradually increased until the test subject slips. Each test subject walks four times until they slip, with the average of the eight tests being recorded. If there are individual values with a difference greater than 2° of this average, the test is repeated. This average is the final average critical gradient of the tested surface. Before the test subjects are allowed to perform this test, they must qualify by walking on three calibration surfaces within a specified range of gradient; if a test subject does not succeed in this, they are disqualified from performing the test.

Figure 2 - Schematic drawing of the ramp method



* Sports floors and paving materials for vehicles are outside the scope of CEN/TS 16165.

Annex B - Ramp method, with footwear
This method is identical to the method described above for Annex A, however the subjects now wear special safety shoes ('reference' shoes) and a layer of 10W30 engine oil is applied evenly on the surface before the test. Here, every test person carries out the test three times. Before the test subjects are allowed to perform this test, they must qualify by walking on three calibration surfaces within a specified range of gradient; if a test subject does not succeed in this, they are disqualified from performing the test. The calibration surfaces are different from those of method A.

A classification is assigned to the surface depending on the critical gradient achieved by method A or B. This serves as a basis for choosing the right surface for floors where specific requirements are set for slip resistance. Aspects that are important in determining the minimum class for an area of application include local conditions and the expected nature and quantity of contamination. This test is not mobile, so it can only be performed in a laboratory. In principle, it is used only for product specifications: selecting the floor with the right properties for the intended use.

Advantages and disadvantages of the ramp method (annex A and B)
Advantages
- It is the method best suited to human gait.
- It is reproducible in terms of the prescribed gait and speed.
- It can be applied to all surface types, even those with profound relief.
- The use of calibration surfaces provides the operator with increased objectivity.
- It is usable on the basis of classification linked to intended use.

Disadvantages
- It is a laboratory test; on-site testing is not possible.

Annex C - Pendulum friction method
In this method, a rubber slider of a specified hardness is attached to the end of the pendulum arm by means of a spring mechanism. The pendulum is released from a 90° angle. This method measures the loss of energy that occurs when the slider is dragged and decelerated over the surface to be tested, which affects the swing of the pendulum. This maximum swing is read on a scale; the smaller the swing, the higher the score and the lower the risk of slipping. The test is performed in at least two directions, eight times in each direction, with the average of the last five measurements recorded.

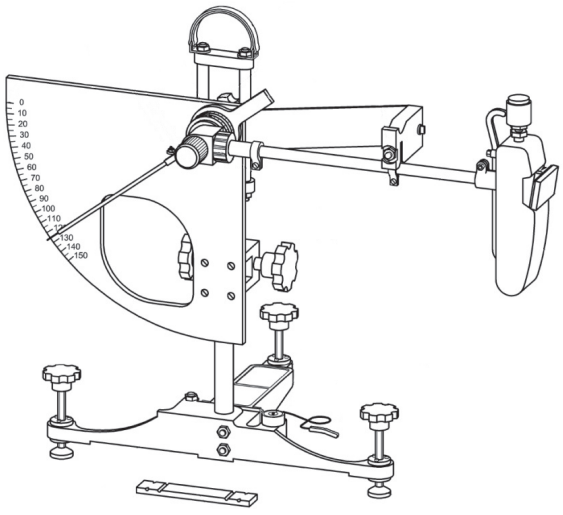
The test can be carried out wet and dry as standard, and with two types of rubber sliders:
- Slider 57* (soft rubber) simulates barefoot use;
- Slider 96 (hard rubber) simulates use with footwear.

This test can be carried out either in a laboratory or on-site, and can be used to choose the right floor for the intended use and to monitor risks during use of the floor.

Advantages
- The measurement is mobile; on-site testing is possible.
- It is easily reproducible if properly adjusted and used by a skilled operator.

Disadvantages
- The device is sensitive to incorrect adjustment and requires regular calibration; a high level of expertise is required at the institution.
- The measuring surface of the slider is very small.
- The measurements can be strongly influenced by individual elevations in the floor and are therefore not readily applicable to surfaces with deep relief.

