ASSESSING THE CHALLENGES AND IDENTIFYING SOLUTIONS FOR PORCELAIN TILE INSTALLATION ON PEDESTAL OR RAISED FLOORING SYSTEMS IN THE ABSENCE OF CURRENT OR RELEVANT INTERNATIONAL STANDARDS

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Porcelain tiles, with their superior durability, aesthetics, and versatility, have become a popular choice for various architectural and construction projects. In recent years, the utilization of porcelain tiles on pedestals has gained significant attention due to their benefits in enhancing exterior spaces. Porcelain tile and its superior technical performance, lower cost and reduced thicknesses and weights used over pedestal or raised floor constructions is attractive when compared to traditional concrete or natural stone products or ceramic/porcelain installed over mortar or adhesive. However, the absence of relevant or current installation guidelines and standards poses several challenges to achieving optimal, safe installations.

This technical paper aims to address the issues faced when specifying and installing porcelain tiles on pedestals worldwide, where the lack of specific guidelines or standards leaves professionals navigating uncharted territory. The article discusses the implications of relying on outdated or generic standards for ceramic tile installation and explores the risks associated with inadequate impact and load-bearing capacities, insufficient wind-uplift resistance, and potential thermal expansion problems.

Drawing from international best practices and experiences, including previous papers published at Qualicer this paper presents a comprehensive overview of the key considerations for successful porcelain tile installation on pedestals.

It highlights the importance of accurate load calculations, pedestal system selection, and perhaps most importantly how to safeguard installations and ensure the safety of the end-user. This paper explores innovative technologies and materials that can address the unique challenges encountered in these installations.

Through an examination of case studies and expert insights, the paper also provides practical recommendations for architects, engineers, and contractors involved in porcelain tile installations on pedestals. It emphasizes the need for proactive collaboration among industry stakeholders to develop robust local standards and guidelines that align with emerging trends and evolving construction practices.

In conclusion, this paper identifies the challenges and proposes practical solutions, it aims to contribute to the ongoing dialogue within the industry, promoting safer and more efficient practices in this rapidly growing field.

INTRODUCTION

In the past 4-6 years, there has been a marked increase in the use of porcelain on pedestal or raised flooring systems in both domestic and commercial applications.

The increased commercial availability of gauged or calibrated porcelain tiles in 20mm (0.78inch), coupled with their increased technical characteristic, particularly related to vastly increased breaking loads compared to porcelain thicknesses used in traditional bonded floor systems of 6-11mm (0.23-0.43inch).

The use of 20mm porcelain in Australia, and other countries in raised floor applications in lieu of other building products is advantageous from a commercial perspective due to the following factors:

- Significant cost saving of using porcelain tile compared to natural stone or concrete products
- Reduced material thicknesses allow for both easier/safer handling and also in the case of minimum termination heights for membranes or finished floor levels, more flexibility during construction.
- Where tiles are manufactured within EN, ANSI, ISO standards, accurate calibration facilitates easier installation compared to other products.
- Inert nature of porcelain is desirable as they are viewed as a long-term application with little maintenance required compared to natural stone or concrete materials.
- Lower weight and the elimination of potential efflorescence problems stemming from tile beds.

Since the identification of issues with installing porcelain on pedestal and raised floor systems, my research has identified significant steps taken both by manufacturers and tiling authorities and organisations in mitigating risks relating to such systems.

Whilst work has been done in progressing such systems safely, there are still significant issues relating to the safety of such systems. Manufacturers providing incorrect, inappropriate or misleading information, coupled with designers or specifiers concluding 20mm porcelain is 'fit for purpose' on a raised floor systems by referencing existing ceramic and porcelain tile test methods are resulting in increased numbers of problems with these systems.

There are a multitude of considerations that need to be made when specifying or installing pedestal and raised floor systems, this paper comments on the system as a whole, but focused on perhaps the most crucial aspect being Health and Safety and by extension, sustainability concerns specifically due to impact resistance limitations of porcelain in raised floor applications.

