FOREWORD

The Building and Construction Authority's (BCA) Construction Quality Assessment System (CONQUAS) has been widely adopted as the de facto national yardstick for measuring the quality of building projects. To meet the rising expectations of homeowners, the Quality Mark (QM) Scheme was launched in 2002 to promote a higher consistency in workmanship standards for residential developments. Besides setting standards and measuring the level of workmanship through CONQUAS and QM, BCA has developed a series of publications of Good Industry Practices Guide for different trades.

This "Good Industry Practices – Design and Material Selection for Quality – Volume 2" follows from Volume 1 published in 2008. It shares with the industry some of the good practices adopted by developers, practitioners and contractors who consistently deliver high quality work through thoughtful design and choice of materials in construction, particularly in residential buildings. These practices are drawn largely from projects that achieved high CONQUAS/QM scores. The examples in this guide highlight some of these noteworthy projects. While the other guides in the series focus on "doing things right", this guide (including Vol. 1) is different in that it focuses on "doing the right thing" through careful design choices and materials selection.

Some "new" methods and materials are featured in this guide. Comparisons are made with traditional methods and materials that may have inherent difficulties in achieving quality. With a renewed long term drive for higher productivity, these new methods and materials are worth considering to achieve both high quality and productivity.

This guide is not meant to be a definitive textbook on building design and material selection, nor is it the final word on quality, as there will always be new materials and methods with changing technology. To obtain more comprehensive information and guidance, readers should seek advice from professional designers and material suppliers. We gratefully acknowledge the contributions of the practitioners to this guide and trust that the industry will find this publication useful in its pursuit of quality excellence. We welcome any contributions from readers that may improve future editions of this guide.

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CONTENTS

INTRODUCTION

The Building and Construction Authority launched Volume One of the Good Industry Practices Guide on "Design and Material Selection for Quality" in 2008. The guide attempted to showcase buildable and constructible designs that facilitate good workmanship as observed in various projects with high CONQUAS and QM scores. This includes the use of steel structures, drywall partitions, precast elements, prefabricated bathrooms and other factory made components for higher productivity, faster completion time and better build quality. This second volume continues from where the first volume has left. It now focuses on material selection, primarily the architectural components, that impacts quality during construction.

Quality often comes at a price. It would be ideal if higher quality can be achieved without increasing costs. Apart from initial costs, the chosen product must also be functional, aesthetically pleasing, easy to install and maintain thereafter. Generally, though not always, the use of higher quality material may incur higher initial cost. This has to be balanced against possible savings in time (due to ease of installation), better customer satisfaction (due to better quality workmanship) and lower maintenance costs during use (due to less defects and durability of the product). Apart from these, there are other intangible benefits to the developer or builder's reputation, if they consistently deliver high quality projects. These factors need to be considered and balanced against each other when making a choice of which material to use. For example, some choices highlighted in this guide, like use of special fillers and techniques to repair and restore stone and timber are costly and are not intended for ordinary or widespread use. They are presented in this guide to highlight the availability of such precision techniques which can be utilised where circumstances permit.

Unlike manufacturing, construction is often carried out in an open environment subject to unpredictable weather conditions and other environmental factors. This affects productivity and quality outcomes. Build quality is often dependant on the skill level of the workmen employed and how trade sub-contractors are managed and co-ordinated. This can be minimized by shifting much of the work to a manufacturing or factory environment which is not affected by weather conditions and the processes are largely automated. Thus the use of precisely made factory products requiring minimal on-site labour for installation will help to raise productivity levels, ensure better consistency in workmanship and improve overall build quality. This is evident from the many materials listed in this guide.

AGGLOMERATED MARBLE 1

1 AGGLOMERATED MARBLE

1.1 BACKGROUND

Marble is a metamorphic rock originating from limestone or calcium carbonate ($CaCo_3$). Agglomerated marble, also known as reconstituted or compressed marble, is produced by binding selected marble chips (93 to 95%) with specially formulated resin (7 to 5%). It is one of alternative choices to natural marble, as a large part of agglomerated marble consists of natural marble chips and therefore possess similar characteristics of marble.

Fig. 1.1 – Raw material for agglomerated marble: Selected marble boulders.

In natural marble production, large rocks are acquired from quarries. After cutting the selected rocks, the remaining boulders are classified as residue. In the past, the excess material was treated as waste or used as substrate for roads. This is not an efficient use of limited natural resources and does not contribute positively to environmental sustainability. The need to make full use of the natural stone substance to produce a product similar to natural marble led to agglomerated marble as a natural stone substitute.

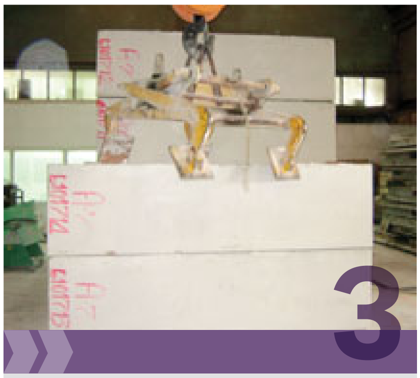
Fig. 1.2 – Natural marble: Acquired from selected large rocks.

Fig. 1.3 – Agglomerated marble: Produced from selected boulders.

1.2 AN OVERVIEW OF A TYPICAL PRODUCTION CYCLE

Selected marble boulders are crushed and sieved into various sizes.

Marble granules are mixed with specially formulated polyster resin and compacted under vacuum by vibro-compression technology.



Large marble blocks are produced and cured for few days.

Cured agglomerated marble blocks are sawn into slabs.

Unpolished slabs are calibrated using digital automatic machine to ensure uniform size and thickness.

Different stages of polishing are carried by automatic machines, the transformation process is closely similar to natural marble production.

Cutting into required sizes by a laser machine to ensure dimensional accuracy.

Final sorting, packing in cardboard boxes and stacking on wooden pallets before dispatch.

Fig. 1.4 – Overview of a production cycle.

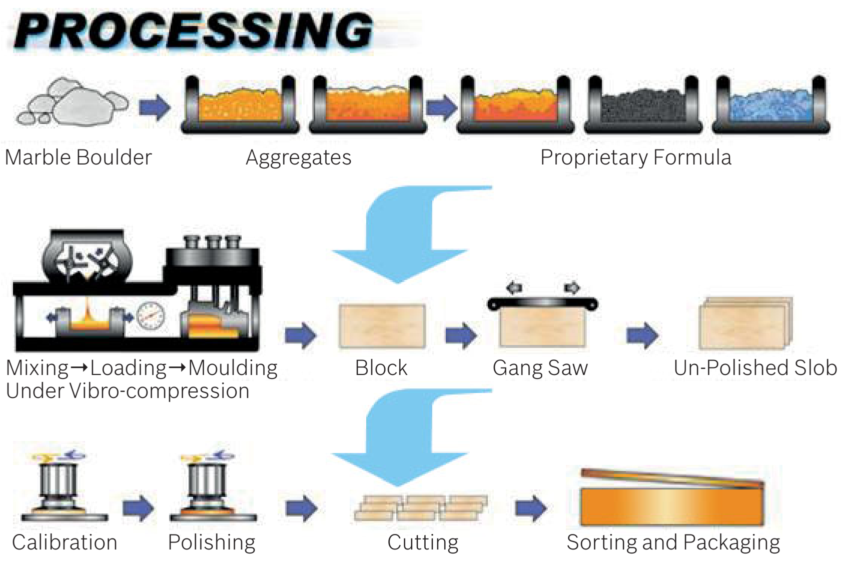


Fig. 1.5 – A schematic outline of production cycle.

1.3 QUALITY FEATURES IN AGGLOMERATED MARBLE

a. Homogeneous body and re-polishable

Agglomerated marble is made of the same materials and the whole body is homogeneous. Gentle grinding and polishing after installation make the floor surface smooth and shiny. This same quality finish can still be achieved years after installation by re-grinding and re-polishing. The measurement of hardness (MOH) scale for agglomerated marble is just slightly higher than natural marble. Thus, the tools and equipment used for polishing natural marble can be employed for agglomerated marble.

Fig. 1.6 – Homogeneous body can be repeatedly polished and renewed.

Fig. 1.7 – Polishing tools are similar to those for natural marble.

b. Less effort required on dry lay

Most end users especially in residential developments prefer to have a consistent colour tone in the finishing work. Dry lay or pre-selection is not an uncommon practice when using natural stones. This is to minimize tonality and other issues inherent in the natural material. Dry lay is often a meticulous, time consuming and labour intensive process, especially in large scale residential projects. Sufficient space is also required to carry out this process. Separate dry lay shop drawings based on layouts need to be prepared and the selected marble must be installed according to the numbered sequence to ensure consistent results.

Fig. 1.8 – Dry lay requires additional manpower and sufficient space for segregation and storage.

Fig. 1.9 – Direct installation (without dry lay) saves time and cost in construction.

The addition of resin and inorganic pigments in agglomerated marble production process helps to minimize tone variations in the same batch of production. However there may be variations between different batches of production. It is therefore advisable that orders be placed for the total requirement for a project, so that the manufacturer can blend the raw materials in one batch and minimize the risk of tonality differences.

Fig. 1.10 – Sorting stones by production "batch code" to minimize tone varitation.

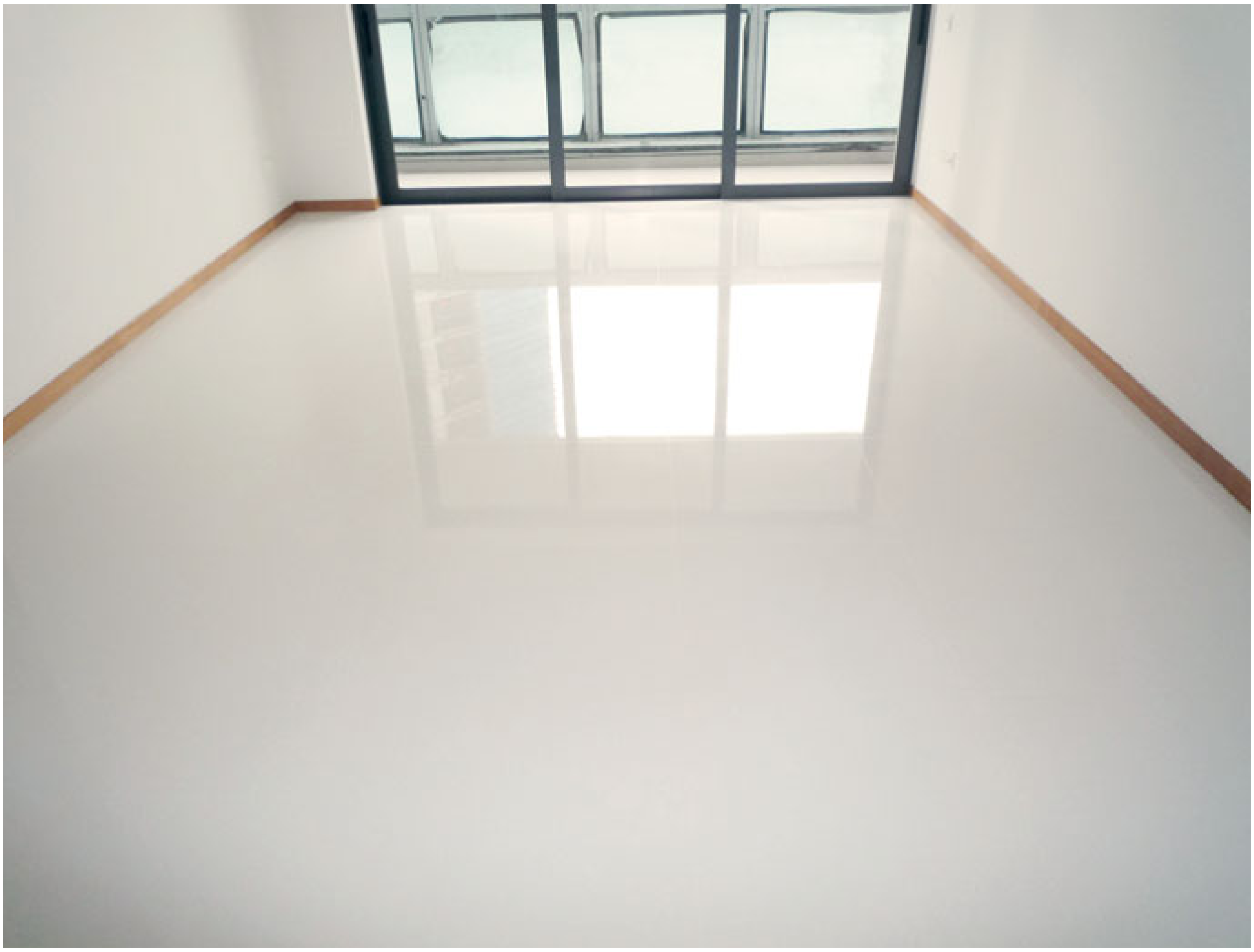


Fig. 1.11 – Tonality consistency is a key feature in agglomerated marble finish.

c. Less inherent imperfections in the surface

The inherent imperfections like open veins, tone variations and pinholes are common in natural stones. These imperfections are sometimes classified as "defects" by end users. In most situations, it is not easy to rectify these flaws, especially after installation. Much time and cost need to be expended to address such "imperfections", apart from the inconvenience to end users. For this reason, dry laying is often necessary in natural stone works. A well controlled mechanism in the manufacturing process for agglomerated marble, together with the compressed vacuum technology will reduce concerns like pin holes and open veins in flooring.

Fig. 1.12 – Difficult to address inherent flaws in natural stones, especially after installation.

1.4 QUALITY CONSIDERATIONS AND PREVENTIVE MEASURES IN AGGLOMERATED MARBLE

a. Stain ingress and etching

Stains: All natural stones are porous to a certain extent with micro interconnected capillaries through which liquids and gases can move. Agglomerated marble, although considered a dense material, have similar porosity characteristics like natural marble as they are made substantially from the same material. Given sufficient time, liquid and moisture can penetrate the material and cause staining. Porosity is also affected by its finish – a highly polished marble is a little harder to penetrate than marble with a honed (matt) finish. Due to presence of iron in the stone, prolonged exposed to water may develop stain marks. The other common sources of stains are spillage and ingress of liquids like juice, coffee, etc.

Etching: Calcite-based stone such as marble, limestone and travertine reacts with acidic substances on contact, leaving dull marks or even deep furrows over time. This is known as acid etching. The use of inappropriate materials for maintenance like acidic or alkalis products can cause such etching. Even mild household acids, including cola, wine, vinegar, lemon juice and milk, can damage these types of stone. The milder the acid, the longer it takes to etch; stronger acids can damage the stone in seconds.

Fig. 1.13 – Liquid ingress and acid reactions are main reasons for stain and etching.

To prevent strain ingress, it is suggested that a compatible impregnator be applied on the surfaces of agglomerated marbles. Impregnator is a subsurface treatment, formulated to penetrate the stone which enhances resistance to stains. The impregnator will resist stain ingress from top and block entry of salts from bottom. Further information on impregnators and its application can be found in Chapter 7.

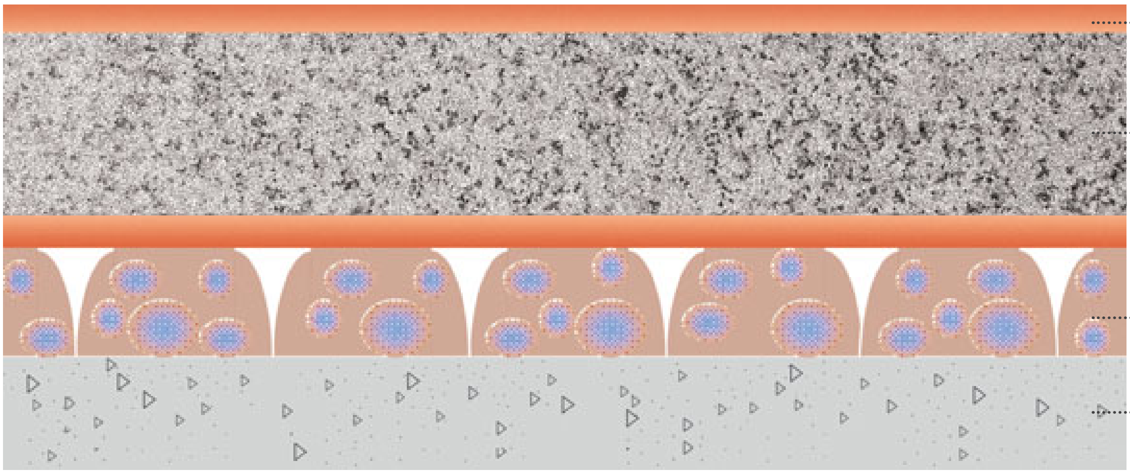


Fig. 1.14 – Application of suitable impregnator enhances stain resistance.

b. Scratch and damage

The **M**easurement **O**f **H**ardness (MOH) scale value for agglomerated marble is about 3.5 to 4.5. This is slightly higher than natural marble (see MOH scale range). The MOH scale measures material resistance to hardness. A material lower on the MOH scale will not scratch or cause damage to a material higher on the MOH scale. For example, a piece of hard plastic (MOH #2) will not scratch calcite (marble) (MOH #3). However, a grain of sand (MOH #6) will scratch calcite (marble) but not quartz (granite) (MOH #7). The major composition of agglomerated marble is calcite, hence it tends to get scratched or damaged if it is exposed in heavy traffic areas. Furthermore during construction, many activities take place concurrently. Proper protection is therefore necessary to prevent damage to agglomerated stone by other trades.

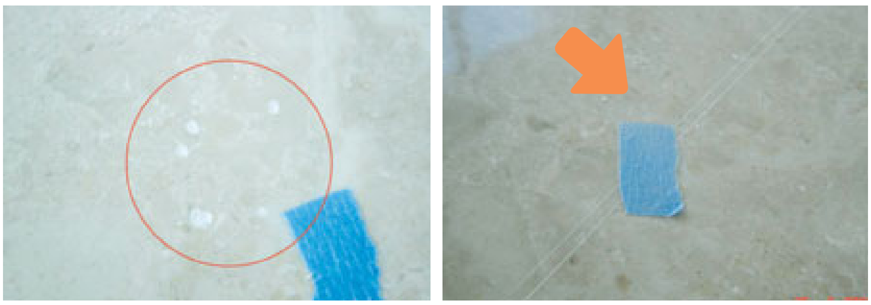


Fig. 1.15 – Scratches and damage by other trades during construction.

Fig. 1.16 – Protection is necessary during construction stage.

MOH SCALE RANGE:

10 Diamond
9 Corundum
8 Topaz
7 Quartz (Granite)
6 Feldspar (Granite)
5 Apatite
4 Fluorite
3 Calcite (Most Marbles)
2 Gypsum
1 Talc

Agglomerated marble MOH value: 3.5 to 4.5

c. De-bonding and grouting discoloration

Use of incompatible adhesive is one of the root causes for agglomerated marble de-bonding. Unsuitable grouting (pointing) material can cause staining when it reacts with water. The presence of iron oxide in the stone can discolour the edges. At times, the incompatible grouting may not form a sound bond with the marble, so it may surface at the joints during polishing or over a period time. The use of polymer based adhesive system and epoxy based grouting materials can potentially reduce these issues. More information on such adhesives and grouts can be found in Chapters 5 & 6.

Fig. 1.17 – Use of compatible adhesive and grout enhances the performance of agglomerated marble.

d. Maintenance

Agglomerated marble can react with acids and alkalis. Thus it is advisable to apply compatible impregnator to prevent or minimize stain ingress and other reactions. Also, it should be cleaned only with pH neutral detergents. Some other tips to maintain the original surface finish are:

- Protect during construction
- Remove spillage immediately
- Avoid using cleaning agents containing soluble salts like sulphate or chloride
- Use neutral cleaner or plain water for regular maintenance

1.5 TESTS FOR AGGLOMERATED MARBLE

The following key tests are adopted broadly by industry to ensure the quality of agglomerated marble. Although the tests are carried out by sampling, it is advisable that the selection of samples should be taken from different production batches to ensure reliability and consistency of results.

S NO	TEST STANDARDS	PURPOSE OF TEST
1	BS EN 14617-12: 2005	Determination of dimensional stability (Manufacturing tolerance)
2	BS EN 14617-15: 2005	Determination of compressive strength
4	BS EN 14617-10: 2005	Determination of chemical resistance
5	BS EN 14617- 1:2005	Determination of apparent density and water absorption
6	BS EN 14617- 4:2005	Determination of abrasion resistance
7	EN 101:1991	Determination of scratch resistance

Table 1.1 – Test standards for agglomerated marbles

As each site presents its own particular requirements, it is important to understand the characteristics of the materials and match it to the conditions for its intended use. For example, the stone used for internal flooring of a house should be more resistant to stains and scratches. To achieve the desired results, the selection of stones, adhesives and other supplementary products should be chosen according to the specialist recommendation, specific type of application and the environment.