Figure 3 - Schematic drawing of the pendulum device



* Formerly Slider 55, see also BS 7976:2 later in this technical information sheet.

Annex D - Tribometer method
A device with a specified weight, equipped with sliders of a specified material and shape, is pulled over the surface to be tested at a constant speed by reeling a steel ribbon. The so-called dynamic friction coefficient (μ) of the surface is calculated by dividing the force required to draw the weight horizontally by the vertical force exerted on the surface by the body. This test can be used in both wet and dry conditions.

This test can also be carried out both in a laboratory and on-site, and can be used to choose the right floor for the intended use and to test and monitor the risk of slipping during use.

Advantages
- The device is mobile; it can be used both in a laboratory and on-site.
- The method has good reproducibility and is less dependent on the operator than the other methods.

Disadvantages
- Surfaces with deep relief cannot be measured as they adversely affect the even movement of the device.
- Surfaces that are very smooth can show apparently high slip resistance due to 'stiction' (strong friction between the test surface and the sliders).

Figure 4 - A tribometer

Difference between American and European tribometer
The major difference between the American and European tribometers is found in the method of propulsion; the American tribometer is a self-propelled device with wheels while the European tribometer is propelled by rolling up a steel band using an internal winding mechanism. The advantage of the latter is that there is no risk of influencing the measurement results through loss of traction as a result of the wheels slipping.

Combined use of methods
The different test methods can be used separately, but also to complement each other; a floor material can be chosen on the basis of ramp methods A or B and the classification derived from them, and then measured immediately after installation on-site using methods C or D. This so-called baseline measurement allows the effect of use and maintenance on slip resistance to be monitored.

Comparisons of the values of different methods are not permitted because they are based on different physical principles.

Theoretically, the dynamic friction coefficient (μ) can be determined by calculating the tangent of the gradient; the result of this can be represented as a dimensionless number in μ.

However, as the table below shows, after conversion using the tangent, a tile classified as R10 on the basis of the ramp method in accordance with DIN 51130, and which would therefore be well suited for indoor applications under clean or slightly dirty conditions, would be classified as 'unsafe' or 'reasonably safe' (0.20 - 0.44 μ) and would have to be supported by additional risk-reducing measures. For application in a wet area, where 0.44 μ is the lower limit according to DIN 51131, a tile with barefoot classification C would have to be used, although according to the ramp method in accordance with DIN 51097 a B value would be sufficient.

Such a comparison can therefore lead to under-specification or over-specification. The different methods can therefore only be used independently or in addition to each other for specifications and monitoring.