CONCERNS WITH PORCELAIN ON RAISED FLOOR SYSTEMS.

Past papers submitted to Qualicer have accurately identified the following issues that specifically relate to using porcelain on pedestal of raised floor applications[1]:

- Wind resistance, where high-rise or external use is concerned, what industry requirements need to be met to prevent up-lift of tiles, is there a need for specific wind resistance requirements where porcelain tile is used on raised floors.
- Maintenance of the pedestal systems including potential for lippage issues over time through repeated traffic and vibrations and also responsibility allocations for membrane maintenance and cleaning where such products are used. Maintenance of the pedestals themselves and degradation due to UV exposure and exposure to the elements on the membrane and pedestal needs to be mitigated through correct product selection.
- Fire rating, similar to wind resistance, whilst porcelain itself are non-combustible, does the system as a whole require confirmation of adequate or expected resistance to fire.
- Ponding water on surfaces of the tile. Where tiles are installed 'flat' (with sub-surface drainage) it can result in ponding issues which may increase the risk of slips, trips and falls.
- Durability. Porcelain is durable however brittle in nature, and impact damage poses a safety risk where raised flooring systems are employed.

The main concern of this paper is breaking strength and impact resistance, which has been commented on by others however overlooked by many that still refer to inapplicable or incorrect standards.

ISO 10545-4 Modulus of Rupture and Breaking Strength of ceramic tiles and ISO 10545-5 Determination of Impact Resistance by Measurement of Coefficient of Restitution are commonly referenced by porcelain manufacturers to determine suitability of their products for use across **ALL** applications, including pedestal application.

[1] Qualicer 2022, Podium Tile installations.

This information is entirely relevant to the tiles expected performance where 20mm or thicker porcelain is used in a correctly installed, bonded application. Breaking strength testing provides an indication of the tiles ability to withstand static load when supported on 2 edges only, however there is no test that covers sudden impact of any kind apart from ISO 10545-5 which is irrelevant in raised floor applications due to the test method encompassing a test specimen bonded to a concrete substrate using epoxy adhesive.

