9.1 PAVING: MATERIALS, FINISHES, WEAR, SLIPPERINESS

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INTRODUCTION

Many types of stone are used for paving and flooring in a wide range of buildings, from polished granite and marble in prestige commercial buildings (and domestic residences) to random (crazy) slate paving in the gardens of suburbia.

Many of these stones are extremely durable, can give exceptionally long life, and require minimal maintenance. Nevertheless, there are also many potential problems relating to the use of stone as a flooring or paving material, and these need to be carefully addressed if the finished application is to provide satisfaction to both user and owner over an extended period of time.

The principal matters for consideration when designing stone flooring or paving are as follows:

- type of stone;
- appearance;
- surface finish;
- environment;
- resistance to wear;
- slipperiness;
- maintenance;
- resistance to staining;
- method of fixing.

TYPE OF STONE

Most types of stone can be used for flooring or paving. The only materials which are not suitable for use in some situations are the soft, porous limestones and the softer argillaceous sandstones.

Most types of slate, flagstone, marble and hard limestone, quartzite and quartzitic sandstone, granite and other igneous rocks are suitable for paving or flooring in some applications. Different performance under different conditions indicates that some of these stones are unsuitable for particular applications.

In general, high traffic areas (e.g. commercial applications: hotel and lift lobbies, entranceways, shopping arcades) require harder stones that are more resistant to wear, and less porous stones that are more resistant to soiling and staining. Areas with less intense traffic (such as function rooms, light commercial) can utilise softer stones that are less resistant to wear and soiling; and for domestic applications, where traffic is minimal, a much wider range of stones can be used.

APPEARANCE

The colours and textures of stone which may be used for flooring or paving range widely.

Granite can be obtained in colours from pale grey to black, including reds, blues and browns. The colours are most brilliant when polished, less brilliant when honed, and muted with other textured finishes.

Marble is available in a wide range of colours and patterns. Many are of minimal suitability for flooring, due to softness and the inherent defects in many decorative types.

Slate is generally dark in appearance, although the range of colours is extensive, from greens and browns through blues and purples to greys and blacks. Uniform and patterned varieties are available. Again, a wide range of quality and performance is available.

Sandstones are generally only suitable for external use, although some quartzites will take a polish and can be used in other situations. They are usually white to yellow, red or brown in colour.

PAVING UNITS

An increasing range of paving units are becoming available for different types of stones. Traditionally, stone paving was either in the form of flagstones, relatively regular rectangular units, or cobbles. Today, cobbles have taken on another form, and are hydraulically split, usually from granite, and flagstones have given way to sawn, exfoliated or bush-hammered slabs.

Tiles, in a range of unit sizes, are increasingly used, particularly for interior fitout work, and are generally available in polished granite or marble, or split slate. Some sandstone tiles are marketed, but unless very hard and non-porous are generally only suitable for domestic or some external applications.

SURFACE FINISHES

Many different surface finishes are available for paving or flooring applications. The more common of these are listed below:

Polished — A high gloss, smooth finish which brings up the colours of granite, marble and quartzite to a high level of brilliance. It is achieved by repetitive grinding with increasingly finer grit, with final rubbing with tin oxide or similar polishing compound. Polished stone is susceptible to scratching, scuffing and consequent dulling of finish. It is also highly slippery when wet, like most smooth, flat surfaces.

Honed	A smooth finish which does not have the gloss of polished surfaces. The polishing process is stopped before the final polish is applied. This is available on granite, marble and quartzitic sandstones. It is less slippery than polished surfaces, and also does not show scratches or scuff marks as readily.
Rubbed	Some slates can be rubbed to produce a smooth surface finish similar to that obtained by honing of granite or marble.
Diamond-sawn	A flat, relatively smooth finish, which is standard for sandstone and acceptable for granite and some marble when used for external paving. It is much less slippery than polished surfaces, is not readily scratched or marked, but does not have the same intensity of colour of either honed or polished surfaces.
Gang-sawn	A smooth to rough ribbed finish which is only appropriate for granite, bluestone and sandstone. This finish can often result in a rust-stained surface due to the use of steel shot as an abrasive during cutting.
Exfoliated	A rough textured finish produced by application of a flame to the surface of quartz-rich stone (usually granite) followed by immediate quenching. This surface is more susceptible to staining in some granites, but is more slip-resistant than most other finishes. However, in high traffic situations, the appearance can be changed rapidly due to soiling and loss of high contour on the surface.
Bush-hammered	A mechanical textured finish for granite and some marble with an appearance midway between gang-sawn and exfoliated.
Split	Natural split surface obtained on slate, sandstone and granite. The last requires hydraulic pressing, the first two can be split by hand in some cases.
Grit-blasted	All stones can be grit-blasted, although the technique is primarily applied to granite. This allows application of comparatively complicated masking patterns to give intricate patterns of different textural finishes (i.e. polished plus grit-blasted).