ENGINEERED QUARTZ STONE 2

2 ENGINEERED QUARTZ STONE

Natural stones, especially granite, have been used for flooring and countertop material in high-end homes for its beauty and elegance. However, even though it is very durable, scratch and heat resistant, it has other inherent less desirable characteristics. They are naturally porous and are prone to staining by oils, acids and some cleaning products, especially if they are not properly sealed or resealed periodically. It also contains tiny pits and natural fissures that may appear to be cracks, although these are inherent features. Besides, they are subject to tone variation and it is not easy to achieve smooth transition in the range of shades when it is used in large areas. An alternative to natural stone is engineered quartz stone which is also durable but without the less desirable characteristics of natural stone.

2.1 WHAT IS QUARTZ?

Quartz is a naturally occurring silicate mineral composed of silicon dioxide (SiO_2). It is one of the most common and available minerals on the earth's surface. It ranks 7.0 on MOH (Measurement of Hardness) scale, behind topaz (8.0), sapphire (9.0) and diamond (10.0). Granite is ranked 6 on the scale (Refer to Chapter 1, page 16 for MOH scale range, which is used to gauge the scratch-resistance of a material).

2.2 WHAT IS ENGINEERED QUARTZ STONE?

Quartz exists naturally in clusters and does not form huge stone blocks like granite (which contains 40% - 60% quartz), limestone or other types of rock. This makes it unsuitable for use in its natural state in countertops or other large slab applications. This means that it needs to be converted into another form i.e. engineered stone, to make it usable in such applications.

Engineered quartz stone (also known as reconstituted or re-composed stone) is manufactured from a mix of quartz aggregate chips, a resin binder (typically an unsaturated polyester), pigments and additives. Engineered stone slabs and counter tops are available in a wide range of colors, patterns, and even textures. Its texture can be fine or coarse, depending on how it is processed, and can be combined with glass and other reflective materials for a sparkling finish. They are increasingly popular in high-end applications combining the benefits of granite's durability and non-porous nature of quartz.

2.3 MANUFACTURING PROCESS

The manufacturing process begins with selection of raw quartz materials. They are crushed and blended in the ratio of 93 % quartz aggregates to 7% polyester resin and other additives.

The mixture is compacted into slabs by a vacuum and vibration process of approximately 100 seconds at a pressure of about 100 tons. This process minimizes porosity and reduces water absorption. The slabs are then cured in a kiln at a temperature of 85 degree for a period of 30 minutes to attain the essential properties of resistance to stain and impact. The curing process may be accelerated by using ovens or steam. When curing is completed, the slabs are gauged, calibrated, polished and prepared for packing.

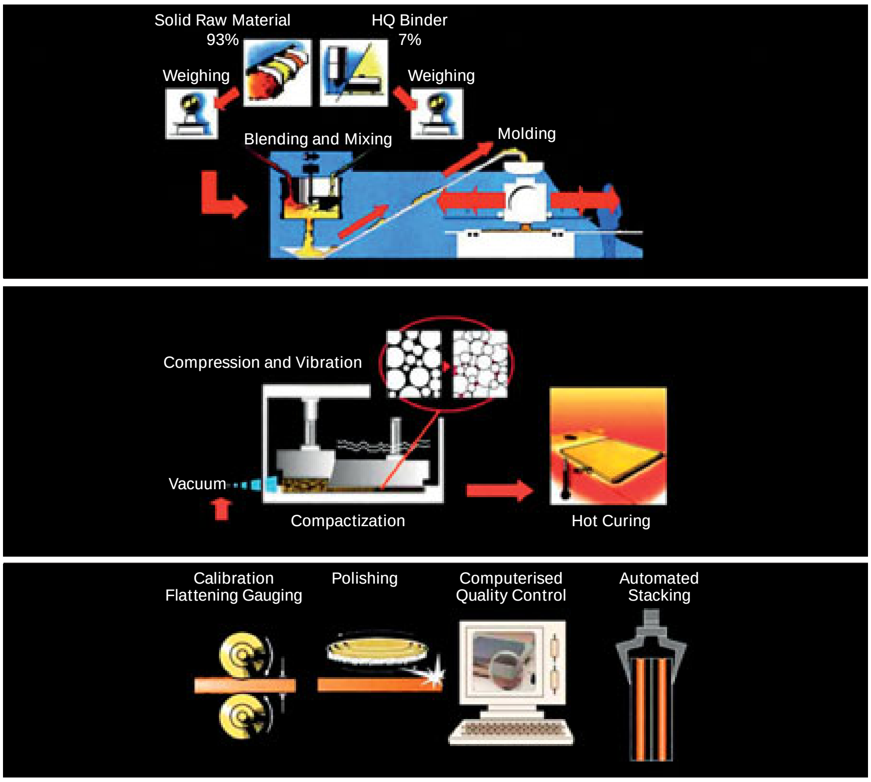


Fig. 2.1 – A typical production cycle of engineered quartz stone.

2.4 TECHNICAL CHARACTERISTICS OF ENGINEERED QUARTZ STONE VS AGGLOMERATED MARBLE

S NO	CHARACTERISTIC	ENGINEERED QUARTZ	AGGLOMERATED MARBLE
1	Density	2.4 to 2.5 g/cm^3	2.4 to 2.5 g/cm^3
2	Water Absorption	0.01 to –0.2%	< 0.20 %
3	Modulus of Rupture	41-58 Mpa	20-35 Mpa
4	Compressive Strength	150-240 Mpa	110-150 Mpa
5	Abrasion Resistance	58-63 (Index)	20-32 (Index)
6	Hardness	6-7 Mohs	3-4 Mohs
7	Acid Resistance	Yes (certain extent)	No

2.5 KEY FEATURES OF ENGINEERED QUARTZ STONE

- As the manufacturing process allows uniformity and consistency in dimension and shade, pre selection effort (also known as dry-lay – a common practice when using natural stones) is minimized. This saves considerable time during construction.

- The high MOH score and better scratch resistance properties make the material suitable for commercial flooring applications where traffic and abrasion factors are high.

- Most patterns of engineered stones resemble natural stone, but with a consistent pattern, texture and color. Thus flooring or countertops have a uniform appearance.

- The hard, non-porous surface retains its polished lustre and does not need sealing treatment on the surface. It can also be cleaned and maintained with normal or soapy water.

- In addition to kitchen countertops, engineered stone products are suitable for shower and tub surrounds, vanity tops and other surfaces in wet areas, unlike porous stones, which can foster bacteria growth. They are therefore ideal for locations such as commercial buildings, canteens, hospital food service areas, etc.

- As they are man-made, these materials can be fabricated in large sizes, resulting in less joints and better aesthetics.

Fig. 2.2 – Most patterns resemble natural stone.

Fig. 2.3 – Resistance to acid and food safe: Suitable for kitchens and wet areas.

Fig. 2.4 – Porosity in natural stones attracts liquid and moisture ingress.

Fig. 2.5 – Non-porous surface does not require sealing in the counter-top.

2.6 LIMITATIONS AND OTHER FACTORS TO CONSIDER WHEN SELECTING ENGINEERED QUARTZ STONE

- Although engineered stone resembles natural stone, it still lacks the uniqueness and beauty found in natural stone e.g. beauty marks, flowing veins, known as “movement” of the stone. From an aesthetic standpoint, engineered quartz countertops may appear artificial.

- The high MOH score gives better hardness and scratch resistance properties. However, once the tiles are installed, they cannot be ground and polished (similar to granite) if there is any lippage or unevenness in the flooring.

- The back-splash at counter tops or sinks cannot be integrated like acrylic materials solid top materials. So back-splash joints are inevitable in the counter-top.

Fig. 2.6 – Sink and back-splash can be integrated in solid surface materials but not when using engineered quartz stone.

- The cost of materials can be higher than natural stone in some cases depending on the variety and supply source.

- Engineered stones are primarily stone particles with a bit of resin and pigment. Not all variety of stones used in manufacture will have a consistent quality. The end product may therefore vary from one batch production to another depending on the raw materials used, mixing ratio of resin, quality of resin and other pigments and type of machinery employed for the production.

2.7 SUMMARY

It is important to understand the characteristics of the materials and match it to the conditions for its intended use. The use of compatible adhesives and grouting, correct method of installation and maintenance are also important. In addition, it is advisable to select samples from different production batches for laboratory tests to ensure their reliability and technical properties before actual installation. Finally, it is always important to consult the manufacturer for detailed information and technical support on the suitability and applicability of the product for the intended use.

RECTIFIED CERAMIC TILES 3

3 RECTIFIED CERAMIC TILES

The manufacturing process of ceramic and homogeneous tiles has undergone considerable changes in recent times. More automated methods have been employed in production and a wide range of tile products with different characteristics are available on the market for various uses. The following section identifies some new developments in tile production and in particular rectified tiles, which can be used to achieve better workmanship quality.

3.1 TYPES AND CHARACTERISTICS OF TILES

a. Ceramic tiles

Ceramic tile is a mixture of clay and quartz ferrous sand materials along with water. The special clays are mined from the earth, shaped, coloured and then fired in kilns. They can be coloured and the surfaces can be glazed either in a high gloss or matte finish. Most ceramic tiles have either a white or red body colour underneath the glazed finish.

b. Homogeneous tiles

Homogeneous tile is a form of ceramic tile composed of fine porcelain clays but fired at much higher temperatures than ceramic tile. This process makes homogeneous tiles denser, harder, less porous and therefore less prone to moisture and stain absorption than ceramic tiles. They have a consistent property throughout the entire section of the tile. For these reasons, most homogeneous tiles are suitable for both indoor and outdoor use. However they are harder to cut due to their density and hardness.

c. Glazed tiles

The body of ceramic tile, called bisque, may be coated with or without a glaze depending on its intended purpose. The glazed coating comprise of liquid coloured glass which is applied and baked to the surface of the bisque under very high temperatures. The liquid glass coating can be fashioned with texture and design. The main features of glazed tiles are ease in cleaning and protection of the bisque from staining.

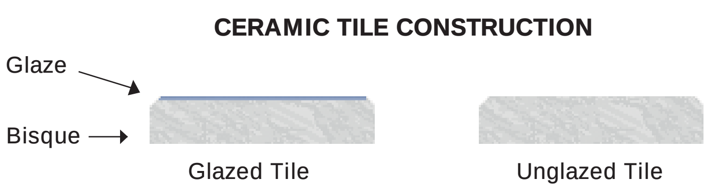


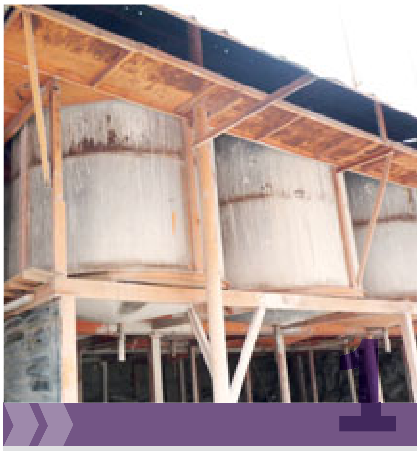
Fig. 3.1 – Body of glazed and unglazed tile.

d. Rectified tiles

A rectified tile has all its edges mechanically finished to achieve a more precise dimension. Unlike a typical factory-edged tile, a rectified tile is created by cutting the tile to size after the firing process. This creates precise 90 degree angle smooth edges. As a result, the tiles can be laid with consistent grout joints. Most tiles (homogeneous and ceramic) can vary in size (up to 1.0%) after the firing process but this can be substantially minimized by sawing or grinding the tile after firing.

Fig. 3.2 – Size variation can be substantially minimized in rectified tile.

3.2 AN OVERVIEW OF TILE PRODUCTION

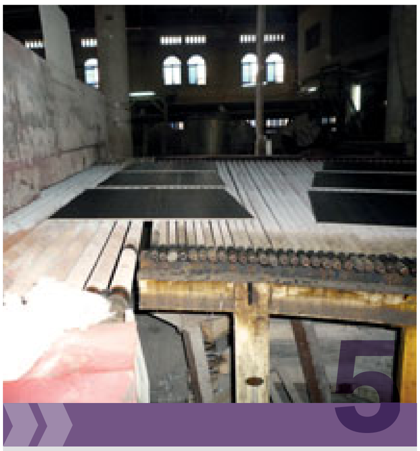


Mix ingredients.

Dry press to make bisques.

1st firing.

Colouring/glazing.



2nd firing.

Mechanical cutting.

QC Check.

Packing.

Fig. 3.3 – Overview of tile production.

3.3 IMPACT OF MANUFACTURING PROCESSES ON TILE QUALITY

a. Size variation

Other than poor workmanship, inconsistency in tile joints is due to dimensional variations among the tiles. This variation occurs mainly during the kiln firing as the bisques tend to shrink during this process and the shrinkage may not be constant in all tiles. This result in different tile sizes and the variation can be up to 1% of the tile size depending on the manufacturing process and the kiln atmosphere.

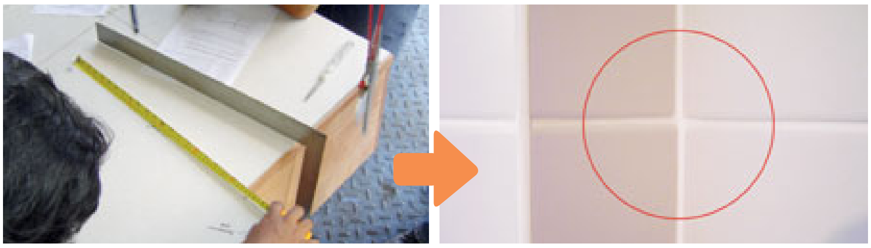


Fig. 3.4 – Size variation will lead to inconsistent joints.

The inconsistent joints can be substantially reduced by using rectified tiles which require the additional process of cutting and grinding after kiln firing. The rectified tiles with controlled tile dimensions and straighter edges make the joints consistent and aesthetically pleasant.

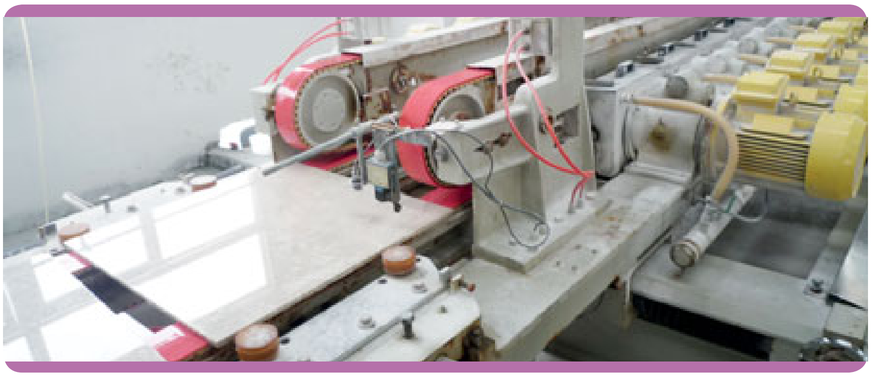


Fig. 3.5 – Tiles being cut by an automated mechanism after kiln firing to ensure dimensional consistency.

Another way to minimize inconsistent joints during laying is to use a gauge box on site to group the tiles according to their sizes. Typically measurements are marked on the box and the tiles are placed and grouped according to the sizes. For example, if the tile size is 300 x 300 mm and the manufacturing tolerance is + or – 1 mm, the gauge box will have markings of 299, 300 & 301 mm. Although this is a time consuming process, segregating and grouping the tiles according to the sizes first before laying will lead to better and consistent joints.

Fig. 3.6 – Gauge box used on site to group tiles according to size.

Fig. 3.7 – Good dimensional tiles aid better consistency in joints.

b. Warpage

Warpage is curvature in the face of a tile which can be concave or convex in shape. This is due to changes that occur during the firing and cooling process of production. Edge warpage is measured at the centre of a tile's edge and diagonal warpage is measured at the center of the tile. Both are expressed as a percentage of the tile's linear dimensions. Most tiles (both homogeneous and ceramic tiles) will exhibit some warpage after firing.

Fig. 3.8 – Warpage on tiles may occur after the firing and cooling process.

Tile warpage is often the cause (apart from poor workmanship) of lippage or unevenness between tiles. Lippage is a condition where one edge of a tile is higher than adjacent tile, giving the finished surface a ragged and uneven appearance. Lippage in floor tiling often causes discomfort to end users walking with bare feet and may result in injury especially on sharp edged tiles. It also affects the visual appearance of the floor and in wet areas, it can impede water flow and build up stagnant water.

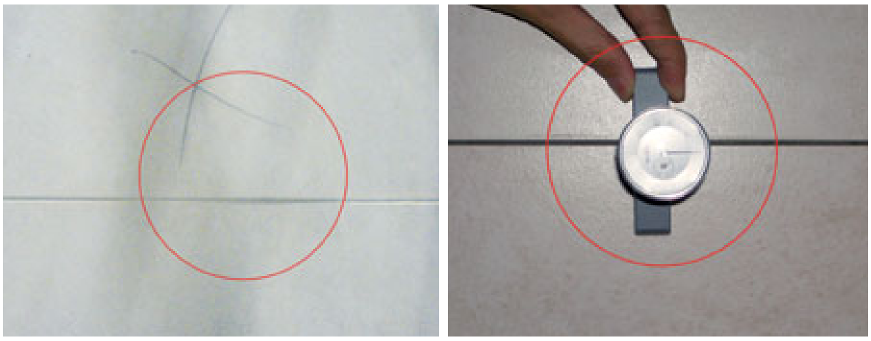


Fig. 3.9 – Depth gauge used to measure lippage or unevenness between tiles

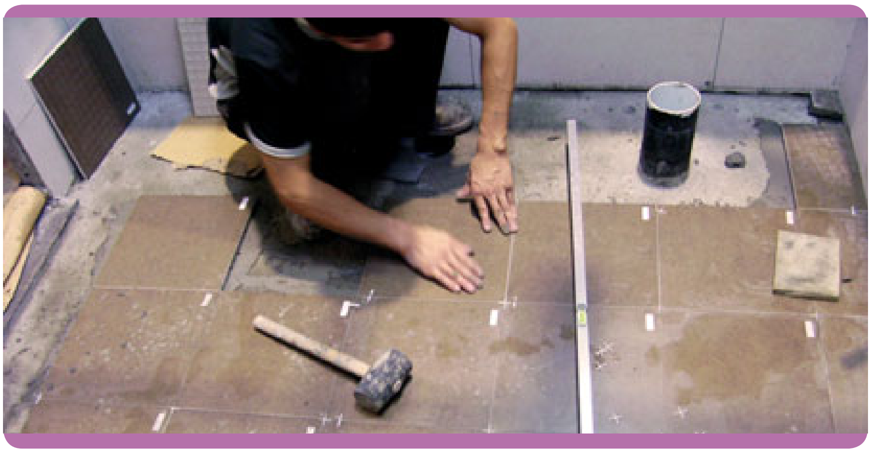


Fig. 3.10 – Lippage in wet areas can build up stagnant water.

c. Water absorption, surface cracks and damage

The raw material used and the manufacturing process affect the density of the tile. This in turn controls the water absorption rate of the tile. There is a direct relationship between the water absorption rate and the suitability of the tile for interior or exterior use. The following are some general classifications used by some factories based on water absorption rates and the recommended use of the tiles:

Non vitreous tiles: Absorb 7% or more of its weight – Suitable for dry indoor area.
Semi vitreous tiles: Absorb 3% to 7% of its weight – Suitable for dry indoor area.
Vitreous tiles: Absorb 0.5% to 3% of its weight – Suitable for dry & wet area indoor use.
Impervious tiles: Absorb between 0 and 0.5% of its weight –Suitable for both indoor and exterior use.

Crazing is a defect or phenomenon in a glazed tile where thin cracks appear on the surface. This is usually caused by tensile stress between the bisque and glaze. When the bisque and glaze expand and contract at different rates, fine cracks may appear on the glazed surface. The other reason could be thermal shock where in the kiln, the tiles are either brought up to high temperature too soon or cooled too quickly.

Degree of Hardness of a tile is achieved by the choice of raw materials used and the manner in which the tile is manufactured. Ceramic tiles are made from clay and not all clays have the same properties and mineral content. During the manufacturing process the soft clay tiles are subjected to high temperatures in a kiln. The final hardness of the tile is directly related to the mineral content, the temperature reached in the kiln and the duration of time the tiles are fired. MOH (Measurement of Hardness) test is used to rate the tiling hardness from 1 (softest) to 10 (hardest). Ceramic tiles with a value of 5 or more are suitable for most residential floor tile applications. Tiles with a value of 7 or higher are normally acceptable for most commercial applications or heavy traffic areas.