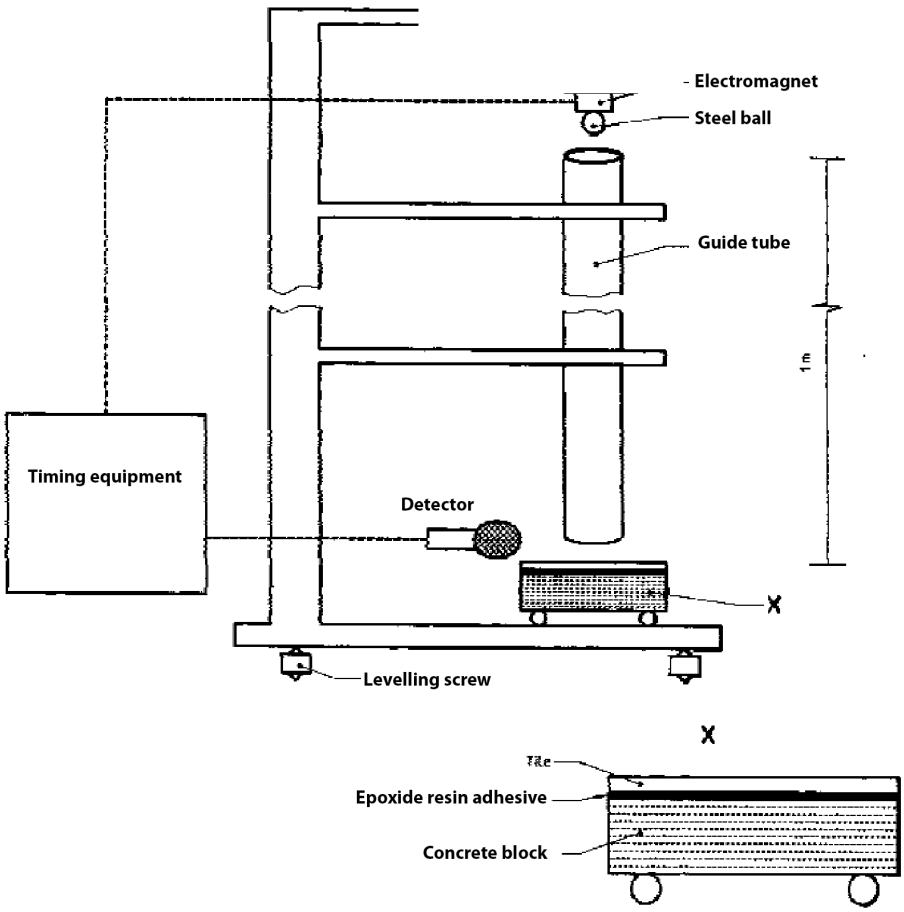


Figure 1 — Ball-release apparatus

***Figure A**. Reproduced from ISO 10545-5.*

This standard provides useful information on tiles in a bonded system; however, manufacturers are using such successful testing to this standard as justification for advertising porcelain for raised floors.

Some manufacturers go so far as to provide misleading information to the consumer with conflicting information of which only a person with specific knowledge of test methods relating to ceramics may identify.

***Photo 1**. Reproduced from a supplier's website.*

The image above is a gross misrepresentation of information, the image shows a masonry brick being dropped on a 20mm porcelain tile over pedestals, however the literature on the right details impact resistance testing to ISO 10545-5. The impact testing result advertised by this particular manufacturer is completely irrelevant to the tiles ability to withstand impact from a brick.

Incorrect use of test method ISO 10545-4 Determining of modulus of rupture and breaking strength as the main evidence of determining suitability of a 20mm porcelain tile over a raised floor system is a starting off point, however more guidance is needed to ensure a safe and successful installation.

I have worked on projects where 20mm porcelain tiles are breaking under foot traffic (a primary school application) where a structural engineer had signed off on the tile as suitable for use due to the breaking strength of 11792N according to ISO 10545-4 as the result was determined as exceeding the engineering authorities' factor of safety requirements.

Although the tile can withstand over 1000kg(2200lbs) of force before rupturing, there were children falling through tiles that were sporadically broken by impact, sometimes to a depth of 300mm+ given the height of the pedestals in this particular application.

The limitations of length in this paper do not allow further expansion of this point, however my investigations determined a gross shortfall in design when considering potential risks from impact on porcelain tiles which resulted in significant safety concerns.

In Australia, it could be argued that impact resistance for raised floor systems has not been considered due to a lack of applicable standards, this may be true at present, however EN 12825: Raised floor systems was adopted basically like for like in Australia as AS *4154/4155* up until it was withdrawn in 2017.

The scope of EN 12825 specifies the characteristics and performance requirements of raised access floors which the main intended use is internal fitting out.

Whist designed as an internal standard only, the test provides absolutely critical testing information relevant to both soft and hard impact resistance and also the intended performance expectations of the system as a whole particularly:

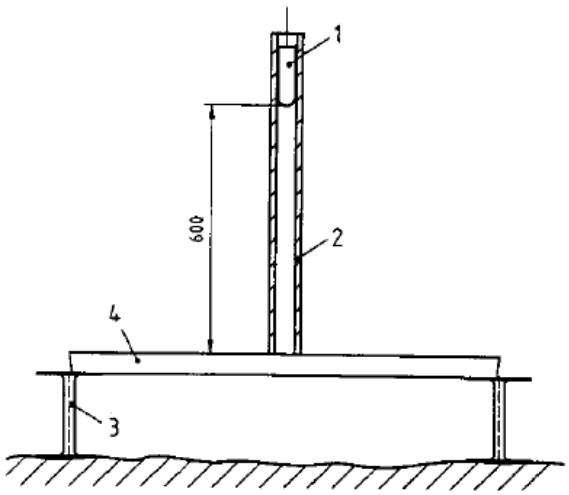
'The raised access floor shall be designed and manufactured in such a way that it provides mechanical resistance and stability and that the loading is liable to act upon it during its intended use will not lead to deformation or collapse'

Extract B. *Reproduced from EN 12825:2001.*

This statement directly correlates to the hard and soft body impact tests that the system needs to pass in order to be deemed successful.

