Limestone is extremely popular at the moment, the material is used in practically every element of our built environment. However, tiles must be carefully evaluated to define fitness for purpose. (Image courtesy of CDK Stone).

Stone in the built environment – a guide to specifying limestone tiles

Limestone is in fashion – this can be seen in its ubiquitous use as a floor finish throughout shopping centres, homes and commercial buildings. Its popularity can be largely attributed to its versatility and variety.

By Jim Mann, Principal of Stone Initiatives and a director of the ASAA

Limestone is a sedimentary rock. Every millimetre of sediment laid down has a slightly different composition and is converted into the stone we know under varying conditions over millions of years. The result of this prehistoric manufacturing process is that every slab of limestone is unique. This exclusivity is one of the appealing aspects of natural stone, but with this variety comes challenges that, if not addressed, can turn into problems after installation.

Stone Initiatives has investigated limestone failures in a broad range of locations. Most of these failures are related to inappropriate installation practices or the use of stone that is not fit for its intended use. This article provides guidelines that can assist in the specification of limestone and is intended as a first step in ensuring fitness for purpose when using limestone as a floor tile.

Whether installed in a domestic bathroom, a shopping centre or the lobby of a commercial building, the tiles should be evaluated for fitness for use based on the following four performance properties:

Durability

All tiles are to some degree exposed to moisture. Tiles installed in a wet area such as a bathroom are subjected to regular wetting during use, while dry-area tiles are likely to become wet during the cleaning process. In both cases, the tiles must have adequate durability to withstand wetting and drying cycles as well as exposure to cleaning chemicals.

Wet-dry cycling can result in deterioration of the surface finish of the tiles, and this most commonly presents as spalling. This spalling is usually due to detachment of flakes of stone along features called stylolites, which appear as fine, zig-zagging veins on the surface of the tile.

Stylolites develop at pressure-dissolution boundaries, where insoluble minerals within the stone (e.g. clay) accumulate. The development of these planar features usually results in the formation of clay-lined veins and micro-porosity; as a result, there is a localised increase in water absorption capacity. This increase in water absorption can cause a reaction between the clay and moisture, the consequence of which can be a reduction in strength and durability.

Load-bearing capacity

For a tile to be fit for use, it must be able to withstand relevant service loads.

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Imposed loads are usually confined to pedestrian traffic but may also include light traffic such as trollies or wet-vac scrubbers. While a limestone may be inherently strong, the load-bearing capacity of a tile may be compromised by the presence of stylolites that can present a zone of weakness.

Stain resistance

Water-absorption capacity is the most relevant physical property for determination of stain resistance. In practice it is a complex relationship between porosity, chemical composition and appearance. All limestone is composed predominantly of calcium carbonate and is therefore sensitive to etching from acidic materials such as wine or soft drinks. The tonality, surface finish and figuring also have an effect on the apparent stain resistance of a tile.

Wear resistance

Limestone is a relatively soft stone and this can be an issue in high-traffic areas. Abrasion of the surface may change the surface texture, resulting in a change in appearance and a reduction in slip resistance.

Specification guidelines

The key performance indicators for limestone tiles are considered to be:

- water absorption
- bulk specific gravity
- modulus of rupture (3-point bending strength)
- abrasion resistance
- durability

The table pictured (Table 1.) sets out properties recommended for limestone tiles that are to be installed internally on an adhesive bed. The recommendations in the table were developed by Stone Initiatives based on the requirements for high-density limestone set out in ASTM C568M-15, which covers limestone for "general building and structural purposes". Stone Initiatives further developed the ASTM specification values after its investigations revealed that, in order for limestone to be fit for use as a floor tile, it should meet performance requirements that are more stringent than those stated in the ASTM specification.

Bulk specific gravity (commonly referred to as density) is a fundamental key performance indicator. A higher density usually corresponds with improved strength and durability as

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Table 1.

PROPERTY	RECOMMENDATION
Bulk specific gravity (kg.m-3) ASTM C97	Mean: 2560 (min) No individual specimen < 2500
Water absorption (weight %) ASTM C97	Mean: 1.0% (max) No more than 1 specimen should be > 150% of the mean value.
Modulus of rupture (MPa) ASTM C99	Mean: 6.9 (min) – wet and dried condition No more than 1 specimen < 6.0
Resistance to salt attack (weight loss %) AS/NZS 4456.10 A	Mean: 0.2 (max) No individual specimen > 0.5
Abrasion resistance (Ha) ASTM C1353	Mean: 12 (min) No individual specimen < 10

Failure of limestone tile along a stylolite.

Fine stylolite can be seen traversing across the surface of a tile.

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well as superior resistance to wear and staining. Limestone tiles that perform best in service usually comply with the high-density requirements of the ASTM specification. While density does not generally vary greatly within a deposit, a significant variation may suggest a stone with unreliable properties.

The most significant variation from the ASTM specification is related to water absorption. Stone Initiatives has found that limestone tiles that have performed successfully on site usually have a water absorption level of less than 1.0%. Consistency of individual results is equally important, as a broad variation in individual results is likely to be a sign of open stylolites, which present a risk to durability and strength.

Consistency in results is also important when it comes to modulus of rupture. A stone with a high mean strength can be compromised by occasional low individual results 'hidden' within the average. These low results may be an indication of the presence of unstable stylolites or unfilled veins. It is important to note that compliance with the modulus of rupture requirement does not necessarily mean that a particular tile size is able to withstand the flexural loads that may be imposed upon it on site. As well as inherent strength, the load-bearing capacity of a tile also depends on its length-to-width ratio and thickness. The greater the length-to-width ratio, the greater the flexural stresses applied to the tile (square tiles are less prone to flexural overload). Thickness is also important as it has an exponential effect on the flexural load-bearing capacity of the tile; doubling the thickness increases the breaking load fourfold – every millimetre of thickness counts.

The standard method for determining the durability of dimension stone is through the resistance to salt attack test. This test involves cyclic immersion in a salt solution followed by oven-drying and gives a good indication of the durability of a tile in a wet environment. Although the test results are expressed as a weight-loss percentage, remarks on the appearance of the specimens after testing also give an indication of the mode of any decay that may occur – whether it is loss of gloss, spalling, cracking or pitting. As for the other properties discussed previously, it is important to review the variability in the individual results, as this will assist in determining if any large flakes of stone are lost through spalling.

As for density, abrasion resistance does not generally vary greatly within a deposit, although any significant variation within individual results may suggest a stone with unreliable properties.

All physical properties are interrelated, so it is important that all results are reviewed together. This will provide a holistic view of the limestone's likely performance. The guidelines for selection discussed above should be considered only as one tool in your arsenal. To ensure adequate performance of your limestone tiles it is vital that careful attention is given to the design of the installation method, including the type of adhesive and grouts used, the location, type and spacing of expansion joints and the selection of a suitable sealer. Once these elements have been considered, you are well on the way to producing a flawless floor finish. ●