Fig. 3.11 – Tiles with low MOH rating are not suitable for heavy traffic areas.

d. Shade variations

The variation in color, texture and tone between individual tiles is termed as shade variation. Shade variation is an inherent characteristic of majority of fired ceramic products. The color is bound to vary to some degree in each production run. So it is important to purchase sufficient quantity of tiles from the same batch of production to complete the job. If not, obtaining additional tiles from a different batch production even from the same factory may lead to shade variation. The following is a general guideline used by some factories for grading tiles according to their shade variation.

V1-Uniform Appearance
V2-Slight Variation
V3-Moderate Variation
V4-Random or Dramatic Variation

Fig. 3.12 – Shade variations may affect visual appearance.

It is also a common practice that tile size, color shade and other information are printed on each carton in order to group them on site to get better consistency.

Fig. 3.13 – Typical information on tiles packing.

3.4 SUMMARY

Ceramic and homogeneous tiles are available in a wide range of grades and classifications. Hence it is important to ensure that the tiles meet the required standards before starting installation. The various tests for tiles such as slip resistance, water absorption, breaking strength, impact resistance, abrasive hardness, chemical resistance, etc are valuable to builders when choosing tiles for specific application. It is also advisable to select samples from different production batches for laboratory tests to ensure their consistency. The selection of compatible adhesives and grouting, correct method of installation and maintenance are other important factors to ensure performance.

LIGHTWEIGHT COMPOSITE STONE PANELS 4

4 LIGHTWEIGHT COMPOSITE STONE PANELS

Composite stone panel consists of a thin natural stone veneer (3 mm - 5 mm) bonded to a backing panel. The backing panel can be of aluminum (honeycombed or ply), fiberglass, ceramic or other material, depending on the type of use. The two parts are tightly bonded together with high strength glue under high temperature and pressure. The resultant composite panel not only preserves the natural beauty of the granite or marble, it also overcomes inherent properties and characteristics like fragility and heaviness present in natural stones. Composite panels can be produced virtually in any natural stone material including granite, marble, limestone, slate and sandstone. They are used in a wide range of applications like exterior and interior wall claddings, elevators, over-lays, counter-tops and other special applications.

Fig. 4.1 – A cross-section of a typical aluminum honeycombed composite panel.

4.1 CHARACTERISTICS OF COMPOSITE STONE PANELS

a. Light weight

The standard composite panel comprising stone veneer with plastic laminated panels reinforced with honeycomb aluminium is 1/2 or 1/3 lighter than solid stone panel. This reduces the dead load of the building. As it is lighter, the erection speed is also improved, especially in high-rise building claddings. There is therefore savings in structural requirements, labour and time. Besides providing stability to the thin layer stone, the fabrication technique eliminates warpage – a natural characteristic often seen in long stone panels. The composite stone panel can be installed on most substrates using a variety of installation methods including adhesion or mechanical fastenings like concealed screws or interlocking channels.

Fig. 4.2 – Lightweight panels and mechanical fastening installation expedite erection.

b. Better impact resistance, flexural strength and water resistant

Composite stone panel has better impact resistance and flexural strength due to their backing support. The backing support panels can be flexed, making them ideal for a variety of architectural applications. They reduce the fragile and brittle properties of natural stones and can be used in place of natural stones for their aesthetic beauty. In addition, the epoxy skinned composite panel is impervious to water penetration, even with open structured stones such as travertine or limestone.

Fig. 4.3 – The backing technology yields better flexural strength.

c. Increase stone utilization ratio

The use of thin stone veneer in composite panels maximizes the usage of natural stone. The utilization ratio is generally about 3 times higher than if the material comprise wholly of natural stone. For example, 1 m^3 of raw stone can be used to fabricate up to 135 m^2 of composite stone panels compared to about 45 m^2 of natural stone panels. This is a more efficient use of limited resources, reduces the exploitation of natural resources and promotes environmental conservation. Furthermore, getting a larger quantity of stone veneer from a single block allows the manufacturer to achieve a more consistent tone and texture in the end-product.

Fig. 4.4 – Thin cuts from same block increases utilization ratio.

4.2 TYPES OF COMPOSITE BACKINGS

a. Aluminum honeycomb backing

The honeycomb backing is suitable for both marble and granite finish. The thickness of the stone can be as thin as 3 mm and the backing can be in the range of 10 to 25 mm. This backing is not only lightweight, it also has high strength, better resistance to moisture, corrosion and fire. Furthermore, the aluminum alloy plates between the honeycombs provide good impact resistance and flexural strength. The panel's properties permit its use in internal or external wall claddings and counter tops.

Fig. 4.5 – Aluminum honeycomb backing with thin marble.

b. Aluminum polymer backing

The thin polyester aluminum backing panel is about 2.5 to 4 mm thick and such composite panels are suitable for applications requiring light weight and thinness. It can be used for internal wall claddings, lift interiors and decorative ceilings. Apart from being light weight, the polyester aluminum panels are more even and resistant to corrosion and chemical attack.

Fig. 4.6 – Thin aluminum polymer backing with marble.

c. Fiberglass net backing

This method is more suitable for granite and less common for marble finish as marble is softer and more fragile than granite. The advantages of using fibreglass net backing are its strength, stiffness and lightness. The panels can be installed using either adhesive or mechanical fastening.

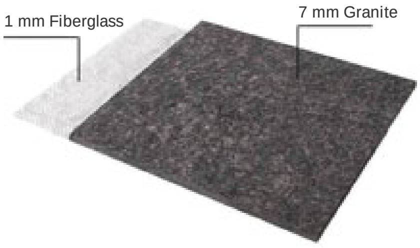


Fig. 4.7 – Layer of fiberglass net backing with granite.

d. Glass backing

The composite panel is formed by glass, stone and epoxy. The glass can be either tempered or laminated and bonded to the stone using a translucent epoxy that does not affect the natural colour of the stone. This method works well with stones of translucent onyx, alabaster or white marble as the pattern of natural veins of the stone will glitter and be transparent under lighting. Such composite panels are used in hotel proscenium, feature walls, elevators and ornamental ceilings.

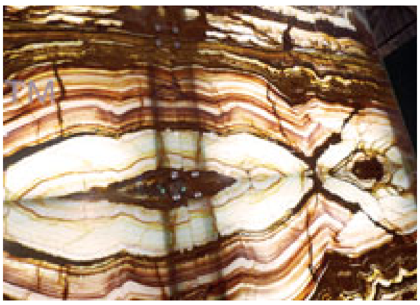


Fig. 4.8 – Glass backing with marble is bonded by translucent epoxy.

e. Ceramic backing

This method is often used with marble finish as marble is softer and have the characteristic of open veins. The marble needs a stronger backing particularly for flooring applications. The composite tiles can be installed by cementing for flooring or mechanically anchored for wall claddings. The marble can be cut to ultra-thin veneer of 3 mm thickness and adhered to ceramic backing of 8 mm thickness. Although the ceramic backing gives a strong base, these panels are heavier than the other methods.

Fig. 4.9 – Ceramic backing with marble: Primarily for flooring.

4.3 AN OVERVIEW OF FABRICATION OF COMPOSITE STONE PANELS

The natural stone from the quarry in the form of blocks are cut into thin slabs. They are bonded to backing panels by special resin followed by application of uniform heat and pressure to ensure proper bonding throughout the whole slab. Once the glue has set, the slab is sawn into half and the pieces are polished or honed. Finally, the pieces are cut to size mechanically according to customer's requirements.

Apply resin on stone to bond with backing material.

Double sided bonded backing.

Apply pressure & heat.

Sawn into half.

Polish.

Mechanical cutting.

QC Check.

Packing.

Fig. 4.10 – Composite panel fabrication process.

4.4 LIMITATIONS AND CONSIDERATIONS IN COMPOSITE STONE PANELS

Although the technology economizes the use of natural stone, speeds up installation and improves the performance and range of applications, it may not be cost effective in applications involving natural stones with low and medium cost range. However for applications that use high-end luxurious stones like onyx marble or sky blue granite, there are potential benefits and savings as the usage of the more costly raw material is greatly reduced.

The strength and performance of the composite stone panel are very much dependant on the manufacturing technology and the quality of resin used. Hence it is important to ensure the right materials and suppliers are chosen to supply the product.

The choice of installation methods e.g. mechanical fastening or by adhesive glue, requires appropriate skilled labour to ensure the effectiveness of the installation. Hence it may be necessary to ensure there are adequately trained workers to carry out the installation works before considering light weight composite stone panels.

BEDDING ADHESIVES FOR STONES AND TILES 5

5 BEDDING ADHESIVES FOR STONES AND TILES

Before starting stone or tiling works, it is important to select the correct bedding adhesive to ensure its performance. No one single formula adhesive can be used with all stones/tiles and substrates. The first step in choosing a tile adhesive is to consider the location of the installation e.g. whether the stones/tiles are to be installed inside or outside the building, to the wall or on the floor, in a wet or dry area, and the type of receiving substrate e.g. concrete, render, screed drywall, etc.

Polymer-modified cementitious adhesives

Polymer-modified adhesives are widely accepted in the industry and often referred to as thin-set mortars. The blended polymers interact with cement components to improve the physical and mechanical properties such as increased adhesion, reduced shrinkage and lower water absorption. In most cases it is suitable for wet or dry installations. The polymer additives add strength and flexibility to the mortar, without which the bedding can crack easily.

The polymer modified adhesives are commonly available in two types. One comes with powdered polymer as pre-mix. Hence, during the application, only water is required to be added to make a bed. The other type requires addition of liquid latex additive rather than water. The second type is generally used for natural stones which are prone to moisture ingress and also for a fast setting installation. It also reduces the effect of back staining on natural stones and gives better shear bond strength to the bed.

5.1 CLASSIFICATION OF ADHESIVES

Based on ISO 13007 -1:2004, tile adhesives fall into three major categories:

Type C (Cementitious): Mixture of hydraulic binding agents, aggregates and additives; to be mixed with water or other liquid just before use.

Type D (Dispersion): Ready -for-use mixture of binding agents in the form of polymer dispersion, additives and other mineral fillers.

Type R (Reaction Resin): Single or multi-component mixture of synthetic resin, mineral fillers and other additives in which the curing occurs by chemical reaction.

The above categories can be further divided into the following classes:

(i) Normal adhesive (Tensile strength > 0.5 N/mm^2) : **Class 1**

(ii) Improved adhesive (Tensile strength > 1.0 N/mm^2) : **Class 2**

They can be categorized according to the following characteristics:

(i) Fast-setting with early tensile strength adhesive : **F**

(ii) Slip-resistant adhesive : **T**

(iii) Adhesive with extended open time : **E**

(iv) Special deformable characteristic (Type C only) : **S**

Classification and performance criteria for cementitious adhesive based on EN 12004/12002 and ISO 13007-1

CLASSIFICATION	CHARACTERISTICS	REQUIREMENT
C1 – Normal	Tensile strength @ 28 days (Open time @ 20 minutes)	≥ 0.5 N/mm^2
C2 – Improved	High tensile strength @ 28 days. (Open time @ 20 minutes)	≥ 1.0 N/mm^2
F – Fast setting	Early tensile strength @ 6 hours.	≥ 0.5 N/mm^2
T – Slip (Non sag)	Downward movement of a tile on a vertical surface.	≤ 0.5 mm
S1 – Deformable	Capacity of a hardened adhesive to be deformed	< 5 mm ≥ 2.5 mm
S2 – Highly Deformable	Capacity of a hardened adhesive to be deformed	≥ 5 mm
E – Extended open time	Extended open time @ 30 minutes with the tensile adhesion strength	≥ 0.5 N/mm^2

5.2 QUICK REFERENCE GUIDE FOR COMBINATIONS OF FINISHES, LOCATIONS, AND SUBSTRATES

TYPE OF FINISH	LOCATION	SUBSTRATE	SUGGESTED ADHESIVE CLASSIFICATION IN COMPLIANCE WITH ISO 13007-1 EN 12004/12002
Natural Marble & Granite	Wall & Floor (Internal/External)	Concrete/Cement render/Screed	C2 TE
Natural/Agglomerated Stones (prone to moisture and staining)	Wall & Floor (Internal)	Concrete/Cement render/Screed	C2 F/S1 2-Component
Natural/Agglomerated Stones with size 600x600 mm or more	Wall & Floor (Internal)	Concrete/Cement render/Screed	C2 FTE /S1
		Deformable substrates such as drywall, board and plywood	C2 FTE /S2
Homogeneous tile/ Ceramic tile with low water absorption	Wall & Floor (Internal)	Concrete/Cement render/Screed	C2TE 1-Component
Ceramic tile with high water absorption	Wall & Floor (Internal/External)	Concrete/Cement render/Screed	C2TE 2-Component
Glass & ceramic mosaic	Wall & Floor (Internal/External)	Concrete/Cement render	C2TE
Ceramic / Homogeneous/Mosaic	Wall (Internal)	Deformable substrates such as drywall, board and plywood	C2FTE/S2
1.Tiles 2.Glass mosaics 3.Rapid installation	Wall & Floor (Swimming pool)	Concrete/Cement render/Screed	1. C2 T 2. C2 TE/S1 3. C2F/S1 (2-Component)

Fig. 5.1 – Less-absorbent stones with a substrate of cement render or concrete.

a. For less-absorbent natural & agglomerated stones and tiles

Improved high tensile strength adhesive is suitable for less-absorbent natural stones and glass mosaics for both internal and external applications. The adhesive is a mixture of cement, selected sand aggregates with additives and synthetic resin. The latex (polymer) added into it can be a separate liquid or integrated into the powder. The special feature of the adhesive is that it hardens without undergoing noticeable shrinkage. However the C2TE type may not be compatible with deformable substrates that may be subject to movement and vibration e.g. drywall, chip-board, etc.

b. For moisture sensitive natural & agglomerated stones

High performance fast-setting with early tensile strength and deformable adhesive is compatible for installation of stones which are prone to moisture ingress and requires rapid drying. Because of its improved bonding strength and fast setting properties, it is also suitable for floors which are subject to heavy traffic and places that require rapid re-flooring or retrofitting such as supermarkets, hospitals, airports, etc. The use of epoxy material (R type adhesive) is an alternative choice for moisture sensitive tiles or stones. However the cost of epoxy based adhesive is often higher than cementitious adhesives.

Fig. 5.2 – Porous natural stones with a substrate of cement render or concrete.

c. For stones and tiles on deformable substrates

The downward movement on a vertical surface is generally high in deformable substrates such as plywood or board partitions. These substrates require the adhesive to be fast setting, deformable and slip resistant for better performance.

Fig. 5.3 – Installation of tiles and stones on partition board substrate.

d. Ceramic tiles with high water absorption

High performance fast setting with early tensile strength 2-component adhesive is compatible for ceramic tiles with high water absorption. The addition of latex liquid instead of water prevents possible back staining on tiles.

Fig. 5.4 – High water absorbent tiles with a substrate of cement render.

e. Ceramic tiles with low water absorption

Fig. 5.5 – Tiles with low water absorption on a rendered substrate.

High performance, deformable cementitious adhesive is suitable for tiles and stones which are less prone to moisture absorption. The bedding thickness can range from 3 mm to 10 mm for thin-bed adhesives or up to 15 mm for medium bed adhesives. As the polymers are integrated into the mortar, it does not require separate latex liquid for mixing other than water.

f. Swimming pool mosaics

Latex fortified 2-component adhesive is preferable for mosaics with continuous water submersion and water pressure. The latex mortars reduce the effect of chemical reactions, improve adhesion and flexibility to withstand expansion due to stress and differential movement.

Fig. 5.6 – For swimming pool mosaics.

5.3 1-COMPONENT VS. 2-COMPONENT ADHESIVES

1-component adhesive mortar is in powder form with premixed modified polymers. Generally, they are suitable for stones and tiles with low water absorption and laid on cement sand screed or rendered substrate. Only water is required to be added during application since the polymer is already integrated into the powder. Thus, it is easier to control the mixing ratio when it is used extensively in a large project.

Fig. 5.7 – 1-component adhesive: Add powder + clean potable water.

2-component adhesives consist of a mixture of cement-based powder mortar (component A) and separate latex liquid (component B). They are appropriate for tiles and stones which are prone to moisture ingress and back staining hence requiring a rapid setting adhesive. They are also more suitable for special applications like water features and swimming pools. However both systems also can have the additional properties of fast setting and deformability.

Fig. 5.8 – 2-component adhesive: Add powder + latex liquid.

5.4 SCREED-LESS BEDDING ADHESIVE

The conventional cement-sand floor screed comprises a layer of mortar of Portland cement and concreting sand which is cast in situ on to a concrete slab. The screed thickness can range from 20 to 30 mm and it needs to be cured for a minimum of 14 days before laying of tiles. Failure to observe this requirement can lead to cracks or de-bonding of tiles due to inadequate surface preparation.

Fig. 5.9 – A typical conventional floor screeding process using cement-sand mortar.

To avoid the inconvenience of prolonged curing, a medium-bed mortar can be considered. Instead of laying a cement-sand screed, the adhesive up to 15 mm thick can be laid directly onto the concrete substrate followed by the tile. However, the substrate should be reasonably level with good surface preparation, otherwise excessive thick-bed mortar may be required to correct the differences in levels, leading to additional time and cost.

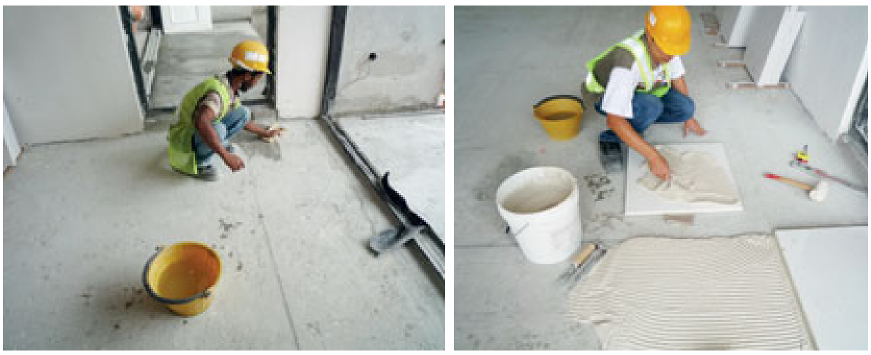


Fig. 5.10 – Screed-less bedding adhesive for laying marble floor.

5.5 COMPATIBILITY TESTS

The adhesive's function is to provide cohesion between the substrate and tile. A weak bond between tile and adhesive or adhesive and substrate are the most common causes of failure. To prevent such failures, a tensile adhesion strength test should be conducted to check the compatibility of the materials. Other trial checks such as water absorption rate and the effect of impregnator on stone surface should also be considered otherwise rectification works may be necessary after installation. As technology advances, new testing procedures like in-situ shear bond testing can be employed to test shear forces closely similar to actual situations after installation.

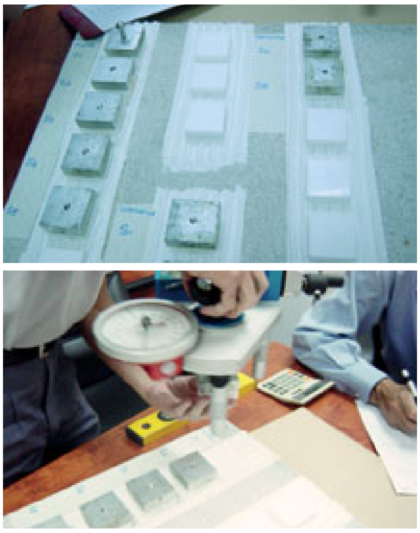


Fig. 5.11 – Compatibility tests to ensure adhesive's performance.

5.6 CONSIDERATIONS IN SELECTING ADHESIVES

Although there are established criteria for selecting adhesives for different types of finishes, substrates and locations, it is good practice to confirm the selection by testing it on site before actual installation. More care should also be taken for moisture sensitive and light coloured natural stones. It would be better to choose white coloured bedding adhesives for light coloured natural stones to avoid back staining. Apart from selecting the appropriate bedding adhesive, the manufacturer's guidelines on using the material such as mixing ratio and open time should be strictly observed to obtain optimum performance. When in doubt, it is always advisable to consult the manufacturer for technical support on the product and its suitability for the intended use.

GROUTING FOR STONES AND TILES 6

6 GROUTING FOR STONES AND TILES

6.1 TYPES OF GROUT

Grout is the material that is used to fill the space between adjacent tiles and support the joints. It is visible and can be water-resistant. However, in most Portland cement based grouts, water or other liquids are likely to penetrate the joints. There are two major classifications of grout:

a. Cement based (CG) grout

They can be further classified as class 1 (CG1) for Normal Performance and class 2 (CG2) for Improved Performance).