- Absorption of hard body impacts – a 4.5 kg steel indenter with a hemispherical end of 50 mm is dropped at a height of 600 mm inside a tube of 55 mm diameter onto three (3) specified locations on the test panel.
  - Centre of the panel
  - Centre of one edge of the panel
  - Any other point which is the weakest point of the element
- Absorption of soft body impacts - a flat bottomed canvas bag with dry sand of 2 – 4 mm particles size with mass of 40 kg and a maximum diameter of 300 mm is dropped at a height of 1000 mm onto two (3) specified locations on the test panel.
  - Centre of the panel
  - Centre of one (1) edge of the panel

The requirement being that the element sustain the impact and not cause any parts of the element to collapse or crack after any impact.



Key
1 4,5 kg indentor
2 Guide tube, 55 mm diameter
3 Support
4 Load bearing layer

Figure 3 – Hard body impact test

Extract C. *Reproduced from EN12825 Description of soft/hard impact tests and Dynamic Hard Impact drawing shown.*

The majority of porcelain manufacturers in Australia advertise their 20mm porcelain as suitable for all types of flooring, including raised floor application and when questioned on their impact resistance, fall back on compliance to ISO 13006.

From my research products sold in Europe also qualify as suitable based on compliance to ISO 13006, however, they sometimes pick and choose what test results from EN12825 to publish. An example can be found in Photo 2 below.

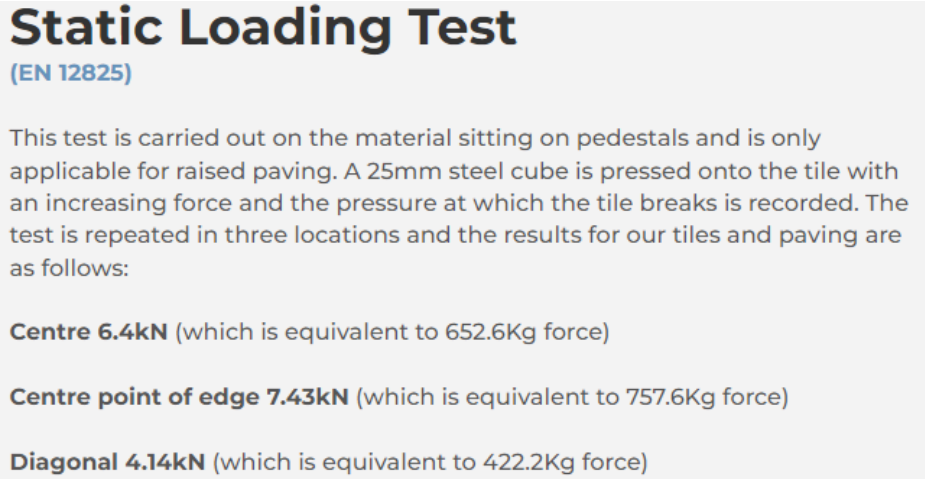


Photo 2. *Reproduced from a porcelain manufacturers website.*

As shown above, the tile has been tested to static loading as per EN 12825 and achieves a high level of static load resistance, however I could find no information relating to dynamic impact testing undertaken to the same standards.

Although the limiting information from this manufacturer is problematic, there are some manufacturers that seemingly understand the issues related to impact resistance of 20mm porcelain on pedestals or raised floors and aim to assist the general public or consumer with providing guidance. See photo 3 below.