ENVIRONMENT

The environment surrounding stone paving and flooring installations can have a strong influence on the performance of the stone.

Adjoining paving materials can be a source of grit which will scratch and wear the surface of the stone, as in the case of exposed aggregate concrete or brick paving outside a polished granite foyer.

Sources of moisture which run out across porous stone paving can lead to staining, salt efflorescence, deterioration and/or algal or moss growth. Moisture sources below the paving installation can lead to efflorescence on porous stones, or staining of the joints on non-porous stones such as granite, marble or slate.

Areas of polished granite or marble adjacent to entrance doorways can be made wet by windblown or trafficked rain, leading to dangerous slippery situations.

Staining or soiling of the surface of the stone can be due to traffic, function (e.g. restaurant or function room) or adjacent sources of contamination.

The use of extensive areas of matting in doorways and entrances to stone floors can reduce the effect of some of these environmental influences. Such mats must be effective collectors of grit and moisture from the soles of shoes, and should be large enough that all people should place each foot onto the mat at least once.

RESISTANCE TO WEAR

The resistance to wear, or abrasion, of stone used as flooring depends on the type of stone. In general, granite (and other igneous rocks) are most resistant to wear, quartzite and flagstones are next most resistant, followed by marble and slate, and argillaceous sandstones.

Within each group, however, the abrasion resistance can vary considerably. Very few granites will show measurable abrasion over several decades, however some granites can lose their polish within six months of installation. This is due to scratching by harder materials, and is a separate phenomenon to physical loss of surface material.

Some marbles perform well as paving (e.g. Carrara) whilst others are generally unsuitable in all but domestic applications. In general, finer-grained marbles are more abrasion resistant than coarser-grained marbles. Even good marbles will tend to lose surface material and become scratched and dull within ten years in high traffic situations, and polished surfaces are rapidly dulled to a lustrous worn finish similar to a honed finish.

Marble is very susceptible to damage by 'bruising', or impact of sharp pointed objects, such as stiletto heels. These appear as small circular areas of whitened marble, representing an area of crushed calcite. These can only be removed by regrinding of the surface to below the level of damage.

Materials marketed as slate vary considerably in geological nature, with the only common feature being their ease of splitting. Consequently, their resistance to wear is also variable and many are coated to resist wear and assist cleaning.

Various tests have been developed to evaluate the resistance to wear of paving materials, and a number of these have been specifically developed for stone. Two of the major procedures are summarised here:

ASTM C241 This procedure uses three small square specimens which are placed under a load, and rotated on top of a revolving lap. Abrasive grit is gravity fed onto the lap at a constant rate. Each set of specimens is subjected to a standard number of revolutions. The loss of mass is calculated after completion of the test.

This procedure is difficult to obtain consistent results from, and is currently under review by the ASTM Committee C18 on Dimension Stone. A modified Taber machine (see below) is available as an alternative to the original Kessler machine.

At this stage, ASTM Specifications for Dimension Stone recognise the following minimum values for H_a, or abrasion hardness, as measured by this procedure:

slate and sandstone	8
marble and limestone	10
granite	na

Taber The Taber abrader uses a small rotating table, to which a specimen is fixed, and weighted abrasive wheels which rest on top of the specimen, and hence rotate freely as the specimen rotates. Each specimen is subjected to a standard number of revolutions, and the loss of mass measured. This is converted into an index figure.

The basic method is used for a wide range of flooring materials, from fabrics to vinyl tiles, ceramic tiles and stone.

At this stage, the procedure is only a draft Australian Standard, but is under consideration by ASTM C18.

The following values of the Taber abrasion index are commonly obtained for dimension stone:

granite	40-240
quartzite	20-50
marble	6-26
slate	7-22
sandstone	3-15
limestone	<1-10

Correlation with performance in situ has not been confirmed, but general observations suggest the following scale:

Taber abrasion index	Appropriate uses
> 20-25	All uses; high abrasion resistance
15 - 20	Moderately high abrasion resistance; suitable for most uses, including high traffic prestige commercial flooring.
12 - 15	Moderate abrasion resistance; suitable for all but high traffic prestige commercial flooring.
8 - 12	Moderately low abrasion resistance; suitable only for light commercial or domestic flooring situations.
< 8	Low abrasion resistance; suitable only for domestic or light external traffic situations.

A modified procedure using softer wheels has been developed in an attempt to assess the potential loss of polish of granite used as flooring. This has identified that the effect tends to be a combination of the precise nature of the mineralogy of the stone, and the colour. Darker coloured granites show the loss of polish to a much greater extent than lighter coloured granites.