In cementitious grouts, there are two basic types: sanded and non-sanded. The general industrial practice for the application of cementitious grouts is as follows:

Sanded grouts	Formulated with Fine Silica Sand for Joint width of up to 6 mm
	Formulated with Coarse Silica Sand for Joint width between 4 mm to 15 mm
Non-Sanded grouts	Joint width of 4 mm or smaller

- **Sanded cementitious grout**

This grout consists of very fine graded aggregates, portland cement, synthetic resins and coloured pigments added with water retentive additive.

- **Non-sanded cementitious grout**

This cement based grout consists of fine fillers, synthetic resins, colored pigments and water-retentive additive. It is designed for use on tile surfaces that are dry when the grout is applied. The water retentive additive allows the grout to stay moist until the cement cures properly.

b. Epoxy based (RG) grout

The grout consists of epoxy resin, silica fillers, pigments and a hardener. They have very low water absorption, higher compressive strength, are resistant to staining and easy to maintain. Epoxy grout is a waterless mix formed by mixing a base material (part A) and a hardener (part B). These components are mixed on site just prior to grouting. Generally, epoxy grouts require no additional sealer to protect the surface. However, epoxy grout is costly and the method of application is slightly more difficult compared to cement based grouts. Also, when resistance to chemical attack is important, prior testing of the grout ingredients against the chemical should be considered before use.

6.2 ADDING LIQUID POLYMERIC ADDITIVE TO CEMENTITIOUS GROUTS

Several latex additives are available that can be added to both sanded and non-sanded grouts as a substitute for water. These additives are blends of acrylics and latex. They will lower the water absorption, increase the strength and improve colour retention of the grout. Some cementitious grouts are premixed with dried latex powder at the factory and therefore do not require additional additives.

The following are some typical locations where grouts with latex additives are commonly used:

- Floors subject to heavy traffic
- Floors and walls on flexible substrates such as plywood, board partitions and others
- Floors subject to frequent cleaning and jet washing or exposed to weather
- Floors to be ground and polished after installation
- Swimming pool tile joints

Fig. 6.1 – Adding liquid polymeric additives to cement grout enhances its performance.

6.3 SPECIFICATION AND PERFORMANCE CRITERIA FOR CEMENTITIOUS TILE GROUT (CG) BASED ON ISO 13007-3

FUNDAMENTAL CHARACTERISTICS FOR CG1 (NORMAL PERFORMANCE)	REQUIREMENT
Abrasion resistance	$< 2000\ mm^3$
Flexural strength under standard condition	$> 2.5\ N/mm^2$
Compressive strength under standard condition	$> 15\ N/mm^2$
Shrinkage	< 3 mm/m
Water absorption after 30 minutes	< 5 g
Water absorption after 4 hrs	< 10 g

FUNDAMENTAL CHARACTERISTICS FOR CG2 (IMPROVED GROUT)	REQUIREMENT
High abrasion resistance	$< 1000\ mm^3$
Water absorption after 30 minutes	< 2 g
Water absorption after 4 hrs	< 5 g

6.4 A TYPICAL APPLICATION OF NON-SANDED GROUT IN CERAMIC FLOOR TILING IN INTERNAL AREAS

Remove foreign materials from joint.

Cleaning.

Mix to a workable ratio.

Apply with an appropriate tool.

Sanding using abrasive paper after drying.

Uniform joint filling.

Fig. 6.2 – Application of grout in ceramic tiling.

6.5 COMPATIBILITY ISSUES BETWEEN GROUT AND NATURAL STONES

Natural stones are prone to staining because of their porosity and absorption characteristics. In some circumstances, the grout's ingredients such as colour pigments and additives can penetrate into the stone's microscopic pores where they are trapped and appear as stains in the stone. This can also be triggered during the wet polishing process.

Fig. 6.3 – Wet polishing on a marble floor.

The most vulnerable area in the natural stone is at "the edges". As the edges or side faces of the stones are often not of polished finish, this facilitates absorption leading to discoloration. Therefore it is strongly recommended to test the compatibility of the grout and stone materials before installation. Where the porosity and absorption rate of the natural stone are high, use of penetrating sealers on the stones prior to the installation can be considered.

The use of sanded grout with a polished marble installation presents another difficulty. Marble has smooth and soft surface. The fine sand in the grout may scratch the polished surfaces during or after installation. Hence, it is advisable to use non-sanded grout for polished marble surfaces.

In some cases, the grout may tend to emerge from marble joints because of its weak bonding or insufficient grout depth. This can occur after grinding and polishing or after certain period of regular mopping. This can be reduced by using some latex additives in the grout to improve the bonding property. Alternatively, where budget permits, epoxy grouting can be considered which will give better bonding and aesthetics.

Fig. 6.4 – Discoloration of grout and edge staining after polishing.

Fig. 6.5 – Emerging grouts from marble joints.

6.6 A TYPICAL APPLICATION OF EPOXY BASED GROUT ON A MARBLE FLOOR

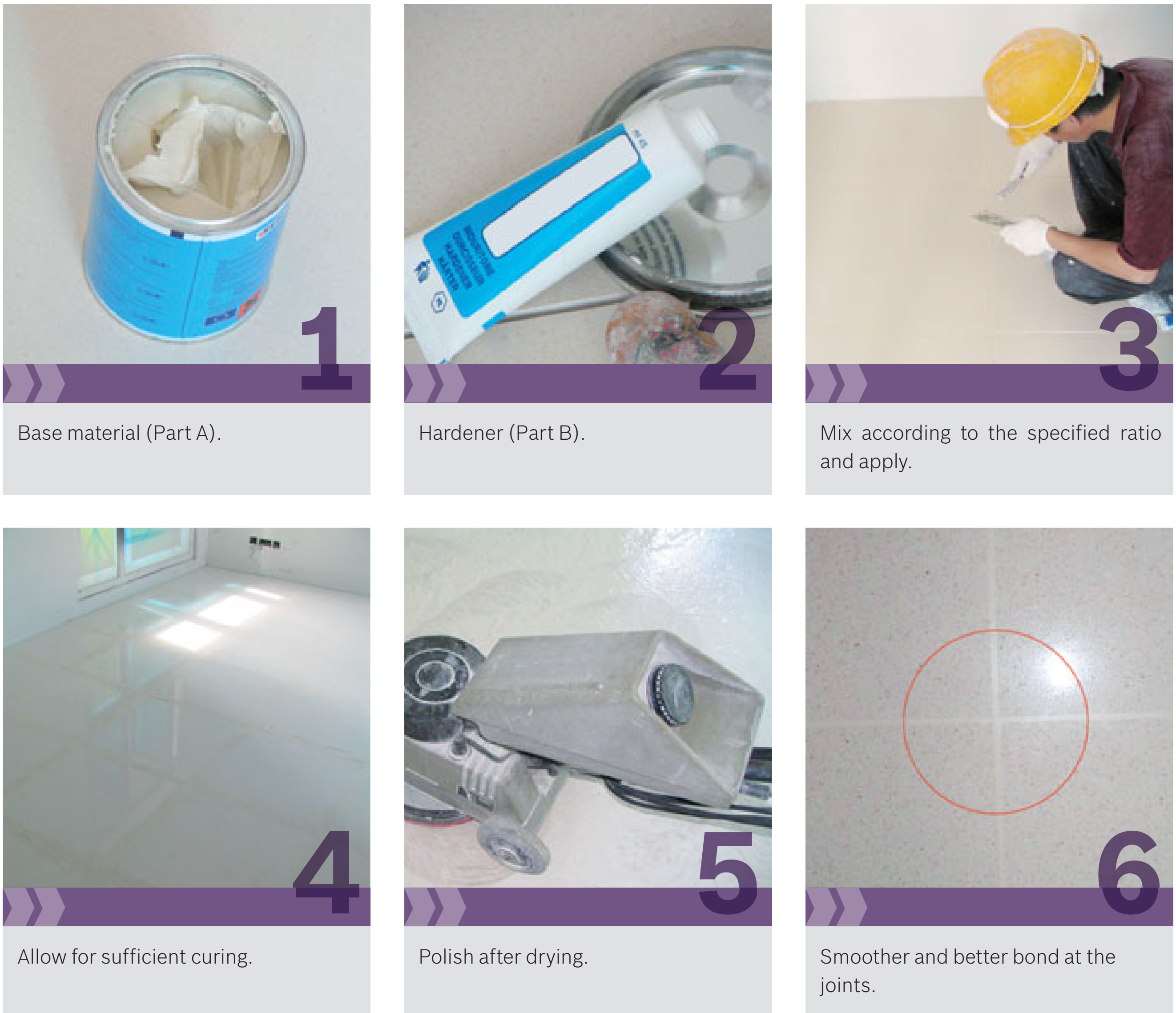


Fig. 6.6 – Application of epoxy grout in compressed marble flooring.

Fig. 6.7 – Better aesthetics and smoother joints on a marble floor using epoxy grout after polishing.

6.7 SUMMARY

Selecting the right grout is as important as selecting the right stone or tile. The manufacturer's instructions on product suitability, mixing, curing and applying the grout should be followed closely for optimum performance. Before proceeding, it is advisable to test its compatibility with the stone. More care should be taken for moisture sensitive and light coloured natural stones to avoid stain ingress. It should be noted that expansion joints on walls and floors must never be filled with grouting material as they are not designed for this purpose.

IMPREGNATORS FOR NATURAL STONES 7

7 IMPREGNATORS FOR NATURAL STONES

7.1 WHY NATURAL STONES ARE PRONE TO STAIN?

Most natural stones are porous, permeable and absorbent to some extent depending on the characteristics of pores and degree of polish finish. Stains can be classified into two types: organic and inorganic. **Organic** stains are caused mostly by food, drinks, plants, wood and dyes, etc. **Inorganic** stains are usually mineral in nature. For example, iron compounds are found naturally in stone which can oxidize and cause the stone to turn yellowish brown. This occurs quite frequently in white marble, granite and some limestone. Other common causes of discoloration of natural stones are:

A. Liquid ingress from top surface
B. Rising moisture from minerals contained in the natural stone
C. Contamination carried up from the mortar bed
D. Moisture from the grouting compound which discolours stone edges
E. Calcium hydroxide in the mortar bed which reacts and becomes calcium carbonate (known as efflorescence)
F. Moisture spots caused by freeze/ thaw activity

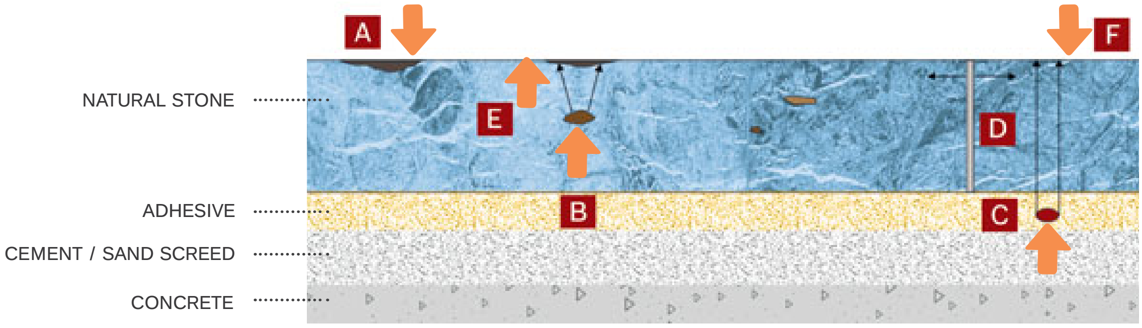


Fig. 7.1 – Common causes of discolouration in stones.

Fig. 7.2 – An illustration of pores structure in a natural stone.

- ***Porosity Vs Permeability Vs Absorption rate***

Porosity is the ratio of pores (micro-voids) in the stone to its total solid volume. Pores and the capillary structure develop differently in each stone group. In most cases, the porosity ratio is lower in igneous and metamorphic stones (granite) and generally higher in sedimentary types (marble).

Permeability is associated with the stone's porosity and the extent to which the pores and capillary structures are interconnected throughout the stone. Their size, structure and orientation affect the degree and depth to which moisture, vapours and liquids can be absorbed into the interior of the stone or migrate from the substrate by capillary action. Permeability may be greater in some directions than others based upon the pore size, shape and the distribution of the interconnectedness of the system. Permeability is increased when a stone is highly fractured or open veined. A particular variety of stone may be highly permeable although its porosity is low.

Absorbency is the result of porosity and permeability. Absorbency is an important determining factor in stones sensitivity to stains. The size of the pores, their orientation, how well they are networked and the type of finish the stone has are important contributing factors to the stone's overall absorbency. The polishing process has a tendency to close off most pores resulting in a low absorbent surface. However, some varieties of stone have large internal pores and capillary structures and they still remain very absorbent even after they are polished.

7.2 PURPOSE OF APPLYING IMPREGNATOR TO STONE

The purpose of applying impregnator is to prevent liquids seeping into the stone and staining it. However this process is quite different to sealing other floor types e.g. sealing of wooden floor which requires a protective coat to be applied to the top layer. But here, the impregnator penetrates into the stone surface and chemically interacting through the pores. This penetration then forms an invisible resistant barrier on the pores surface thus protecting the surface from staining and preventing fluids from penetrating through the pores. However, impregnators do nothing to protect the top surface from physical damages such as scratches and chips and also will not prevent "etching" from acid spills.

7.3 HOW DOES AN IMPREGNATOR WORK?

It is a subsurface treatment formulated to penetrate into stones which enhances resistance to stains. At the same time, it does allow the stones to breathe. This does not refer to the stone breathing is like what we do. Stone is made up of a variety of crystals. Each crystal is made up of different minerals. The minerals that make up the crystallized structure of the stone determine whether it is marble, or limestone or granite. To maintain the integrity of these crystals, they must interact with the air and hence they must be allowed to breathe. It is also essential that water that gets into the stone is able to evaporate by moving through these micro spaces.

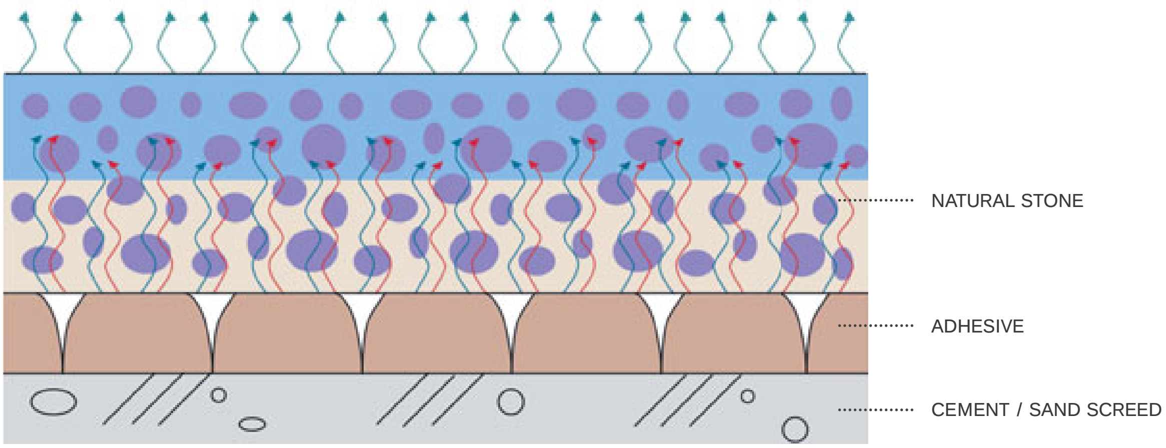


Fig. 7.3 – Stone without the application of impregnator. Possible salt entry from substrate.

Impregnators are a mixture of silicone and resins, and usually mixed with a mineral spirit which is a solvent. But some are water-based, depending on the manufacturer. The mineral spirit is added to the mixture because it acts as a carrier for the silicones and resins. The mineral spirit rides the resin and silicone into the stone in a liquid form. Later, the mineral spirit evaporates out of the stone and leaves the silicone and resin. The silicone and resin now begin to cure and forms a fluid repellent membrane in the pores of the stone. This all happens within five to ten minutes. However a complete curing requires usually 12 to 24 hours depending on the characteristics of the stone.

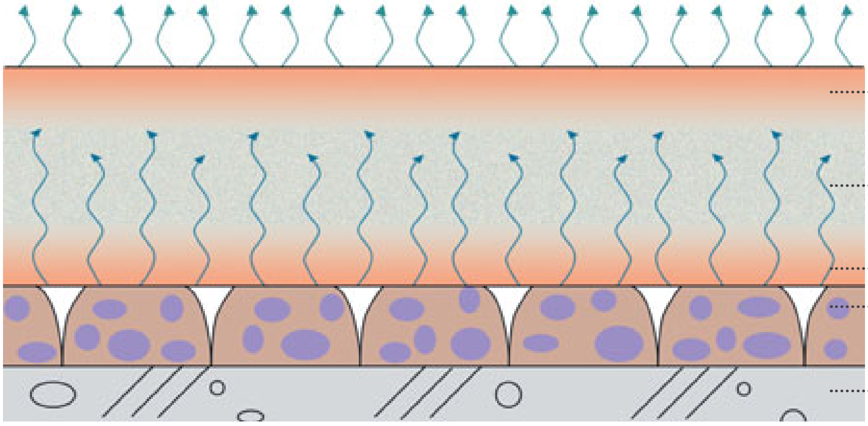


Fig. 7.4 – Stone with application of impregnator to six sides. The thin layer blocks salt entry but moisture may seep and evaporate.

7.4 TOPICAL COATING VS IMPREGNATOR

Coating creates a barrier and forms a protective film on the surface of the stone to protect it from foot traffic, soil, dirt, oil, and other stains. Mostly, they are formulated from natural wax, acrylic and other plastic compounds. Conversely, certain coatings may block "breathing capability" of the stone.

An impregnator penetrates below the surface and becomes repellent. They keep contaminants out but do not stop the moisture escaping from stone. Some impregnators have dual properties such as hydrophobic (water-repelling) as well as oleophobic (oil-repelling). However some solvent based impregnators are unfavorable to the environment as they can release volatile organic compounds (VOCs).

Fig. 7.5 – A topical wax coating on a marble floor, applied after the installation.

Fig. 7.6 – Applying penetrating sealer to marble before installation.

7.5 "SOLVENT BASED" VS "WATER BASED" IMPREGNATORS

The protection repellents come from silicones, silanes, siloxanes and various polymers, and they are carried into the substrate by carriers of either solvent or water. Typically, solvent-based products penetrate into stone quicker and deeper due to their low surface tension. The curing process which is a result of evaporation, can also be faster and adjusted using different solvents. On the other hand, water-based products are generally lower in toxicity and have little or no smell as compared to similar solvent-based products. However the difference in performance of these two carriers are getting narrower due to technological development.

7.6 HOW MANY LAYERS TO APPLY?

Applying thick coats of an impregnator is not always the answer to sealing stone properly. Usually, thin coats are sufficient. The reason is natural stone can only absorb up to a certain extent depending on the voids. Putting on too many layers may be ineffective. Some manufacturers recommend applying the "five minute rule" i.e. if the stone completely absorbs the first coat from the surface within five minutes, a second coat may be required. But if the sealer still remains on the surface after five minutes, no additional coat is required.

7.7 MEASURING THE STRENGTH OF THE IMPREGNATOR

A practical way to measure the strength of an impregnator is to apply liquid on the surface of the stone or soak into pigmented liquid and monitor the absorption. If the stone does not darken or change colour, it reflects that it is not allowing the stone to be penetrated. When selecting an impregnator, it should be noted that there is no single brand or product of impregnator that suits all stone types. The compatibility may vary from stone to stone depending on its characteristics. Therefore trial and error tests (either laboratory or field test) such as determining the absorption rate before and after applying impregnator, and a pull off test to verify the bonding strength with adhesives should also be carried out.

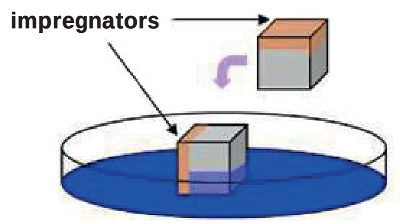


Fig. 7.7 – Soaking a piece of stone into liquid to test the effectiveness of the impregnator.

7.8 LIFE SPAN AND OTHER FACTORS TO CONSIDER IN CHOOSING IMPREGNATORS

The time it takes to break down an impregnator can be accelerated by certain conditions. For example, in a high-traffic floor area, the impregnator wears away as the stone surface wears down. This is because an impregnator only penetrates about 0.5 to 1.5 mm into a stone. Furthermore, though impregnators are transparent liquid; they may pose a slight risk of changing the appearance of the stone to a certain extent. Thus, it is sensible to carry on a sample test before starting actual application.