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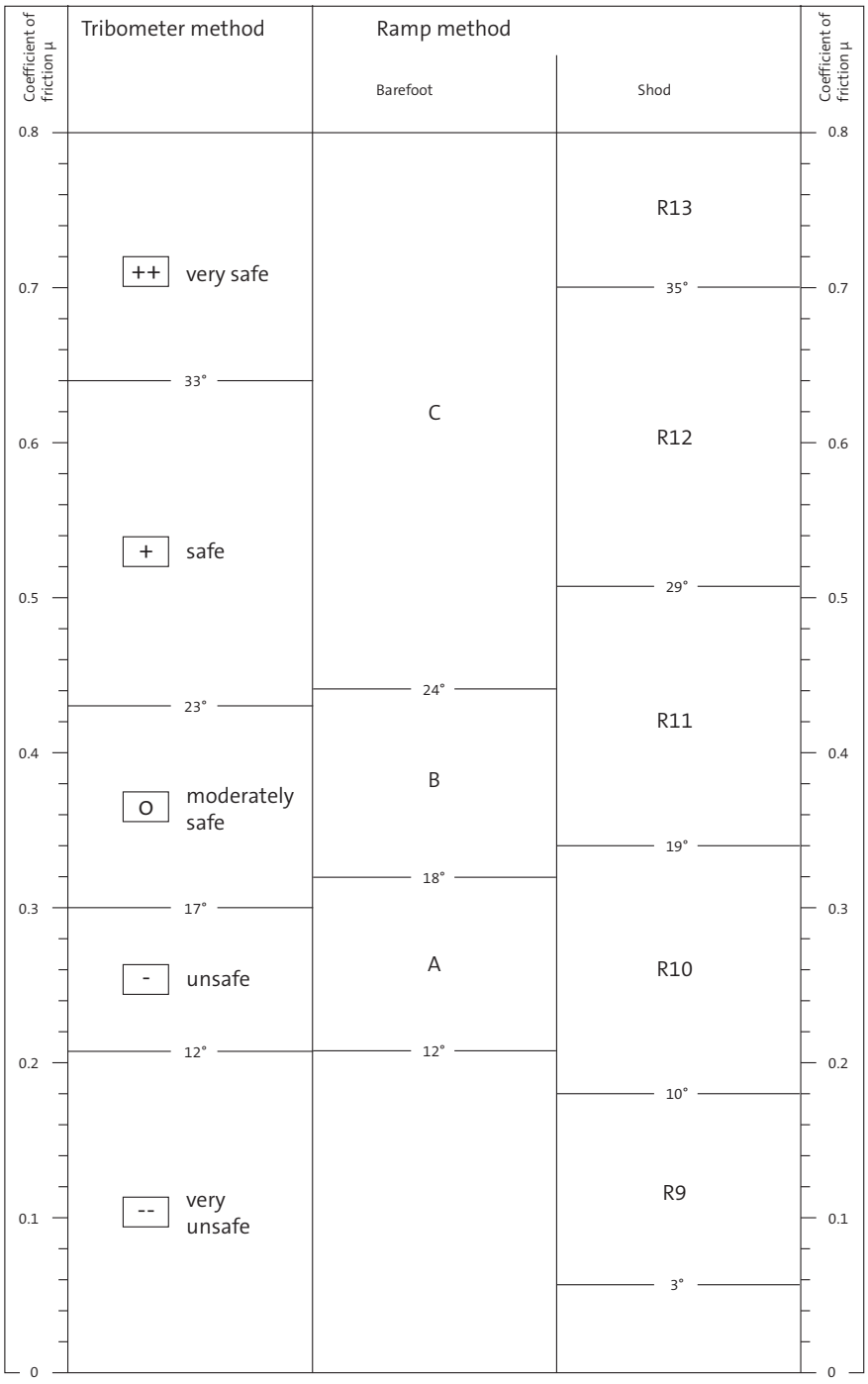
Table 2 - Comparison between μ and R and ABC values



Source: ErgoMed (1995); Das Bewerten der Rutschhemmung von Fußböden, R. Skiba, Wuppertal.

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National standards
The methods described above are based on years of experience with national standards and guidelines within the European Member States. Not every Member State has its own standards or guidelines and often, in determining the suitability of floor covering materials, reference is made to the relevant standards or guidelines of Member States where these have already been laid down. Sometimes other criteria and methods are applied nationally in their own guidelines. These methods not described in CEN/TS 16165 are not discussed in this document.

NEN 7909
NEN 7909 is the Dutch standard that is based on the method described in Annex D of the CEN/TS 16165 tribometer test. In addition to the determination method, this standard also includes application criteria and relates to horizontal and inclined pedestrian surfaces in public and working areas. NEN 7909 is a private law standard, which means that the requirements of the standard are only binding if agreed between the contracting parties.

Table 3 - Overview of the standards on which Mosa Ultragres tiles have been tested and classified