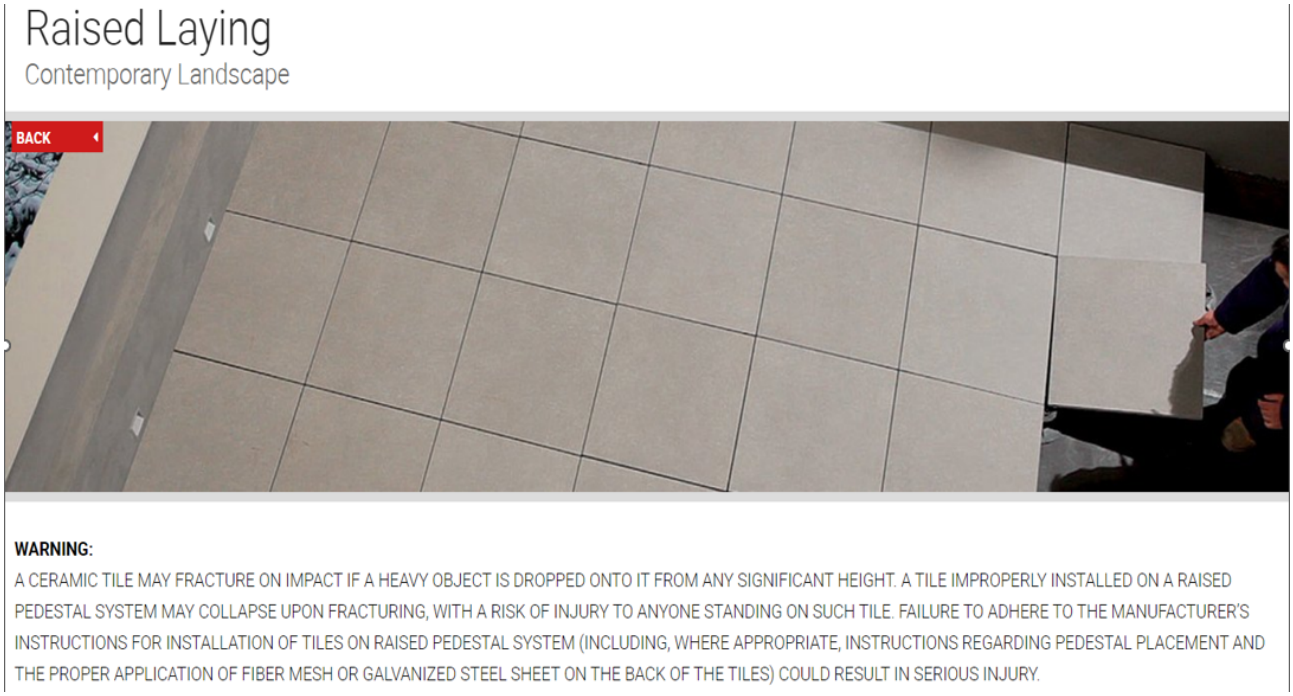


***Photo 3**. Reproduced from the Mirage Ceramics website viewed in June 2022.*

The above information is the only information I have been able to find where a manufacturer states unequivocally that **ANY** tile in 20mm thickness will fail the Dynamic Hard Impact Test and that strengthening, or reinforcement of the material is required depending on the system used, regardless of the manufacturer or quality of the porcelain body at a 20mm thickness.

Based on my investigations and analysis of porcelain tile fracture on raised floor systems and my own independent testing of 20mm porcelain tiles on pedestals this information is very relevant when considering safety of the system for its intended use.

Photo 4. *Screen shot from a video where I was able to break a 20mm porcelain tile dropping a 906g (2lbs) claw hammer from 600mm).*

The hammer load above was dropped from 600mm however the weight was less than 4x the load as designated by the Dynamic Hard Impact Test in EN1825. The tile that I broke had been independently tested for a breaking strength of over 11000N under ISO 10545-4, a strength which the nominated engineering authority deemed safe for this application.

Common-sense dictates that any hard impact can result in a broken tile, and that propensity for impact damage to occur is situational.

The main concerns I had were that a lack of common sense and lack of consideration to perhaps the most critical factor of how to mitigate impact damage has led to serious injury due to the large void created by the porcelain fractures. This can result in injury and damage which could have been avoided if appropriate considerations were made.