Also, impregnators serve only as a preventive measure that provide an extra protection to the stone against stains. Though the stone can be applied with superior impregnators, the stone still needs to be maintained with care. As the time goes, the ability to protect is also reduced due to its life span and other external factors. Hence, a periodic re-application is necessary and the interval should be based on manufacturer's recommendation, which should take into account of other factors such as traffic volume and abrasion resistance of the stone.

ENGINEERED HARDWOOD FLOOR 8

8 ENGINEERED HARDWOOD FLOOR

Fig. 8.1 – A typical section of engineered wood flooring strip.

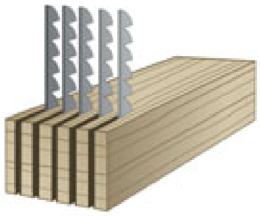


Fig. 8.2 – Sliced cut top layer hardwood veneers.

BACKGROUND

Engineered wood comprises multiple ply layers that are glued together rather than a monolithic solid piece of hardwood. The inner core comprises either a hardwood or soft plywood type material e.g. spruce, MDF (Medium Density Fibre), HDF (High Density Fibre), OBS(Oriented Strand Board), etc which incorporates a tongue and groove jointing system. The top thicker hardwood layer is glued on the top surface of the core and is available in almost any hardwood species. Generally the top layer hardwood is produced by a sliced cut. The thickness of engineered floor strips can be from 8 mm to 20 mm.

To create an engineered hardwood, the multiple ply layers are stacked one on top of the other with the grain of adjacent layers oriented perpendicular to one other. Once the desired thickness is achieved, the boards are then cut into the specified board width. By doing this, the engineered hardwood becomes less susceptible to the effects of moisture and temperature change and dimensionally stable, because wood expands and contracts in the width of the grain direction.

Fig. 8.3 – Engineered wood strips are generally more stable in dimension.

8.1 DIFFERENCE BETWEEN LAMINATE, SOLID HARD-WOOD AND ENGINEERED HARDWOOD FLOORS

Laminate flooring often looks like wood but it is not. It is made of melamine-infused paper glued to a wood chip composite. The prefinished top layer is a photographic layer that should appear identical to the product it replicates, be it wood, vinyl, tile, etc. The product is generally about 10 mm thick and is a floating installation with tongue and groove locking system.

Solid Hardwood is produced from solid natural wood species. The primary advantage of the system is good sanding and refinishing capabilities. The product typically is more pleasing aesthetically as they have natural look.

Engineered wood is not of full solid wood but created from multiple layers of veneer and lumber boned together with an adhesive. The top layer is genuine hardwood and the engineered components underneath make the flooring more stable. The flooring is available in many wood types and colors and generally comes with prefinished form.

8.2 FEATURES IN ENGINEERED WOOD FLOOR

a. Dimensional stability

Wood is a hygroscopic material. Its moisture compensation adapts to the humidity of its environment. This means that wood constantly adjust to its surrounding climate e.g. room temperature and room humidity, by absorbing and releasing moisture. Engineered hardwood flooring could withstand twisting to a certain extent as it is constructed using multiple ply planks. In addition to the top layer hardwood, engineered wood flooring typically has few more core layers at the bottom. The core layers may be plywood, high density fiberboard or others. The layers are placed alternating lengthwise and crosswise grain and this makes the strip dimensionally stable.

b. No grinding and varnishing

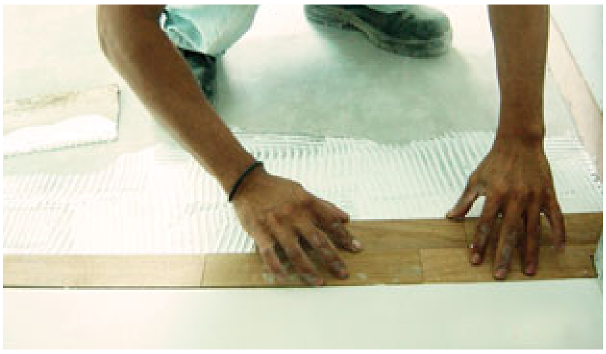
Engineered wood flooring is prefinished, often with durable finishes including UV-cured polyurethane and aluminum oxide for extra wearability. Using a prefinished floor means there is much less mess during construction and it is quicker to install. Often, the process of sanding and varnishing are time consuming and can affect other trades in construction. Apart from using less site labour and shorten the waiting period between processes, there will be reduction of toxic fumes and dust associated with sanding and varnishing operations. The pre-finished coats are applied by a mechanical system in a controlled factory environment, leading to a smooth and uniform finish surface.

Fig. 8.4 – The controlled factory environment provides a uniform coating on the surface.

c. Speedy installation

Due to the tongue & groove fit and better board dimensions, the installation can be done in an efficient manner. Installation can be done directly on a leveled concrete surface/screed using adhesives or a mechanical interlocking floating system. However it is important that the sub-floor must be level. This is to avoid unevenness on the pre-finished timber floor surface. As curing time and several sanding and varnishing operations are eliminated, this helps to save considerable time in construction, particularly in large scale projects.

The table below shows the number of steps involved in the installation process of traditional solid floor and engineered wood floor.

	Sequence of solid timber floor installation	**Sequence of pre-finished engineered wood floor installation**
STEP 1	• Apply adhesive. 	• Apply adhesive or mechanical Interlocking floating method. 
STEP 2	• Installation with tongue & groove. 	• Installation with tongue & groove, and completion. 
STEP 3	• Core sanding (after 14 days Curing). 	
STEP 4	• 2nd Grinding. 	

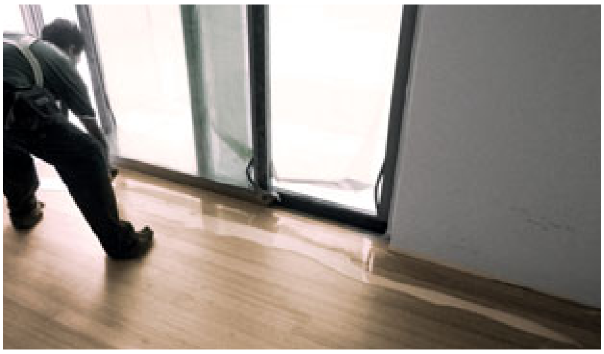
	Sequence of solid timber floor installation	Sequence of pre-finished engineered wood floor installation
	• Apply filler.	
STEP 5		
	• Curing and fine sanding.	
STEP 6		
	• Apply varnish and completion.	
STEP 7		

Fig. 8.5 – Sequence of installation of solid wood and engineered wood flooring.

8.3. TYPICAL QUALITY ISSUES IN TIMBER FLOORING

a. Open Joint

The most frequent issue posed by timber floors in the tropics is open joints. The predominant cause is that wood is sensitive to variation in humidity and temperature and consequently susceptible to deformation. Other reasons include dimensional variation of the timber strip, unskilled installation, moisture level of the material and substrate, etc. Use of small size timber strips is also a factor as it requires more number of pieces to be joined together to construct a floor. The increased joints are more prone to expansion and contraction in a solid timber floor.

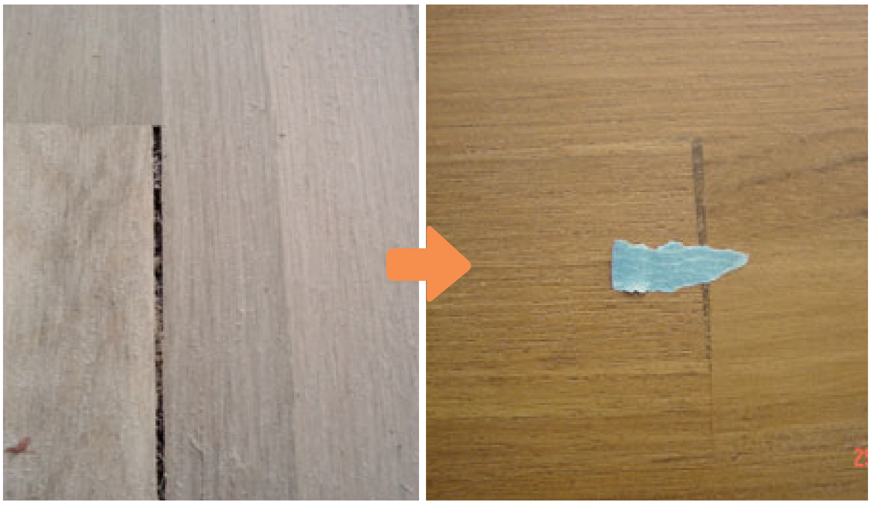


Fig. 8.6 – Open joint in timber floor is the most common issue in the tropics.

b. Nail-hole mark

Nail-down is required when laying timber strips to avoid movement and to secure tight joints in between the strips, especially where the installation is directly on the screed. These nails are removed only after the day of installation. Frequently, the nail holes are patched with timber putty during the first sanding and varnishing stage. It is also not uncommon that improper fillings or discoloration of filling materials affect the aesthetics of the flooring.

Fig. 8.7 – Nail-hole marks and patch-up often undermine the aesthetics of flooring.

c. Unevenness due to over sanding

Apart from undulation in the sub-surface, poor control of sanding on a single spot by unskilled work during the grinding process is another root cause for unevenness in the timber floor surface.

Fig. 8.8 – Poor control in the sanding process may also lead to unevenness in the finished surface.

d. Inconsistency in varnishing

The uniformity of on-site varnish depends on many factors like skill level of the worker, surface condition of the floor and the surrounding environment. In mass production, i.e. for large scale projects, it may not be possible to ensure all workmen posses the same level of skill. As a result, the quality outcome is likely to be inconsistent.

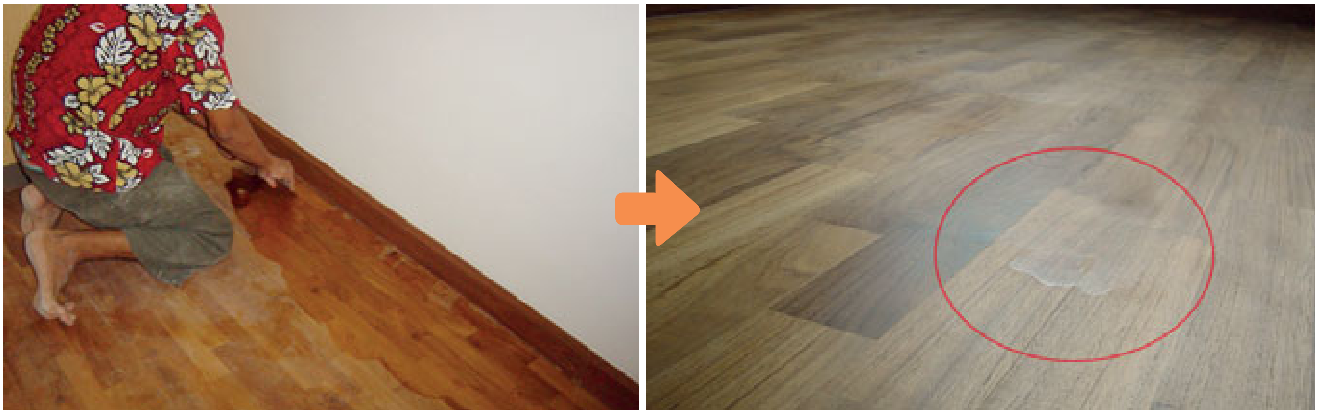


Fig. 8.9 – Consistency of varnishing is likely to vary in manual application.

8.4 CONSIDERATIONS IN SELECTING THE TOP LAYER HARDWOOD FOR ENGINEERED FLOORING

The rigidity of engineered wood floor depends mainly on the top layer of the hardwood veneer. The top layer of hardwood can withstand wearing and dents depending on its Janka hardness rating. The higher the rating, the harder is the species of wood. It also indicates the effort required in sawing the wood. The following are some of the most popular hardwood species used in flooring along with their respective hardness ratings according to the Janka hardness rating.

Other than the selection of top layer hardwood, the choice of core layers and adhesive system is also equally important. For example, if the intended area is prone to moisture, the core material should be HDF board which has better moisture resistant property. Silicone based adhesive system generally performs better than water based glue particularly in terms of bonding and shrinkage. Also, it can bridge over small undulations in the screed to achieve a better level surface.

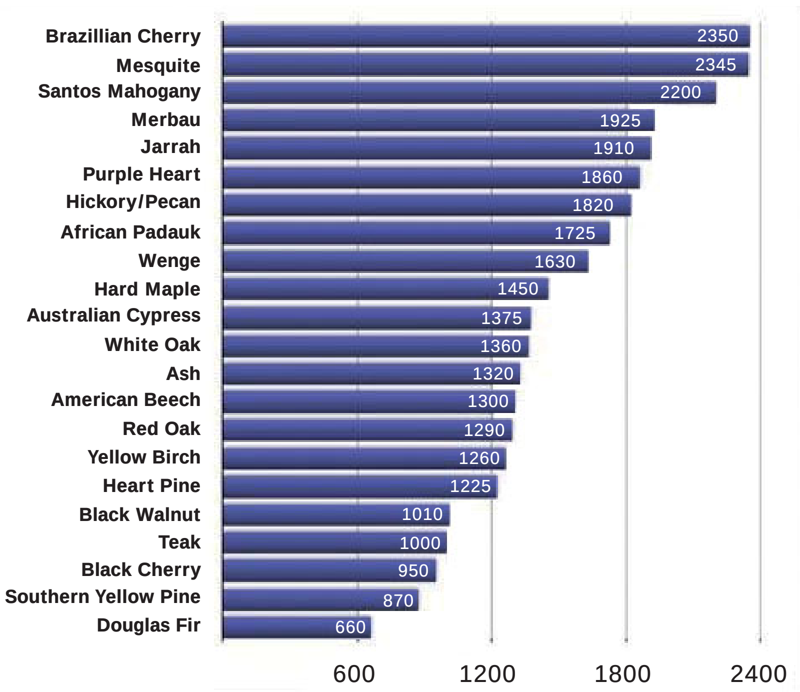


Fig. 8.10 – Janka hardness index for popular hardwood species.

8.5 LIMITATIONS IN ENGINEERED WOOD FLOOR

The top layer in engineered wood flooring is only about 3 to 6 mm thick hardwood, and can be fine sanded for revitalization of surface coat, but not to level the surface. Unlike solid hardwood, deep scratches and dents in engineered wood cannot be ground out by a machine without affecting the integrity of the flooring. Engineered wood floors come in a wide variety of domestic and exotic hardwood species and some brands have a very thin wear layer, that can only be re-coated and cannot be sanded and refinished again once they get worn. However replacement can be done for critically damaged strips by removing and changing the affected strips. Like any other type of wood flooring, engineered wood floor can also be damaged by excessive moisture and adverse weather. Consequently, it is not recommended that the flooring be installed in wet areas like baths or kitchens.

FILLERS FOR REPAIR AND REINSTATING STONE AND TIMBER 9

9 FILLERS FOR REPAIR AND REINSTATING STONE AND TIMBER

BCA's quality standards encourage "Do it right the first time" so as to eliminate subsequent rectification works. However in typical construction processes which require co-ordination of many architectural trades, minor chips and scratches on vulnerable materials like stone and timber cannot be completely avoided. Also, when replacing materials such as natural stones, other undesirable consequences like tonality difference, damage to adjacent stonework, etc. can occur. Rather than replacing a complete section of the works due to "minor" damages, precision repair using compatible fillers could be an alternative way out.

Fig. 9.1 – Stones are prone to minor chips and scratches during construction. Replacing it can have consequences like tone difference, wet polishing and others.

9.1 FILLERS & TOOLS FOR NATURAL STONES

Natural stone has its inherent beauty and versatility. Although hard, it is still susceptible to accidental damage like scratches and chips. As they are made up of crystals, there are many challenges when repairing them like matching the colour, texture, and bringing out the three dimensional reflective effect as in the original condition. **Generally, there are two available methods of rectifying minor chips and damages on natural stones, viz.**

1. Using epoxy resins with stone chips
2. Using modified wax fillers

a. Epoxy filler method

The first step in repair work is to remove all foreign and loose materials from the surface. This is to facilitate proper bonding with glue. During this process, two precautions must be taken. First, ensure there is no excess glue as it may stain the surface after it has hardened. Second, sufficient pressure must be applied for a sufficient duration to ensure a perfect joint with the adjacent surface.

To get the reflective effect as close to the original, flakes from the same stone can be mixed with the resin. However, the ratio of flakes, resin and hardener should be calibrated by trial and error to best imitate the shade of the stone. Once the glue is cured, the surface should be dry polished with a range of sanding pads (from rough to fine grit) to create a perfect joint with the adjacent surface. Finally, to bring back the shine, localised wet polishing should be made with the slurry of polishing powder and a fibre pad.

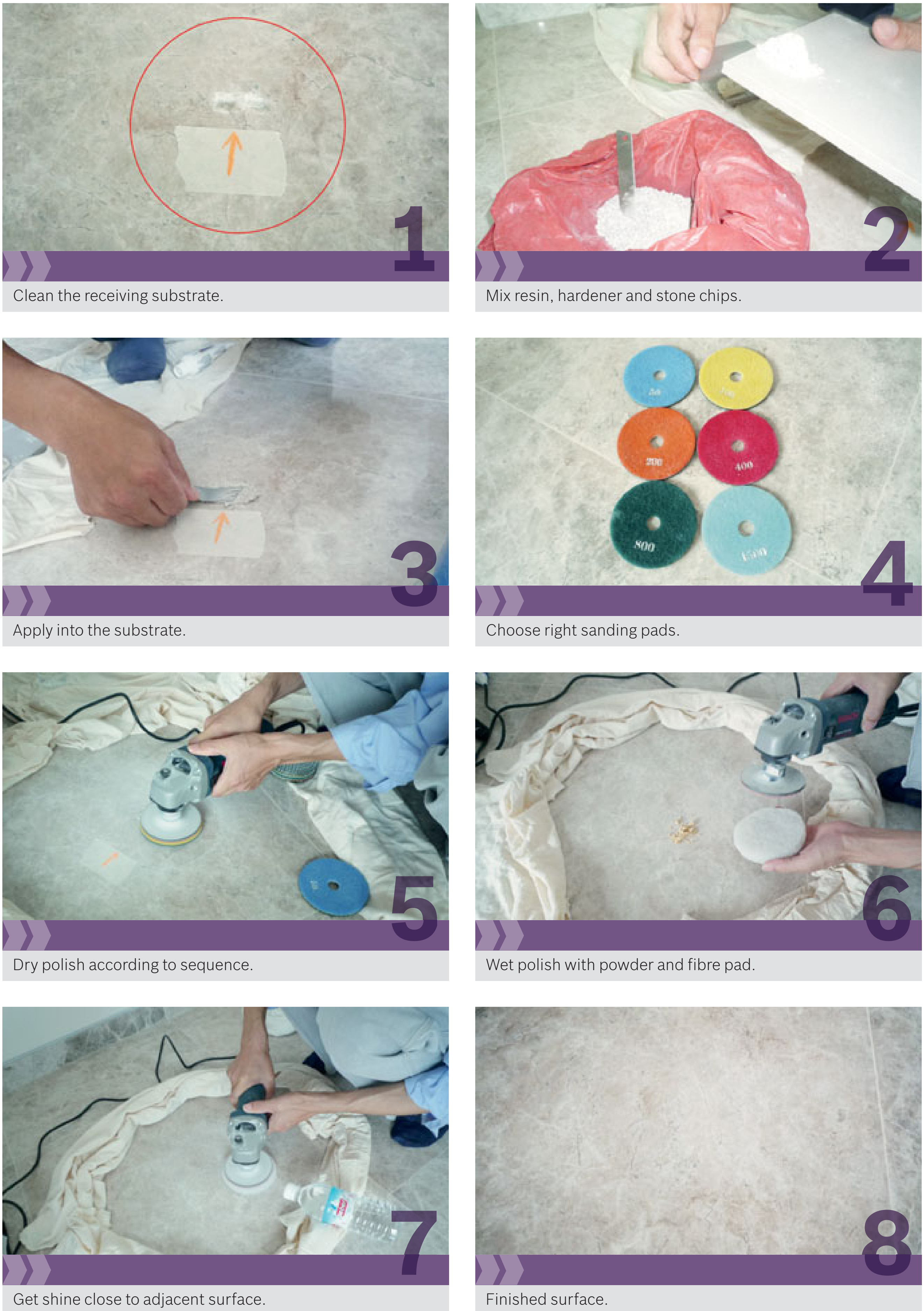


Fig. 9.2 – Sequences in marble rectification using epoxy fillers.

Flowing veins and reflective effect are the natural characteristics of stone. Regardless of perfection in the touch up skill, a very slight distinction can be seen while having a very closer look. If rectification is carried out without inclusion of stone chips, this may cause the surface to have a patchy or artificial look. Further, unskilled localized polishing may result in a "blurred effect" and the surface may not blend with the adjacent surfaces.