SLIPPERINESS

Very smooth hard flooring materials tend to be slippery, especially when wet. Stone is no exception. There is little variation between different varieties of say granite or marble with respect to slipperiness - the dominant parameter is the surface finish. Polished or honed granite or marble tend to be the most slippery: polished is more slippery when wet, but can be less slippery than a honed finish when dry. Exfoliated, grit-blasted or any other textured surfaces on granite have a moderately high slip-resistance, and can in fact be better than many other common paving or flooring surfaces when dry. When extremely wet however, such surfaces can lose much of their slip resistance.

The use of coefficient of friction determinations to evaluate the slipperiness of floor surfaces is widespread, however no consensus has been achieved regarding the most appropriate method for its measurement and consequently, a plethora of techniques exist. Little work on comparison of the results obtained from these various techniques has been performed.

The three main types of methods are static, static/dynamic, and dynamic. The first utilises a loaded pad of known area, and the force required to start the pad moving is used to calculate the coefficient of friction. These are the most simple, but are also considered to be the least relevant.

The static/dynamic method is exemplified by the 'Tortus' friction testing unit which measures the resistance to continued movement of a self-powered unit across the test surface.

The third, dynamic pendulum technique measures the retardation of a pendulum released from a standard height and impacting at the bottom of its swing on the test surface. The edge of the test piece is dragged across the test surface, and the resultant retardation of the pendulum is a measure of the coefficient of friction. The technique is rather sensitive to error, and values for the coefficient of friction should be treated as indicative rather than absolute. However, this procedure most closely models the typical slip situation.

Various workers have suggested a range of values which are considered to be safe for flooring surfaces, and the generally accepted ranges are given below:

dynamic coefficient of friction	criteria
> 0.75	excellent
0.40 - 0.75	good
0.20 - 0.39	poor
< 0.20	dangerous

Typical values for granite, in various conditions, are as follows:

polished, dry	0.40 - 0.55
polished, wet	0.15 - 0.25
honed, dry	0.30 - 0.40
honed, wet	0.20 - 0.30
exfoliated, dry	0.55
exfoliated, wet	0.35

MAINTENANCE

The maintenance of stone paving is an important part of maximising its performance. Regular mopping of polished granite and marble can reduce the rate of loss of polish, as can regular hosing of external paving surfaces to remove loose grit and prevent this from being tracked into the foyers and entrances. Even use of a light strippable polish can prolong the life of granite and marble. Repolishing in-situ is very difficult and awkward to perform, particularly on granite.

Recrystallisation is a technique which is currently being heavily promoted for use on marble - it is based on a principle which uses acid to remove the surface layer of damaged and abraded marble, and then repolishes mechanically the surface. Use of different inorganic reagents results in the deposition of compounds such as calcium fluoride and calcium fluorosilicate, some of which may be harder and more abrasion resistant than calcite. However there is much disagreement over the suitability of this technique, as discussed by McCarthy and Donatelli in a recent issue of *Dimensional Stone*.

RESISTANCE TO SOILING/STAINING

Stone is a porous material, and is consequently susceptible to staining and/or soiling. Granite is most resistant to staining, although it can be stained by fixing mortars and joint sealants, by oils and fats or by some food stains. Marble is far more susceptible to staining - as evidenced by the stains on old marble furniture. It is usually possible to remove relatively fresh stains from marble by poulticing techniques.

Sandstone and limestone are highly susceptible to staining, and if this is likely to present a problem, either should not be used, or consideration given to application of a protective coating. Such coatings are not normally recommended, as application of coatings to porous stone in contact with sources of moisture can lead to early failure of the coating.

Even granite can be rapidly soiled, as can be seen in the Pitt St mall in Sydney, where replacement slabs of Calca Granite are considerably brighter than the worn and soiled material which is only a year or two older.

METHODS OF FIXING

Methods for fixing stone as paving and flooring are generally similar to those used for ceramic tiles, particularly where stone tiles are used. Generally thick-bed techniques are preferred, as these allow greater tolerances for variation in the thickness of the stone tiles, and also for variations in the quality of workmanship. As the consistency and quality of stone tiles increases with the development of better gauging and calibrating machines, the use of thin-bed techniques will rapidly increase.

Problems can occur with the use of cement based mortars, particularly if a comparatively wet mortar bed is used. Loss of moisture from below granite paving slabs is quite slow, and tends to be concentrated along the joints. This can result in unsightly efflorescence along the joints, especially if the sand used is not very clean. The use of latex or other acrylic additives in a cement mortar can allow thinner bedding, and reduced volumes of cement. This can assist in reducing the potential for staining and efflorescence.

Alternative hollow-fixing methods are also available. The stone slabs are supported by load-bearing units which provide a cavity beneath and allow the joints to be left unsealed.

In most situations there is little need to consider the flexural strength of the stone, but occasionally if heavy traffic loads are required, then thicker stone must be used.

REFERENCES

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