Standard	Country of origin	CEN/TS 16165 method	Property	Classification	Limits
NEN 7909	The Netherlands	Annex D - tribometer	Dynamic friction coefficient μ	• dry application • wet application • wet application in swimming pool	μ ≥ 0.30 μ ≥ 0.40 μ ≥ 0.45
DIN 51097	Germany	Annex A - ramp, barefoot	Critical gradient α	• A • B • C	α ≥ 12° α ≥ 18° α ≥ 24°
DIN 51130	Germany	Annex B - ramp, safety footwear	Critical gradient α	• R9 • R10 • R11 • R12 • R13	6° ≤ α < 10° 10° ≤ α < 19° 19° ≤ α < 27° 27° ≤ α < 35° α ≥ 35°
DIN 51131	Germany	Annex D - tribometer	Dynamic friction coefficient μ	• insufficient rigidity, special measures* required • sufficient rigidity, additional measures** recommended • sufficient rigidity, additional measures** recommended • sufficient rigidity	μ < 0.30 μ < 0.30, but meets R rating 0.30 ≤ μ < 0.44 μ ≥ 0.45
BS 7976:2	United Kingdom	Annex C - pendulum	Pendulum Test Value (PTV)	• high slip potential • moderate slip potential • low slip potential	PTV 0-24 PTV 25-36 PTV 36+

* Examples include handrails, safety shoes, post-treatment of the surface or replacement.

** For example doormats, increased cleaning supervision, etc.

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DIN 51097

DIN 51097 underlies Annex A of CEN/TS 16165 and describes:

- the specifications of the test installation;
- the requirements to be set for the operator;
- the way of walking;
- the arithmetical determination of the critical gradient.

A classification is assigned to the tested surface based on the critical gradient achieved. The standard does not describe areas of application. Furthermore, the use of calibration surfaces to qualify the test subject is not yet included in the German standard as it is still subject to research.
In Germany, the areas of application have been established by the joint statutory occupational health insurers on the basis of risk analyses and set down in the guidelines GUV-I 8527. These describe the class that floor-covering materials to be applied in barefoot applications (public swimming pools, washing facilities) must at least satisfy, and are legally binding in Germany.

DIN 51130

DIN 51130 underlies Annex B of CEN/TS 16165 and describes:

- the specifications of the test installation;
- the requirements to be set for the operator;
- the method of calibration;
- the way of walking;
- the arithmetical determination of the critical gradient.

A classification is assigned to the tested surface depending on the critical gradient achieved. The standard does not describe areas of application.

The areas of application are based on the probability of contamination present, the nature of the contamination, and the impact of the contamination on slip resistance in public areas and working environments (entrance areas of public buildings, in shops, in workshops and canteens for instance). This has been established by the joint statutory occupational health insurers in Germany and laid down in guideline GUV-R 181. This is legally binding in Germany.

Below you will find an overview of some common applications and the appropriate Mosa floor tiles.

Table 4 - Overview of requirements, available Mosa surface finishes and areas of application

Class	Average gradient	Suitable for (amongst other things)	Mosa version (size)
A	α ≥ 12°	• areas in which people walk barefoot, mainly dry • changing rooms • pool floors > 31.5 inch water depth	• V • VV
B	α ≥ 18°	• shower areas • swimming pool surrounds • paddling pool • pool floors ≤ 31.5 inch water depth • stairs - max. 39.4 inch wide with handrail on both sides - leading into the water	• AS (12 x 12 inch) • CR • LS • MR • RM • RQ
C	α ≥ 24°	• sloping pool surrounds • stairs leading into the water (not covered by B) • wading pools	• AS (6 x 6 inch) • MZVR, MZVV • RL • TS • WS

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Volume displacement (V)
The V value (volume displacement) describes the extent to which the tile relief allows the displacement of moisture and dirt. This value is expressed in cm^3 of dirt per dm^2 of floor area. If volume displacement is sufficient, the dirt in the relief will be displaced and the tops of the relief will provide sufficient contact and slip resistance.
This value is important in specific areas where larger quantities of substances that increase the risk of slipping are present, such as in meat or fish processing companies. This value may be required in addition to the R value.

V4 at least 4 cm^3 / dm^2
V6 at least 6 cm^3 / dm^2
V8 at least 8 cm^3 / dm^2
V10 at least 10 cm^3 / dm^2

Below you will find an overview of some common applications and the appropriate Mosa floor tiles.

Warning: The displayed slip resistance value on delivery is indicative and may vary in particular cases. Upon request, Mosa can provide a certification with a more precise value for each individual batch of tiles.