As there are many varieties of fillers and resins available in the market for repairing stones, it is important to select compatible materials used in accordance with the manufacturer's instructions. With the right choice of resin, application skill and time, this will ensure the repair work matches the surrounding finish and is durable.

Fig. 9.3 – Fillers without stone chips may not achieve reflective effect of original condition.

b. Modified wax filler technique

The use of modified wax-based fillers and associated material is another alternative repair method for reproducing stone and timber surfaces. These fillers and special applicators not only refurbish the damaged surface, they also aid to reinstate the strength of existing surfaces. Generally, the hard wax fillers have a melting point of 130°C and the colours can be blended well, such that the tonality of the repair work can be graded closely to resemble the original surface finish.

The coloured fillers are embodied in a transparent liquid, which helps to bring back the reflective surface close to the original and it can be applied directly on the surface. Besides that, the adhesion promoter is integrated into the fillers, so a primer is not required before applying the fillers. For glossy faced natural stones, special mica fillers can be blended with the colour fillers to produce a glossy effect.

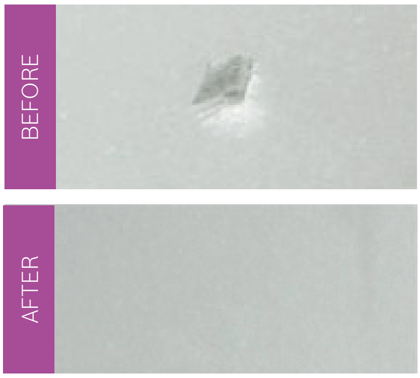
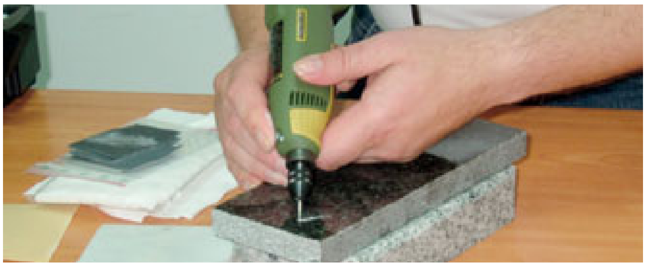


Fig. 9.4 – Before & after rectification of natural stone surface.

Light curing technology for natural stones

The main purpose of illuminating the fillers with an LED light source is that the liquid composite materials can be hardened in a few seconds. The combination of colour fillers and crystalline particles enable the user to create the surface close to the original shade and reflective effect that closely resemble natural stone. The integrated fixative components can be used on granite, marble, engineered stones and tiles. In addition, using appropriate tools such as planer and micro sanding paper, etc. help to achieve better repairs without marring the neighbouring stone surfaces.

Fig. 9.5 – LED lighting with applicators for natural stone.



The substrate has to be dry at room temperature. If necessary, pre-heat. The area should be wiped with cleaner and allowed to dry for approximately 30 seconds.

1

Apply liquid transparent and fillers to the area and place a plastic film and press lightly.

2

Shine the LED power light onto the filler approximately for 30 seconds per cm^2. The power light will switch off automatically after 30 seconds.

3

Make short and quick movements with the planer to strip off excess material. For marble surface, it is recommended to use cuttlebone instead of planer.

4

Use micro sanding paper 2400/3200/4000 with a little water and apply polishing paste. Use the handy polishing machine to achieve the perfect level and shine.

5

Finished surface is close to original surface with reflective effect.

6

Fig. 9.6 – Sequences in natural stone rectification using wax fillers.

9.2 FILLERS & TOOLS FOR CERAMIC TILES

The process of repairing ceramic surfaces is simpler compared to natural stones as ceramic tiles generally do not have three dimensional reflective effect. The fillers for patching damaged tile surfaces are generally harder than hard wax and they have a high melting point. There is a wide range of colours available for fillers and they can be mixed well to match the surface. Due to its hardness, the fillers also suit matt rough external stone floorings. The tools such as planer with metal blade should be used for careful stripping and levelling to replicate the appearance of the original surface.

1 **Preparation**
The area to be clean and dry.

2 **Filling**
Hot knife tip to apply the ceramic fillers.

3 **Leveling**
Transparent planing applicator to level the surface.

4 **Cleaning**
Clean surface to see the colour effect.

5 **Fine sanding**
Fine sand surface to get the smoothness.

6 **Colour adjustment**
Special lacquer pen tip to fine-tune the colour and pattern.

7 **Gloss sheen**
Fibre cloth polishing to bring back the close match.

8 **Final Finish**
Close match.

Fig. 9.7 – Sequences in ceramic tiles rectification.

9.3 FILLERS & TOOLS FOR REPAIRING TIMBER SURFACES

Refurbishment of timber surfaces (both natural and artificial) requires special attention to retain its beauty and strength of the surface. Matching colours with the existing shine and grain patterns are the most challenging part in this process. **There are two methods of rectification, viz.**

1. Timber putty with colour pigments
2. Modified wax fillers

a. Wood putty method

Wood putty is a substance used to fill imperfections, such as nail holes, minor scratch and damages on natural and artificial timber surfaces. It is often composed of wood dust combined with binder and pigment. It is advisable to keep more than one colour on hand while trying to match the wood shade; having a variety of colours available allows to mix up just the right shade. The filling should be slightly higher than the surface, as the putty tends to shrink. Once it is dried completely, the area should be sanded with a fine sand (abrasive) paper to achieve the level and smoothness before applying the stain or paint as desired.

Fig 9.8 – Timber putty and colour pigments.

Dented veneer surface.

Clean and sand the surface.

Keep variety of colours to close match the surface.

Fill the dent with putty.

Sand the area with a fine sand paper.

Blend colour pigments to get close match.

Apply the right stain on the surface.

Apply a coat of lacquer.

Finished surface.

Fig. 9.9 – Sequences in veneer surface rectification using timber putty.

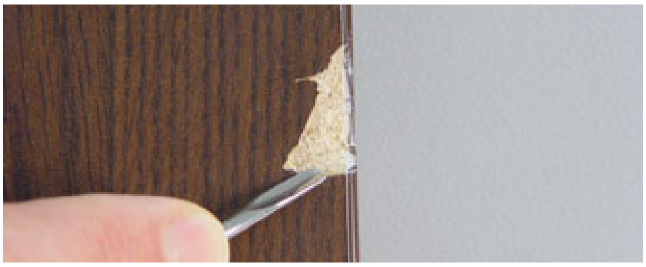
It should be noted that wood putty often comes in handy when repairing wood. But, at times, the putty itself can cause problems when it is improperly applied or lack of skill on colour matching makes unsightly blobs on the surface. Furthermore this material and method is suitable for only minor repairs as it does not "reinstate" the damaged part of the timber.

b. Modified wax filler method

Wax fillers are available in stick form in a range of timber colours and can be blended with pigments to create many different shades. They can be used to rectify scratches and dents in the timber surfaces including pre-finished melamine boards. The choice of wax fillers is also determined by the severity of the damage i.e. from minor to intense. The following table shows some of the filler characteristics and their use for timber and artificial surfaces:

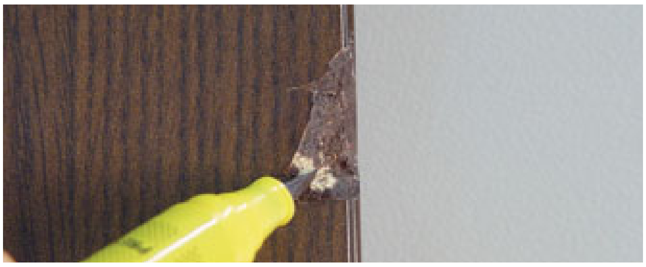
Fig. 9.10 – The broad range of fillers and lacquers for repairing timber surfaces.

1.Quick fillers	Easy to apply and use for small scratches.
2.Soft wax	Soft, easy to apply with the applicator and use to fill nail holes and cracks.
3. Hard wax	Hard, only to be applied with heat and should be stripped off with special applicator. Use for medium range damage.
4. Hard wax PLUS	Very hard, only to be applied with heat. Mainly for furniture with severe damage.
5. Rex-Lith	Two component fillers for repair to locations subject to very severe damage such as wrenched out hinges or locks.
6. Acrylic Lacquer	To match sheen and where more hard-wearing and weather resistance are required.



Remove all loose particles and clean the surface. Cut damaged edge and straighten down with edge planer.

1



Pre-colour the substrate with covering lacquer brush pen corresponding to the adjacent area.

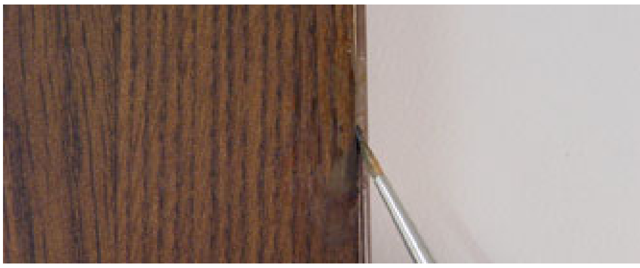
2

Choose several colour shades of hard wax plus corresponding to the surface. Let colour wax mixture flow into the damage in the direction of the grain.

3

Remove surplus wax with special filler applicator.

4



Make an intermediate sealing by misting with special repair lacquer PLUS from a distance of 30-40 cm but do not spray too wet. Restore the grains with touch up paint and a marten brush.

5

Seal the filled damage by misting with lacquer PLUS.

6

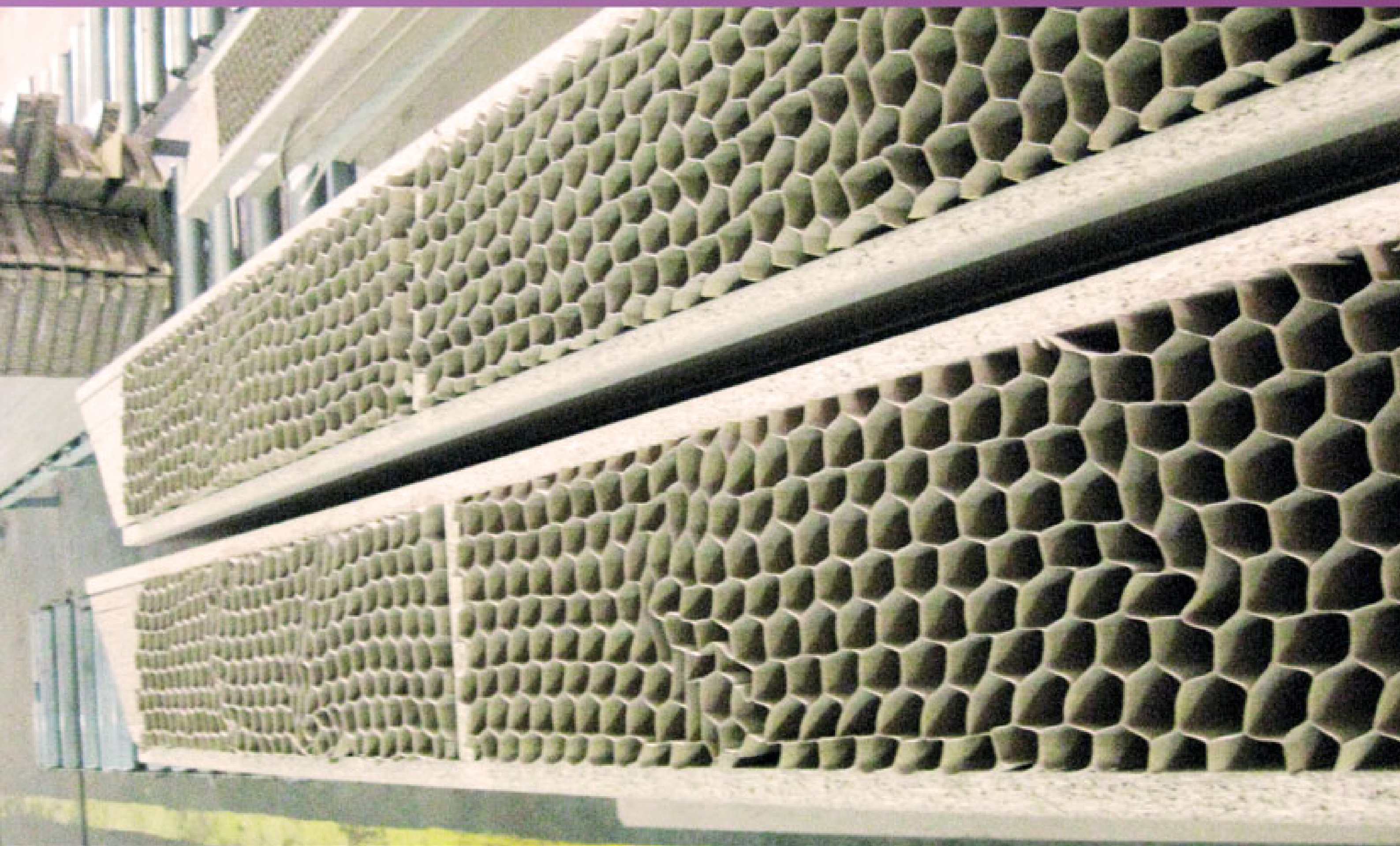
Fig. 9.11 – Sequences in rectification of veneer surface using wax fillers.

9.4 LIMITATIONS AND CONSIDERATIONS

To ensure repairs are carried out to the highest possible standard, it is essential that the correct techniques should be used. Good application skills and understanding the range of products and tools are vital if the user is to maximise its potential. While intending to try with new products like wax fillers, it is strongly recommended to attend the hands-on training and short courses by the product specialist before using the product. Matching of colours may require some trial and error tests to get close to the original surface colour. Therefore it may take a longer time to learn and apply the techniques initially but with continued practice and experience, the pace and quality of touch up should improve.

While wax fillers can be employed to achieve precision repair, the cost of such repairs, its durability and compatibility should also be considered. Wherever possible, the works should be carried out getting it right the first time. This will limit the extent of costly repair works to minor scratches and damages. Where damage is severe, extensive or in prominent locations, it may be more cost effective to replace the whole section of the works instead of repairing it.

HONEYCOMB TIMBER DOOR AND INTEGRATED ARCHITRAVE FRAME 10



10 HONEYCOMB TIMBER DOOR AND INTEGRATED ARCHITRAVE FRAME

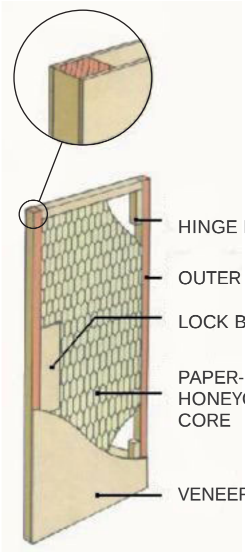


Fig. 10.1 – A typical section of hollow core timber door.

10.1 BACKGROUND

Hollow core door comprises a framed door in filled with structural paper formed into a honeycomb pattern to provide support and rigidity which is glued in place between the door skins. As there are no solid materials within its frame, these doors are lightweight and are an affordable alternative to solid core timber doors. The door surface is usually wrapped with veneer to achieve a uniform appearance. Often, the veneer is sanded and varnished to create a striking appearance. However, hollow core doors are not suitable for exterior use for safety reasons as they are easy to break.

Honeycomb paper

The honeycomb shaped inner core material is made from layers of paper or cardboard, bonded together in parallel and uniformly spaced. When it is expanded for use, it forms a honeycomb configuration with hexagonal cells. It is manufactured from recycled paper and generally is non-toxic. The honeycomb sheets can be made of various thicknesses and cell sizes to cater for a variety of applications. It can replace the solid filling materials used in solid core doors.

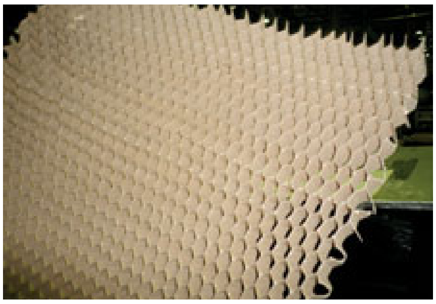


Fig. 10.2 – Honeycomb structure enhances resistance to perpendicular crushing forces.

The following are key features of honeycomb in-filled timber doors or panels:

- Light weight and easy to handle
- Less hinges needed for hanging panel
- Suitable for lift-off hinges door system
- Allows flexibility in design and shapes
- Possible to make tall and thin panel
- Economical
- Produced from recycled paper

10.2 CAUSES OF WARP AND TWIST IN TIMBER DOOR PANELS

“Warp" is any distortion in the panel itself and does not refer to the relationship of the door to the frame or jamb in which it is hung from. Warp is mainly due to timber expansion and contraction caused by temperature and humidity changes. The term "warp" also includes bow, cup, and twist, and they are measured by the deviation from a straight-edge or string placed on the suspected face of the door at any angle (i.e. horizontally, vertically, diagonally) with the door in its installed position. The chances of warpage are higher in longer panels, because of its higher length to width ratio.

Fig. 10.3 – Warp or twist are caused mainly by expansion and contraction of timber.

Occurrences of warp and twist can be minimized with infill like honeycomb papers, especially for tall panels. During the production stage of the honeycomb paper, moisture content is about 14% (8% from paper, 6% from glue). This can be reduced and its pressure strength increased through an expander cum dryer in the manufacturing process. The highest pressure strength can be achieved at 3% moisture content.

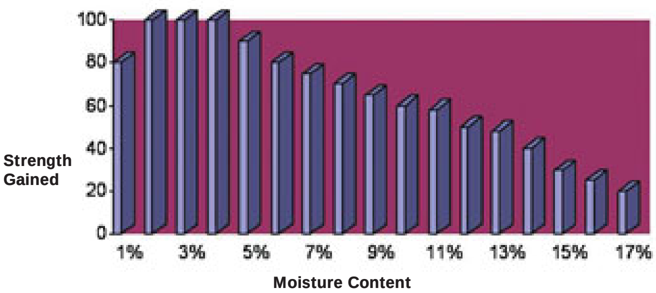


Fig. 10.4 – Relationship between moisture content and pressure strength.

Fig. 10.5 – Honeycomb papers stretched mechanically and dried to achieve the desired strength.

Fig. 10.6 – Tall and thin panels are possible using honeycomb infill.

Fig. 10.7 – Hollow core door suitable for lift-off hinges door system because of its light weight.

10.3 MANUFACTURING PROCESS OF HONEYCOMB INFILL DOOR PANEL

Form a skeleton by solid timber.

Stretch and dry honeycomb infill.

Fasten infill into frame.

Cover frame with veneer board.

Sand and varnish veneer surfaces.

Install ironmongery.

Fig. 10.8 – Key steps in the manufacturing process.

10.4 INTEGRATION OF DOOR FRAME AND ARCHITRAVE

Fig. 10.9 – A typical cutting profile of timber architrave.

An architrave is a piece of timber that covers the gap between the door frame and the wall. When the frames are fixed on the door opening, a joint is formed between the timber and masonry. Since timber and masonry do not bond well due to dissimilar expansion and contraction properties, the architrave serves to cover the cracks or gaps between the dissimilar materials.

Typically, the architrave mitres will need cutting to 45 degree profile in order to align with the main frame. They are fixed to the main frame using nails. This process of cutting, assembly and fixing is often carried out on site. If the works are carried out on site, quality issues such as misalignment of architrave, exposure of nail holes, or non-matching timber putty colour can often occur due to variation in the skill level of trades men or other constraints.

Further, the works consist of three separate operations i.e. installation of sub-frame followed by main-frame and finished with the architrave. This will require close monitoring, coordination and added time to the process.

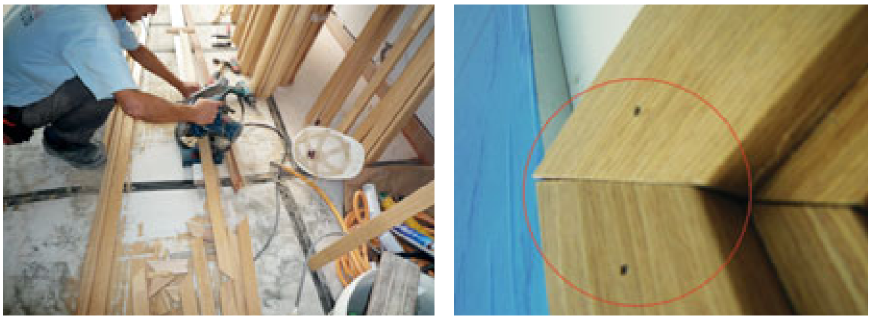


Fig. 10.10 – Misalignment of mitre joints and visible nail holes in traditional installation.

The quality issues posed by the traditional 3 stage installation process can be minimized by using an integrated door frame and architrave system where the architrave is preassembled and fastened together with the main frame at the factory. The members are secured with glue and concealed nailing. Thus, no nailing is required during site installation resulting in better consistency in workmanship. It also eliminates onsite manual effort and expedites the installation process.