It is evident that similar concerns have been identified by the TCNA, The 2022 edition of ANSI 137.3 American National Standard Specifications for Gauged Porcelain Tiles and Gauged Porcelain Tile Panels/Slabs provides useful information specifically related to requirements of porcelain used on raised floor or pedestal systems.

This standard includes traditional test methods such as Modulus of Rupture, Breaking Strength and impact resistance, however where 20mm+ tiles are concerned on floors, also includes their own soft and hard body impact testing.

Table 6 (continued)

Property	If Specified for Floors		If Specified for Walls/Countertops	
	Minimum	Maximum	Minimum	Maximum
Allowable Nominal Thickness	20 mm (0.79 in)	N/A	20 mm (0.79 in)	N/A
Average Difference from Nominal Thickness (ASTM C499)	-1.0 mm (-0.04 in)	1.0 mm (0.04 in)	-1.0 mm (-0.04 in)	1.0 mm (0.04 in)
Thickness Variation[9] (Thickness range within a measured sample, tested per ASTM C499)	N/A	Range: 1.5 mm (0.06 in)	N/A	Range: 1.5 mm (0.06 in)
Soft Body Impact Resistance (Section 8.6)	Pass[10]	N/A	N/A	N/A
Hard Body Impact Resistance (Section 8.7)	Pass[10]	N/A	N/A	N/A

Extract D. *Reproduced from ANSI 137.3*

The test methods for the Hard Body Impact Test are similar in procedure between EN 12825 and ANSI 137.3 when used on raised flooring/pedestals. The main noticeable differences between the tests are:

Standard	Type/Weight	Height of test	Test Criteria	No: of specimens
EN12825	Hemispherical indenter 4.5kg (9.92lbs), 50mm in diameter	600mm (24inch) Centre/centre edge/weak point.	Any collapse or fracture is a failure	3
ANSI 137.3	Chrome steel ball bearing 51mm, 1.2lb (540g)	18+1 inch (46cm). Centre of each specimen	Breakage in 2 or more pieces, is reported as a failure.	3

From review of the test methods, correlated to my own independent testing, the EN12825 may be too onerous with regards to porcelain tile as 4.5kg steel dropped from 600mm would crack all porcelain tiles and most masonry products apart from concrete in excess of 60mm thickness. The ANSI test method, however, may not be onerous enough given I was able to break a tile on pedestals with a steel hammer dropped form 600mm, a force which would be considered expected and akin to a bottle of champagne dropped from waist height or the leg of a piece of furniture placed unintentionally heavy handedly on tiles on raised flooring.

The ANSI standard does consider reinforcement backing where the EN does not. I have tested varying types of backing to support the tile and tested large loads (10kg/22lb+) and found particular fiberglass-based products capable of allowing a 20mm tile on pedestals to remain completely load bearing even where fractured or broken in multiple pieces, significantly reducing if not eliminating safety risks of otherwise unreinforced systems. See photo 5 below.

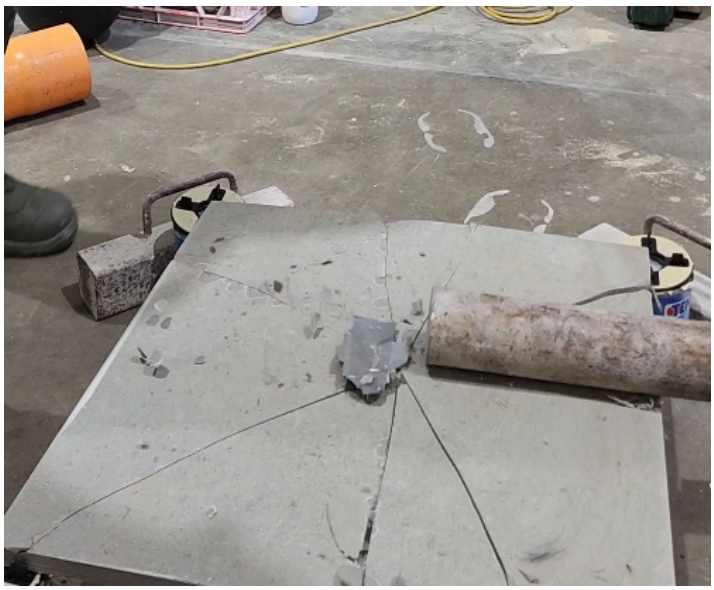


Photo 5. *Tile fractured on pedestals, reinforced with a fiberglass matting adhered with cementitious adhesive. Load used to break the tile was a 10kg steel weight with a diameter of 60mm.*