BS 7976:2
BS 7976 underlies Annex C of CEN/TS 16165 and describes:
- the requirements set for the operator and calibration tools;
- the method of calibration;
- the adjustment of the device;
- the method of performing the test.

In this standard, the term 'Slider 55' is used for the soft rubber, also known as 'TRL rubber'. The limit values have been determined by the British national health and safety authorities. Based on these, a floor covering material can be classified into the following categories:
- high slip potential PTV 0-24
- moderate slip potential PTV 25-35
- low slip potential PTV 36+

Table 5 - Overview of requirements, available Mosa surface finishes, and areas of application

Class	Average gradient	Volume displacement	Suitable for (amongst other things)	Mosa version
R9	6° ≤ α < 10°		• entrance areas, inside • stairs, inside • canteen, dining area	• whole range
R10	10° ≤ α < 19°		• bathroom facilities • dry food processing • laboratories and surgeries	• CR • MR • MZVR, MZVV • V • VV
R11	19° ≤ α < 27°		• entrance areas, outside • large kitchens < 100 place settings per day • bakeries • cheese factories • fish processing • animal feed production • areas for medicinal baths, hydrotherapy • cold store, packaged goods	• AS • LS • RL • RM • RQ • TS
R12	27° ≤ α < 35°	V4	• rinsing area in large kitchen • large kitchens < 100 place settings per day • frying, grill kitchens • fast food kitchens • cold stores, unpackaged goods	• WS
R13	α ≥ 35°	V10	• abattoirs • meat processing • fish processing	• XS

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Total overview Mosa
Below you will find an overview of Mosa surface designations and their anti-slip results.

Installation and maintenance
When installing tiles with relief, extra attention must be paid to removing residual mortar and grout from the recessed parts of the relief. This is important in order to allow the color and relief to show up better and to guarantee the functional properties.

Floor tiles with relief and tiles with raised designs are more sensitive to dirt and generally require more intensive maintenance than smooth tiles. Cleaning products and methods should be adjusted to meet the particular conditions. The choice of detergent and cleaning method should not have a negative effect on the anti-slip properties of the floor tiles. Choose a scrubbing disc that is sufficiently flexible (such as a white disc) or a brush that is capable of adjusting to the texture of the floor. See www.mosa.com for the latest maintenance recommendations.

N.B.: Third-party anti-slip treatment for Mosa floors - either chemical or mechanical - may have a negative impact on the optical and physical properties of the floor tiles. Mosa does not accept any liability for this.

General questions
For general questions and questions relating to slip resistance, or to obtain test reports, please contact our Customer Service Department at info@mosa.com or on (212) 729 6332.

Table 6 - Total overview of Mosa surface versions and their anti-slip ratings

Surface	Size (in inches)	R rating	ABC rating	μ rating	PTV rating		UNE
					Slider 96	Slider 55	
AS	6 x 6	R11	C		55		
	12 x 12	R11	B		55	≥ 42	Class 2
CR	12 x 24, 24 x 24, 36 x 36	R10	B		40	≥ 33	Class 2
LS	6 x 6, 12 x 12	R11	B		48	≥ 31	
MR	6 x 6, 24 x 24	R10	B	0.42	39	≥ 34	
MZVR, MZVV	12 x 12	R10	C				
RL	12 x 12, 12 x 24, 18 x 18, 24 x 24, 24 x 48, 36 x 36	R11	C		54	≥ 52	Class 1
RM	6 x 6	R11	B	0.50		≥ 62	
RQ	12 x 24, 18 x 36, 24 x 24, 36 x 36	R11	B		52	≥ 49	Class 2
TS	6 x 6	R11	C			≥ 25	
V	4 x 4, 6 x 6, 12 x 12, 12 x 24, 18 x 18, 18 x 36, 24 x 24, 24 x 48, 36 x 36, 40 x 40	R10	A	≥ 0.39	39	≥ 25	Class 1
VV	6 x 6	R10	A	≥ 0.39	39		
WS	6 x 6	R12/V4	C				
XS	6 x 6	R13/V10					

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