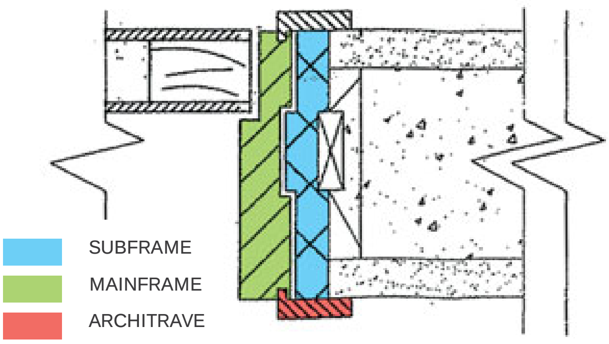


Fig. 10.11 – Three stage process in traditional installation.

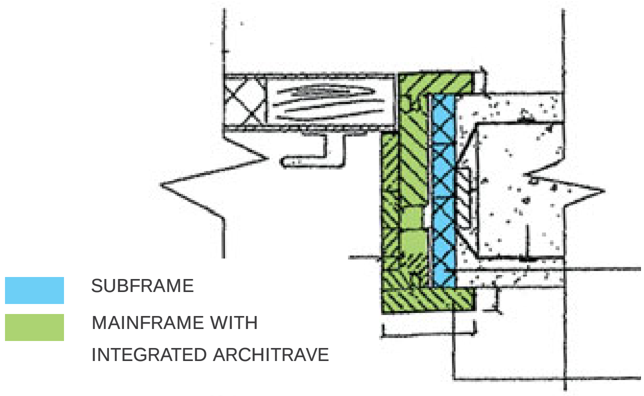


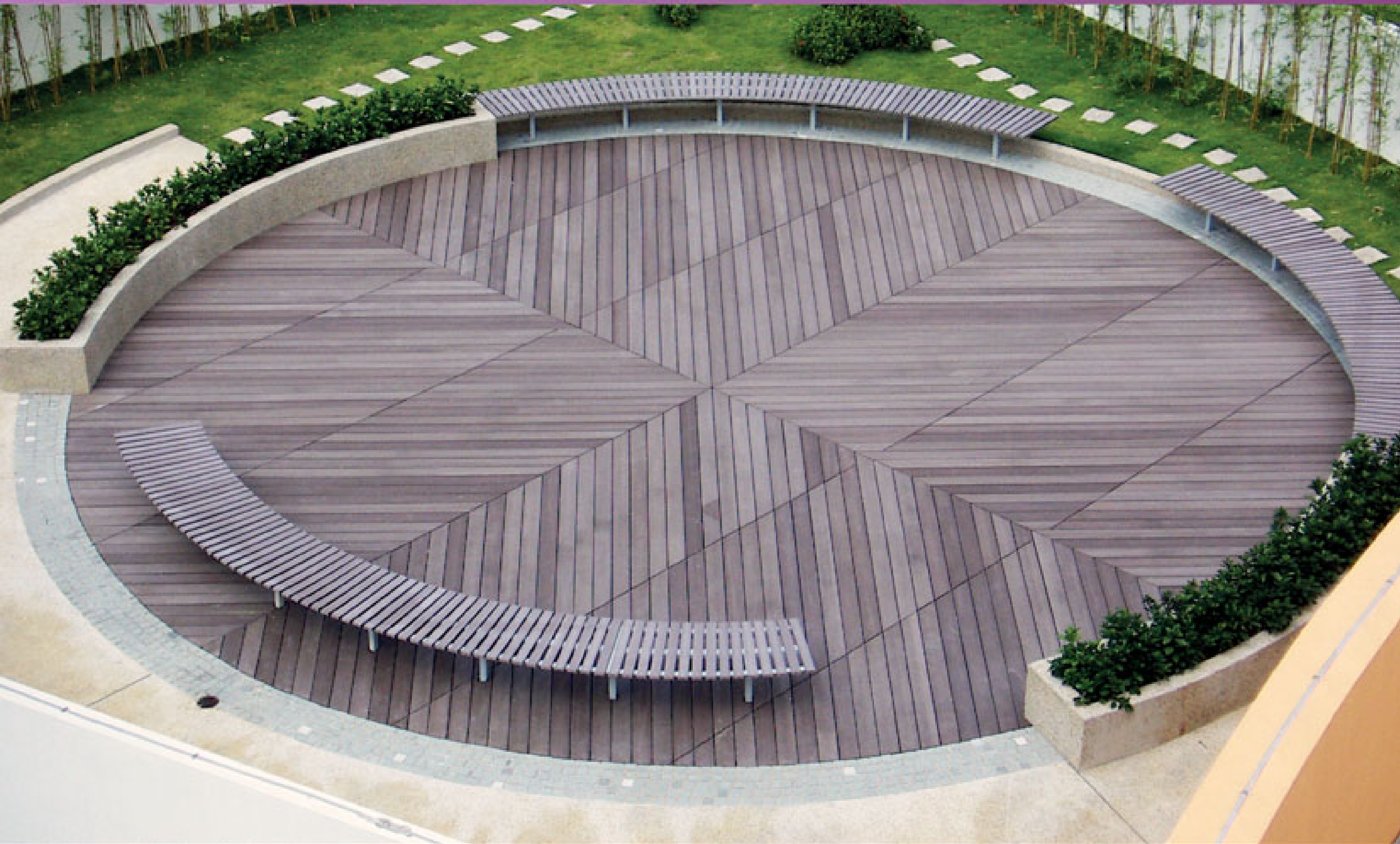
Fig. 10.12 – Two stage process in integrated frame method.

Fig. 10.13 – A typical installation process using integrated frame and architrave.

10.5 SUMMARY

As door is one of the important components in a building, the selection criteria on the type of door to be used should be based on needs as well as performance. Each door system has its merits, limitations and differences in performance. For example, although solid doors are much heavier, they are stronger than hollow core doors and close with a more "solid" feel. It is also important to note that the ultimate performance of any type of door not only depends on the aesthetics but also the supporting accessories and adjacent works.

COMPOSITE FIBRE PLASTIC MATERIAL 11



11 COMPOSITE FIBRE PLASTIC MATERIAL

Natural wood has certain qualities that predispose its use in buildings, especially in outdoor applications. It is used in decks, docks, railings, porches, garden benches, walkways, stairs, pool surrounds and many other outdoor settings because of its strength, elegance and natural appearance which are aesthetically pleasing.

Unfortunately, due to wide-spread deforestation, there are not many tropical forests left to meet the demand for natural wood. Further, the durability of natural wood, which is defined as resistance to decay and insect attack, is affected by its surrounds e.g. swimming pool decks which are constantly wet. Consequently, they need to be treated and periodically maintained against fading, moulding, cracking, splintering and rotting.

Fig. 11.1 – Elegant and strong natural timber requires periodic maintenance to maintain its durability.

As an alternative to natural wood, composite fibre plastic material offers a practical middle ground and can be used to replace timber in some applications. Due to its inherent characteristics such as resistant to weather, moisture and termites and low maintenance, they are increasingly used widely in many applications as a substitute for natural wood. However, composite materials are not load-bearing or structural members and they are not as strong as traditional hardwood.

Fig. 11.2 – Composite material for outdoor use in some applications.

11.1 BACKGROUND

After years of continuous research and development, the base polymer from PVC was discovered as a suitable material that shared the same or closely similar physical characteristics, mechanical properties and workability as timber hard wood.

The composite fibre plastic material is made from a combination of organic fibre (e.g. rice husk or other similar materials) and post-consumer recycled plastics, which have different mechanical properties within the finished structure. The benefit of this composite technology is twofold: the polymer shields the organic fibre from moisture and insect damage, so there is no rotting or splintering. And the fibre protects the plastic from UV damage and gives a solid, natural feel.

11.2 HOW ARE THEY MADE?

The first step in composite fibre plastic fabrication is called compounding, where organic fibres are blended with inorganic recycled polymers. The percent of fibre used in this step is very important as it directly affects the tensile strength and Young's modulus of the end product. Additives are also added in small amounts to enhance its properties. For example, lubricants improve surface appearance and processing, and coupling agents improve adhesion between the fiber and polymer compounds. The powder is blended to dough-like consistency and then extruded to the desired shapes by extrusion and injection moulding.

Organic fibres.

Selected post-consumer recycled plastics.

Blending.

Powder form.

Processing & extrusion.

End product.

Fig. 11.3 – A typical production cycle of composite fibre plastic material.

11.3 PHYSICAL AND MECHANICAL PROPERTIES

S NO	CHARACTERISTIC	TEST METHOD	VALUE
1	Tensile strength	ASTM D638	27 mpa
2	Elongation	ASTM E638	1.9%
3	Flexural strength	ASTM D709	13.8 KN
4	Fire resistance	BS 476, part 7	Class 1
5	Water absorption 24 hour	ASTM D1037-93	Change in wt : 1.02 % Change in Dimension: 0.5%
6	UV resistance after 500 hour	ASTM D4329	1.5%
7	Coefficient of linear thermal expansion	ASTM D696	3.6x10-5 m/m/0C

**The above values are indicative only. The actual values may vary from one manufacturer to another and also depend on the proportion of raw materials used.*

11.4 CHARACTERISTICS OF COMPOSITE FIBRE PLASTIC MATERIAL

The primary use of this material is for external works such as decks, trellis, screen walls, garden furniture, etc. The following are the key characteristics of the material.

Durability

The life of composite materials is generally longer . Although some variety of composite materials can be costly than solid wood, this is often balanced by reduced costly maintenance and less frequent replacement due to rotting and splintering.

Appearance

The material is also popular because of its uniform appearance and consistency in pattern. The synthetic material is manufactured from the “right proportion” of mixed substances, and thus each board has the same appearance as the next.

Moisture resistance

The plastic content in composite decking makes it less susceptible to moisture, which would normally cause wood to expand and contract. This characteristic reduces wear and tear and prevents warping. The synthetic material also protects the surface from decay caused by prolonged exposure to weather.

Resistance to heating and fading

Typically the material is treated with UV stabilizer and hence has better resistance to heating and fading. The added preservatives and colorant keep the uniform appearance and prevent the deck from fading to some extent.

Design flexibility

One of the advantages of composite material over wood is its ability to be moulded to meet special shapes and sizes. It can be extruded to make continuous profiles of desired cross-section with better dimensional consistency and accuracy. It also behaves almost like wood and can be shaped using conventional woodworking tools. Staining is not necessary but colour can be applied, if desired, for aesthetic reasons.

Environment

The material can be considered as environmentally friendly because it uses recycled plastics. It can also be recycled completely, and processed without any significant deterioration in performance.

Low maintenance

They do not require frequent staining, sealing and other additional treatments. Decks can easily be cleaned by normal sweeping, hose or water jet occasionally.

Fig. 11.4 – Versatile composite material for outdoor applications.

Fig. 11.5 – Use of extruded members leads to consistent profile and dimensions.

11.5 LIMITATIONS AND OTHER CONSIDERATIONS

- Composite materials are not load-bearing or structural members and they are not as strong as traditional hardwood. That is why some brands of composite wood decks are still dependent on using a hardwood base to keep it structurally rigid.

- Adequate support, space between joists, fastening method, gap between boards, length of board and end profile are important parameters to consider when using composite materials. The manufacturer's recommendations on the method of installation should be followed closely. Any local codes or other requirements should also be complied with.

- For decking, stiffness of the flooring is an important consideration. Joists for solid wood decking are usually spaced at 600 mm intervals. For composite materials, this spacing should be reduced to get better stiffness. This may increase the cost of the flooring.

- Although composite materials are manufactured with UV coatings, adverse effects of UV radiation may still affect the surface. The hardness of the surface is also not as good as hardwood. Thus the surfaces tend to be damaged or scratched under normal wear.

Fig. 11.6 – The soft surface is prone to scratches and wear.

- Not all composite decks are made in the same way. As there are a number of manufacturers worldwide, the quality of the end product and their characteristics may vary from one manufacturer to another. So, it is important to check with the suppliers and verify the test reports before proceeding to use the material.

WATERPROOFING OF REINFORCED CONCRETE FLAT ROOF 12

12 WATERPROOFING OF REINFORCED CONCRETE FLAT ROOF

12.1 BACKGROUND

Most roofs in Singapore are constructed using reinforced concrete which is known to have pores or capillary tracts. Depending on the designed strength, density and installation techniques, the number of pores can vary. These pores are interconnected within the concrete and water will penetrate through such capillary tracts aided by osmotic effect.

Concrete is known to be inherently weak in tension; cracks and voids can also form due to thermal expansion, contraction and shrinkage. As a result, water will seep through these voids. Therefore, waterproofing is required to keep the roof water-tight since they are exposed to the weather.

Fig. 12.1 – Application of liquid-applied membrane using roller.

12.2 DESIGN AND CONSTRUCTION OF FLAT ROOF

The proper design of falls in a flat roof is an essential consideration in the overall drainage of the roof. Falls create flow paths to direct the drainage of rain-water away from the roof to suitable discharge points. To be effective, it is essential to clear surface water as rapidly as possible from the flat roof to avoid ponding or stagnation of water on the roof itself.

Waterponding on a flat roof is a prime cause of deterioration because variations in temperature between wet and dry areas of the roof can cause differential thermal movement. Together with the accumulation of acids left by evaporating rain, this would cause a breakdown on the roof surface. In general, a minimum fall of 1 in 80 will help to prevent ponding of water.

During construction, precautions must be taken to prevent excessive moisture from being trapped between the reinforced concrete roof structure and membrane. This is one of the common causes of flat roof waterproofing failure. Large amount of water vapour can evaporate from reinforced concrete or a wet screed. Once the waterproofing membrane is laid, drying out of the structural slab will mostly take place from the underside of the deck. Cross ventilation beneath the deck is usually quite restricted due to erected partition walls. Any trapped moisture subjected to increased temperature from the sun will form vapour which will exert itself directly beneath the waterproofing membrane. If this vapour pressure is not released or vented sufficiently, the build-up pressure will begin to form a blister on the membrane itself and residual dampness on the underside of the roof. When the waterproofing membrane has suffered an irreversible stretch, subsequent cooling will not *cause the air pocket to return to its original size*. Therefore, if a dry surface cannot be achieved within a reasonable period of time, direct membrane adhesion should be postponed or an alternative method of laying should be considered.

12.3 ROOF MEMBRANE SYSTEMS

The waterproofing membrane is considered to be most important component of the roofing system as it serves the main function of keeping water out of the building. Below are some common roof waterproofing membranes used locally:

a. Liquid-applied membranes

Liquid-applied membranes are applied on site in a liquid form which is allowed to set and form into a water impermeable membrane. Bituminous-based (except those containing coal tar) and polymeric-based membranes can be applied when they are cold while those containing coal tar are usually applied when heated.

Liquid-applied membranes are seamless, semi-flexible, easy to apply, detail, maintain and repair. However careful supervision and control during application is needed, particularly in ensuring proper curing of concrete, consistent thickness and uniform application.

b. Pre-formed sheet membranes

One type of pre-formed membranes is the polymer-modified bitumen membranes and they are applied by heat or attached with an adhesive. These blended or 'modified' asphaltic product are bonded to a high strength fabric of polyester or fiberglass and produced into rolls. They have elongation and recovery properties which make them suitable to protect against stresses created by wind, temperature fluctuation and normal structural expansion and contraction of the building. Some of these products are also modified to increase their resistance to fire, thus increasing their fire-rating. Styrene-butadiene-styrene (SBS) rolls are modified with 'rubbers' and compatible with petroleum products. Atactic Polypropylene Polymer (APP) rolls are modified with 'plasticizers' and not compatible with all petroleum-based products, grease and oils.

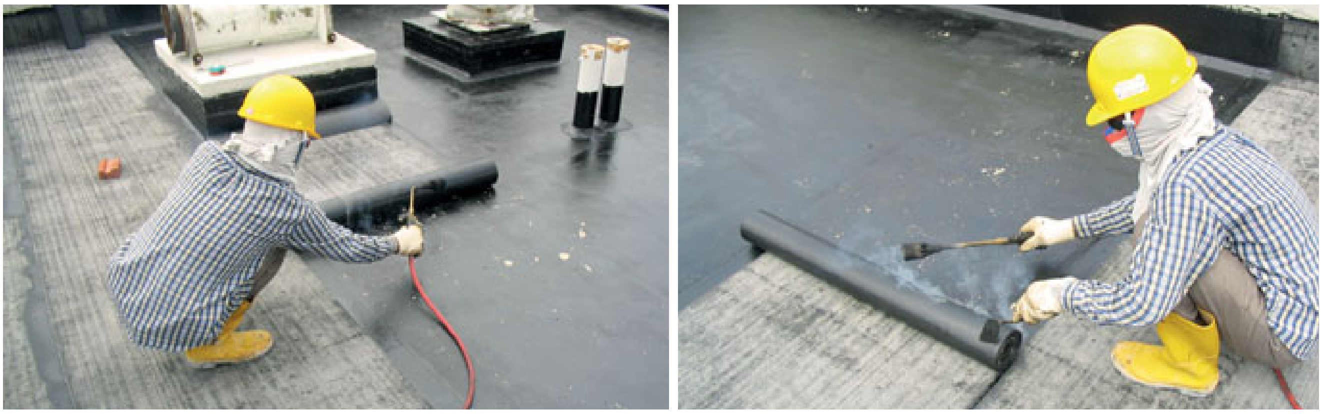


Fig. 12.2 – Softening polymer-modified bitumen membrane by heat welding.

Another type of pre-formed membrane is made of Polyvinyl Chloride (PVC). Although PVC is a hard resin, it is modified with the addition of plasticisers to make it more supple and pliable for use as roofing membranes. PVC membranes are mainly produced by either the calendering or extrusion process. In the calendering process, a reinforcement layer of glass fibre or polyester scrim is normally incorporated into the membrane to provide greater strength and dimensional stability. Like all thermoplastic membranes, they turn soft when subjected to heat. Some proprietary membranes are formulated with heat reflective compounds capable of lowering the surface temperature of the roof membrane by as much as 15%.

Fig. 12.3 – Using hot air torch to weld the joint of PVC membranes.

12.4 GOOD DETAILING PRACTICES FOR LIQUID-APPLIED MEMBRANES

As liquid-applied membranes are not very elastic and do not bridge over cracks and gaps well, it is good practice to fix a lax bitumen membrane over building's expansion and movement joints.

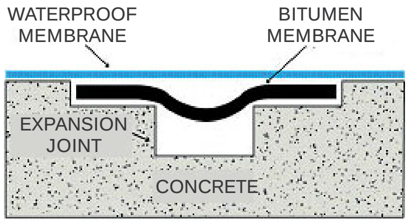


Fig. 12.4 – Typical example of fixing bitumen membrane over building's expansion and movement joint.

12.5 GOOD DETAILING PRACTICES FOR PRE-FORMED MEMBRANES

- Along roof edges and parapets, corners and pipe penetrations, a minimum 25 mm chamfer or fillet should be provided to ensure a smooth contour for easy installation of the membrane. This fillet helps to reduce the bending stresses in the membrane as compared to bending it at 90° without the fillet.

Fig. 12.5 – 25 mm fillets along parapet wall for bitumen and PVC membrane.

- Along edges, upstands, and vent pipe penetrations, the bitumen membrane is normally extended at least 150 mm above the finished roof level and doubly wrapped with appropriate overlapping at corners. It is good practice to form a groove on the parapet wall so that the edge of the bitumen membrane can be "tucked" into the groove. With the groove on the parapet wall and the membrane ending in a horizontal position, it can prevent water, flowing down the wall surface, from seeping through a weakened joint between the membrane and wall surface.

Fig. 12.6 – Groove along parapet wall to tuck in edge of membrane.

- At around corners of parapet walls, the bitumen membrane should be neatly folded and overlapped. The vertical joint at the corner should be sealed off with bitumen to prevent water seeping through any weakened joint.

Fig. 12.7 – Overlapping and sealing at corner.

- For rain-water down-pipe penetrations, before laying the horizontal bitumen membrane, an additional small piece of membrane should be stuck to the inside of the pipe penetration while the top is cut and laid horzontal. Both top and bottom portion should be 50 mm from roof surface. As the joint around the pipe penetration is the weakest area and the horizontal membrane cannot simply just bend 90° into the pipe penetration, the additional piece of membrane acts as a downturn covering the pipe/slab joint.

Fig. 12.8 – Wrapping around pipe penetration.

Fig. 12.9 – After laying the horizontal membrane around pipe penetration.

- For PVC membrane terminating at the parapet wall, a special PVC coated metal strip can be used. First a small groove line can be cut on the parapet wall, then the L-shaped metal strip can be nailed on to the wall. Finally, the PVC membrane can be heat welded on to the metal strip.