The idea of incorporating reinforcement on porcelain used on pedestal applications, is not to eliminate potential from cracking or impact, as this would be difficult or impossible. The aim is to change how the system performs so when the porcelain invariably breaks or fractures due to accidental or unexpected impact, it does not collapse, but rather the reinforcing acts as a laminate that is self-supporting that allows the broken tile to remain load bearing prevents a person falling into an open void, potentially resulting in serious injury.

The tile would perform similarly to a cracked tile in a bonded system, the tile in both systems should be replaced to eliminate laceration risk, however this a far more desirable outcome than injury or even death in extreme cases from persons falling through elevations up to 400mm deep or greater depending on the system employed.

CONCLUSIONS

The problem relating to impact resistance, specifically hard impact on porcelain tile used in raised floor applications is a critical issue that poses a great risk to public safety and health if not identified and mitigated through correct design practices.

In the absence of a robust standard or document that covers the various aspects and considerations needed to be made with regards to raised flooring or pedestal applications, it appears that manufacturers or suppliers are able to interpret information at their behest and in some cases either intentionally or unintentionally mislead the end-user by claiming certain technical performance may relate to a raised flooring application when it in fact does not.

In a world where product innovation that results in cheaper and faster construction times, we seemingly have begun to run before we can walk, where porcelain on pedestals is concerned.

As a tiling consultant responsible for review and specification of systems in addition to defect assessment, I am grateful there has been some good progress made in relation to assessing and identifying the risks of using 20mm porcelain tile on pedestal and raised flooring applications, most recently with ANSI 137.3.

Moving forward, there is still a disparate gulf of information needed to ensure all appropriate considerations are made when specifying or designing raised floor or pedestal systems using porcelain tile.

These considerations are critical not only from a technical aspect such as waterproofing and/or fireproofing, but potentially more importantly to avoid injury or hazards to the public due to safety concerns surrounding impact resistance and slip resistance of tiles.

There is potential at the international level (ISO) to create a global standard that encompasses the following criteria for porcelain used in pedestal/raised floor applications.

A performance-based scope or standard for raised flooring/pedestal application could include the following:

- Measurement, deviation, thickness tolerances for porcelain, potentially manufacture convex porcelain to facilitate drainage in a flat floor finish application.
- Fire resistance/wind resistance table with specific requirements dependent on local codes/standards.
- Long term slip resistance expectations on tiles, if tiles can harbour standing water, does this result in a safety issue over time.
- Correct waterproofing selection (where required) including compatibility in the system and stability to exposure were pertinent.
- Durability requirements for the pedestal or raised flooring system itself and expected lifespan of the products.
- Clear guidelines for maintenance requirements of the pedestals to ensure the system performs as intended and no latent issues due to WP damage, pedestal degradation occurs, including who may be responsible for such maintenance.
- Information outlining the requirement for porcelain to withstand hard impact (and breakage) without losing its capability to be load bearing, including specific information for reinforcement and a performance criterion based on the area of installation.

The above is purely a preliminary scope that can be expanded on or modified by respected members of the ANSI, EN, and by extension ISO community in order to create a robust document that not only allows for sustainable installation of porcelain tile in raised floor and pedestal applications, but also protects the public and consumers. It is necessary to assist manufacturers, specifiers, engineers, and designers where such systems are used to prevent the current lack of applicable and meaningful standards causing distrust of this innovative and potentially large market for ceramics.

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