Fig. 12.10 – PVC coated strips for perimeter terminations.

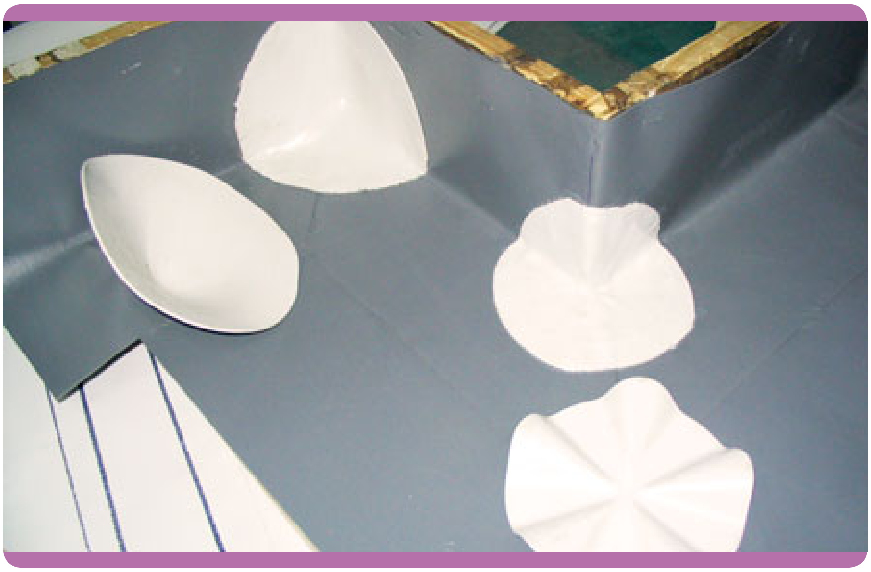


Fig. 12.11 – Prefabricated corner pieces for internal and external corners.

- All internal and external corners should be further reinforced with prefabricated corner pieces usually made from unreinforced PVC membranes to allow for greater flexibility and workability.

Fig. 12.12 – PVC coated strips for perimeter terminations.

- For upturn at pipe penetrations, it is good practice to use an extra piece of PVC membrane to 'bridge' between the horizontal and vertical membrane in order to prevent water seepage at the weak pipe/slab joint.

12.6 SUMMARY

Proper design of falls in reinforced concrete flat roofs is most important in creating flow paths to suitable discharge points. For a roof to be effective, surface water should be discharged quickly without ponding or stagnation. Next, it is important to select the appropriate waterproofing membrane. As the roof is constantly exposed to direct sunlight and rain, it is likely to experience tremendous thermal stresses that will affect its physical properties and performance. Pre-formed waterproofing membranes generally will perform better than liquid applied membrane as it can bridge over cracks and gaps better. Also, as they are more resistant to indentations caused by traffic, they are suited for large flat roofs areas exposed to foot traffic. However, liquid-applied membrane is still preferred for small roofs and roofs with a lot of obstructions.

M&E FITTINGS AND ACCESSORIES 13

13 M&E FITTINGS AND ACCESSORIES

Building services are an intergral component of a building that serves the needs of its occupants. A building will not function effectively without well designed and properly installed mechanical and electrical (M&E) services. After commissioning, the building has to provide its services continuously for the life of the building, interspersed by periodical maintenance. The M&E services start to 'age' and deteriorate immediately from first use. Such failures or breakdowns can be ameliorated by:

- Proper design and fittings selection
- Proper installation, and
- Proper maintenance

This chapter attempts to illustrate some examples of selection of materials, fittings and accessories that enhance workmanship quality during installtion and minimise maintenance issues during operation.

13.1 RECESSED CEMENT BLOCKS FOR EMBEDDING M&E PIPES

Traditionally, solid bricks are used to construct wet areas partition walls. This is to ensure better water tightness. However, as there are a number of services in wet areas like bathrooms and kitchens, the brick walls often need to be hacked to embed the services for aesthetic reasons. This has the following disadvantages:

- A risk of over hacking the wall, which may weaken the structure.
- Hacking is labour intensive.
- Housekeeping is needed to clear the debris.

Fig. 13.1 – Hacking brick walls weakens the wall structure and is labour intensive.

An alternative to brick walls is to use concrete masonry blocks with recessed profiles. Masonry blocks are made of cement, water and aggregates such as sand, gravel or crushed stones. Two types are commonly available viz. cement brick (solid type) and hollow blocks. They are used to construct partition walls and are designed in modular shapes to ease the installation work. Solid cement bricks are preferred for use in wet areas.

Fig. 13.2 – Different profiles of recessed blocks to embed pipes.

Fig. 13.3 – Recess formed to embed services without hacking wall.

13.2 CONCEALED FLOOR GRATING METHOD

A floor trap collects water or liquids discharged from a higher to lower level via gravity flow. The water collected is then discharged through the piping system. Traditionally, a pipe sleeve which forms part of the floor trap, is cast together with the slab concrete. A grating is then installed at the final stage after waterproofing, screeding and tiling on the concrete slab are completed. Generally, the gratings have 5mm perforations to allow water to discharge. This design often leads to tarnishing or discoloration of gratings due to regular contacts with water, perforation blockage due to trapped hair and wear of hinges when it is often lifted up for maintenance purpose. From the aesthetic point, the metal or plastic finish of the grating may not blend with surrounding floor finishes such as marble or tile.

Fig. 13.4 – A typical 100 mm floor trap sleeve cast together with concrete slab.

Fig. 13.5 – Tarnishing and blockage of grating are common after use.

To circumvent these issues, one method is to lay the same floor finish material (tile or stone) onto a stainless steel grating tray, which is then placed on top of the perforated grating insert. The top tray hides the grating perforation and yet allows water to be discharged through the 5mm gap between the tray and insert. This design also does not employ hinges that usually wear off or break over time. The cost of this method is higher than the conventional installation and one will have the weigh the benefits before deciding to employ this method.

The advantages of this design include:

- No sharp or protruding edges.
- No hinge mechanism.
- Accommodates other common inserts like mosquito or cockroach traps.
- Aesthetically pleasing, as it blends with the surrounding floor finish.

However, when using this method, consideration should be given to the design of the gradient or fall leading to the floor trap. If it is too steep, water will quickly rush down to a drainpipe and leave some solids next to the grating rather than carrying them along. This will result in a build up of solids over time and may cause blockage, if they are not removed periodically.

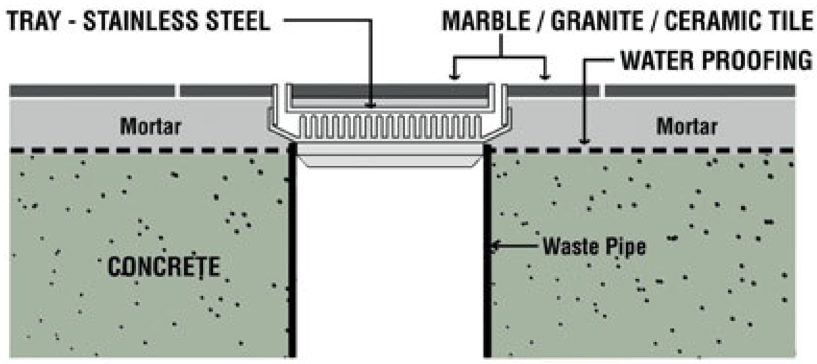


Fig. 13.6 – A typical section of concealed grating method.

Fig. 13.7 – A range of stainless steel sleeves and trays to suit requirements.

Fig. 13.8 – Discharge traps are hidden beneath the floor finishes.

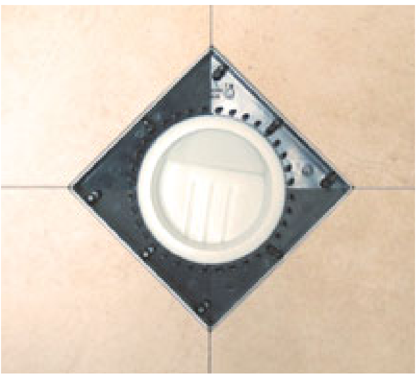


Fig. 13.9 – Standard traps can be installed below the tray.

13.3 PPR-C (POLYPROPYLENE RANDOM COPOLYMER) PIPES

PPR-C pipes, an alternative to conventional metal pipes, are used mainly for interior water distribution systems in buildings and other services. The most significant feature of this non-metal pipe is that it can be used in hot water systems apart from sanitary work installations.

Background and key features

The raw material of PPR-C is thermo plastic resin which comes in pre-coloured granules. The raw material together with other components are heated which plasticizes the mixture and then extruded to form the finished product. The key attributes of PPR-C pipes are as follows:

- It can be used for potable hot and cold water supply as well as floor heating system.
- It is corrosion resistant and scale free such that blockage due to water scales and yellow stains on water can be avoided.
- It has heat insulating properties when the pipes are utilized for hot water systems.
- The pressure resisting test strength is over 5 Mpa (50 kg/cm^2) and it has good ductility and impact resistance.
- The joints and connections are done by hot-fusion method. Hence installation works can be finished quickly.
- PPR-C pipes can also be connected to other metallic materials by flange or metal adaptor.

Fig. 13.10 – Fusion welding expedites connection process.

Fig. 13.11 – Prefabricated fittings facilitate neat and tidy connections.

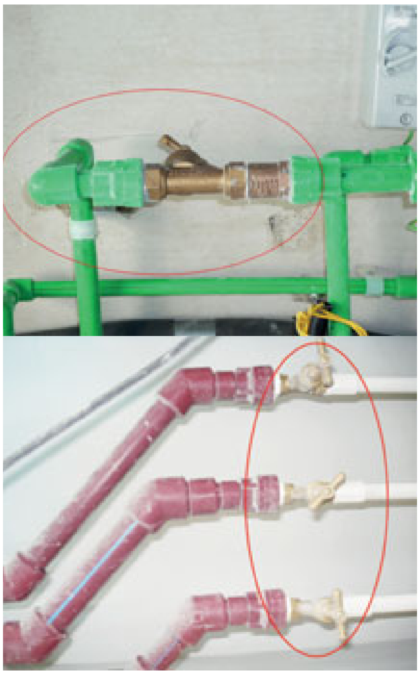


Fig. 13.12 – Possible to connect with dissimilar materials by flanges or adapters.

Limitations and considerations in PPR-C pipes

- Although fusion welding for PPR-C pipes is faster than conventional welding method, this requires skilled installers trained in using this material.

- Currently PPR-C pipes cost as much as metal pipes. However, if more connections and bends are required, there will be an additional cost implication on the supplementary fittings.

- Although PPR-C pipes can be used in hot applications, its use will also need to comply with high temperature test requirements imposed by local regulatory bodies (e.g. PUB) for all non-metallic materials intended for use in hot water applications.

- PPR-C pipes are intended for use primarily in sheltered environment. It is not advised for use where the pipes and fittings are exposed to sun light.

- For isolated hot installations, it may not be necessary to provide insulation as the thermal conductivity of PPR pipe is lower compared to metal pipes. However for centralized heating systems, to prevent heat loss and isolate the pipeline from other utilities, it may be appropriate to provide insulation.

13.4 END-CAPPING FOR FITTINGS & ACCESSORIES

The supply and discharge pipes leading to or from sanitary fittings are often embedded for aesthetic reasons. At the connection to the outlet fittings, the substrates such as plastered walls, tiles or boards have to be cut to allow pipe entry or egress. This has to be done manually and is often time consuming, particularly in large projects where there are many such fittings. Moreover, when the cutting and filling are not carried out properly, it often leaves untidy and unsightly marks which mar the general appearance of the wall or floor surfaces.

Fig. 13.13 – Examples of untidy pipe protrusions from tiled surfaces.

Fig. 13.14 – Untidy water supply inlets through vanity cabinet.

This untidiness can be overcome by choosing fittings and accessories with proper end capping. Permanent end caps are often part of the accessories. However, in cases where it is not part of the standard accessories, it is possible to use some other universal caps that match the fittings.

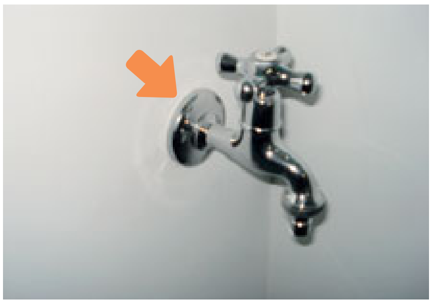


Fig. 13.15 – Permanent end caps for bottle trap and supply pipes conceal untidy work.

Fig. 13.16 – Rubber based universal end cap for sanitary discharge pipe.

13.5 CLIP-TYPE ELECTRICAL SOCKETS

Electrical boxes also known as "knock out" or "KO" boxes serve as end or transition points for electrical wires, which are often run in embedded conduits. Outlet points, such as light switches, TV switches, heater sockets, etc are connected to the KO boxes and allow end-users to access and operate the services. However, there are some issues that are likely to be encountered during construction:

- When the KO box level sinks below or protrudes from the wall level due to differences in the plastering thickness or other reasons, it requires modification to the box. This involves hacking and touching up around the boxes and often leaves a messy and untidy finish.

- Typically, a socket (also called face plate) is connected to the KO box (which is embedded in the wall) by screws. If the wall level is not flat, inconsistent gaps can be observed between the face plate and the wall.

- In typical construction sequence, sockets are usually installed before the final coat of wall paint so as not to disturb the finished surface. Consequently, they have a high possibility of getting stained if they are not protected properly.

Fig. 13.17 – Adjusting position (after plastering and painting) leads to unpleasant consequences.

Fig. 13.18 – Inconsistent gap and paint stains are possible issues.

These issues can be eliminated by using clip-socket method which has three stages in installation instead of two i.e. installation of KO box, base plate and the final socket. In this method, the base plate is installed on the KO box before wall painting. Thus, if there is any undulation discovered on the plastered surface, it can be levelled with putty or other materials before fixing the face plate. As a better level surface can be achieved on the wall, gaps between the face plate and wall if it does occur are often slight and do not require filling with materials like silicone sealant.

Fig. 13.19 – Waviness on the wall can be leveled with putty after the base plate installation.

Fig. 13.20 – The final coat of wall paint can be carried out.

Moreover, the final socket can be clipped on to the base plate before testing and commissioning or handing over. This reduces the chances of it being damaged by other trades. The cost of this method is higher than the conventional method of installation but consideration should be given to the better workmanship quality that can be achieved

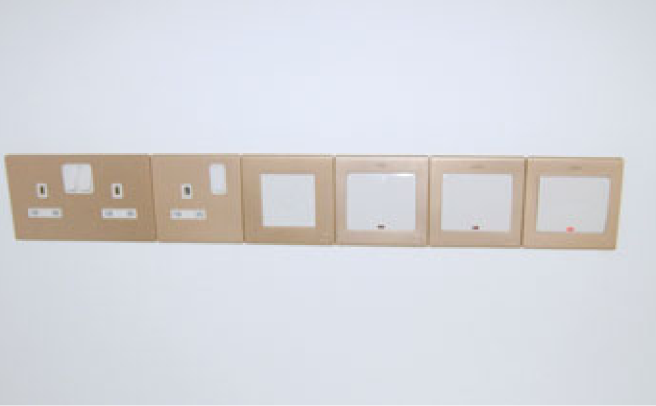



Fig. 13.21 – The clip-type face plate can be installed at the final stage of construction.

13.6 SUMMARY

Each type of fitting and method of construction has its own merits and limitations. The choice should be based on its function that meets end-users requirements. At the same time, other factors like regulatory requirements, integration with other trades and maintainability during use should also be considered. It is highly recommended that product specialists be consulted to determine a product's suitability before use.



EXAMPLE PROJECTS



a. CITY SQUARE RESIDENCES

CONQUAS SCORE: 95.6

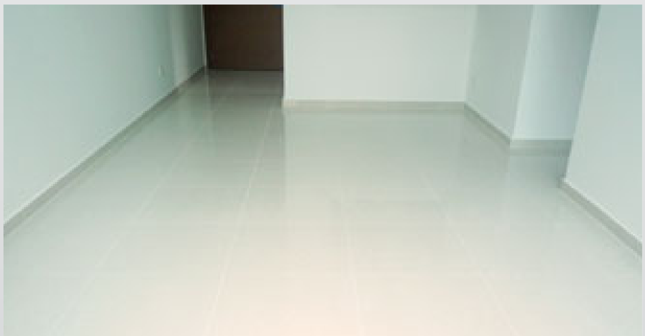
AVERAGE QUALITY MARK SCORE: 91.7

6 Blocks of 28/30-Storey Condominium (Total 910 Units)

DESIGN AND MATERIALS FOR QUALITY

Modular system RC wall

» Less joints & better flat surfaces.



Rectified homogeneous tiles

» Better dimensional and tonal consistency.

Drywall partitions

» Eliminate wet trades.
» Tidy process.

Rebate door with pre-installed architrave

» Good alignment between door frame & leaf.
» No nail-hole patch up.

Capping for M&E pipe protrusion

» Hide untidy joints.

PPR (Poly Propylene Random copolymer) Pipes

» Ease of installation.
» No corrosion.

b. THE SAIL @ MARINA BAY

CONQUAS SCORE: 94.8

AVERAGE QUALITY MARK SCORE: 87.4

2 Towers of 70/63-Storey Condominium (Total 1111 Units)

DESIGN AND MATERIALS FOR QUALITY

Curtain wall facade

» Dry and faster installation.

Drywall partitions

» Better control on alignment and evenness.

Screed-less flooring

» No wet works.
» Better productivity.

Prefabricated Bathroom

» Speedy construction & consistency in workmanship.

Polymer modified adhesive

» Better compatibility to tiles.

Rectified ceramic tiles

» Consistent joint width.

C. PARC EMILY

CONQUAS SCORE: 94.1

AVERAGE QUALITY MARK SCORE: 91.4

5 Blocks of 8-Storey Condominium (Total 295 Units)

DESIGN AND MATERIALS FOR QUALITY

Precast components

» Quality surface finish and buildabilty.

Screed-less flooring

» More productive.
» Minimize de-bonding issues.

Honey comb door with lift-off hinges

» Faster installation and better alignment.

Prefabricated bathrooms

» Less workmanship issues and off site production.

Epoxy pointing for marble floor

» Smooth joints and better aesthetics.

Inner beading between ceiling and wall

» Improves alignment and joints.

d. ST REGIS RESIDENCES

CONQUAS SCORE: 89.4
AVERAGE QUALITY MARK SCORE: 88.9

A Mixed Development of 201 Residential and 13 Commercial Units

DESIGN AND MATERIALS FOR QUALITY

Prefabricated bathrooms

» Faster and dry construction.

Drywall partitions

» Ease of installation and consistent finish.

Rectified tiles

» Stable dimension.

Curtain wall facade

» No scaffolding.
» No wet works.

Modular system cabinets

» Factory assembled and good dimensional accuracy.

Click-fit sockets

» Installed after final painting.

e. INFINIUM @ EVELYN

CONQUAS SCORE: 91.6
AVERAGE QUALITY MARK SCORE: 84.5

2 Blocks of 33-Storey Condominium Housing Development (Total 208 Units)

DESIGN AND MATERIALS FOR QUALITY

Precast components

» Better quality surface finish.
» Faster construction.

Modular system cabinets

» Less manual work and faster installation.

Rebate door with lift off hinges

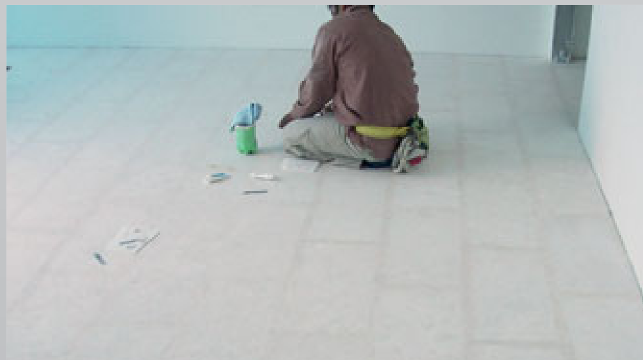
» Better alignment between frame and panel.

Drywall partitions

» No wet work.
» Consistent finish.

Internal spray painting

» Consistent finish.



Epoxy grouted marble floor

» Smooth and consistent finish after polishing.

f. THE AZURE

CONQUAS SCORE: 93.6
AVERAGE QUALITY MARK SCORE: 87.42

Total number of units – 116

DESIGN AND MATERIALS FOR QUALITY

Modular system components

» Factory assembled minimize workmanship issues.

2-component adhesive for marble floor

» Compatible to soft stones.

Epoxy joints for marble floor

» Durable joints and easy maintenance.

Rectified ceramic tiles

» Joint consistency.

Timber strip with plywood base

» Better levelness and invisible nailing.

Honey comb veneer door

» Light weight and warp resistant.

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