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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 workmanship quality of building projects. To meet rising expectations of homeowners, the Quality Mark (QM) Scheme was launched in 2002 to promote consistent high workmanship standards for private residential developments. To help projects achieve the standards in CONQUAS and QM, BCA has developed a series of publications on Good Industry Practices for different trades.

The "Good Industry Practices – Agglomerated Stone Tiling" guide is part of the CONQUAS Enhancement Series which collates and shares some of the good practices adopted by industry practitioners and contractors on how good workmanship quality can be achieved in Agglomerated Stone Tiling work. It provides simple and practical illustrations on the types of agglomerated stone, quality checks during manufacture and proper installation methods. Common issues associated with Agglomerated Stone Tiling, their causes and possible solutions to address them are highlighted.

This guide is not meant to be a definitive dictation on how Agglomerated Stone Tiles must be designed and installed. It only serves to illustrate some of the good practices designers and contractors have adopted while designing and installing Agglomerated Stone Tiles. We gratefully acknowledge the contributions of the industry practitioners in the development of this guide and trust that the industry will find this publication useful.

Neo Choon Keong
Deputy Chief Executive Officer
Industry Development
Building and Construction Authority

ACKNOWLEDGEMENT

This "Good Industry Practices – Agglomerated Stone Tiling" was developed with inputs from Architects, Developers, Builders, Specialist Contractors and members from various industry associations and organisations.

A Technical Committee was formed to review the contents and good practices identified. We wish to thank the members of the Technical Committee for their valuable contributions.

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Agencies, Organizations and Firms
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Choo Building Materials Co. Pte. Ltd.
Keong Hong Construction Pte Ltd
Lian Beng Construction Singapore Pte Ltd
Fujian PengXiang Industrial Co.,Ltd.
Romastone Co., Ltd.
Woh Hup Pte Ltd

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CONTENTS

1.0 INTRODUCTION

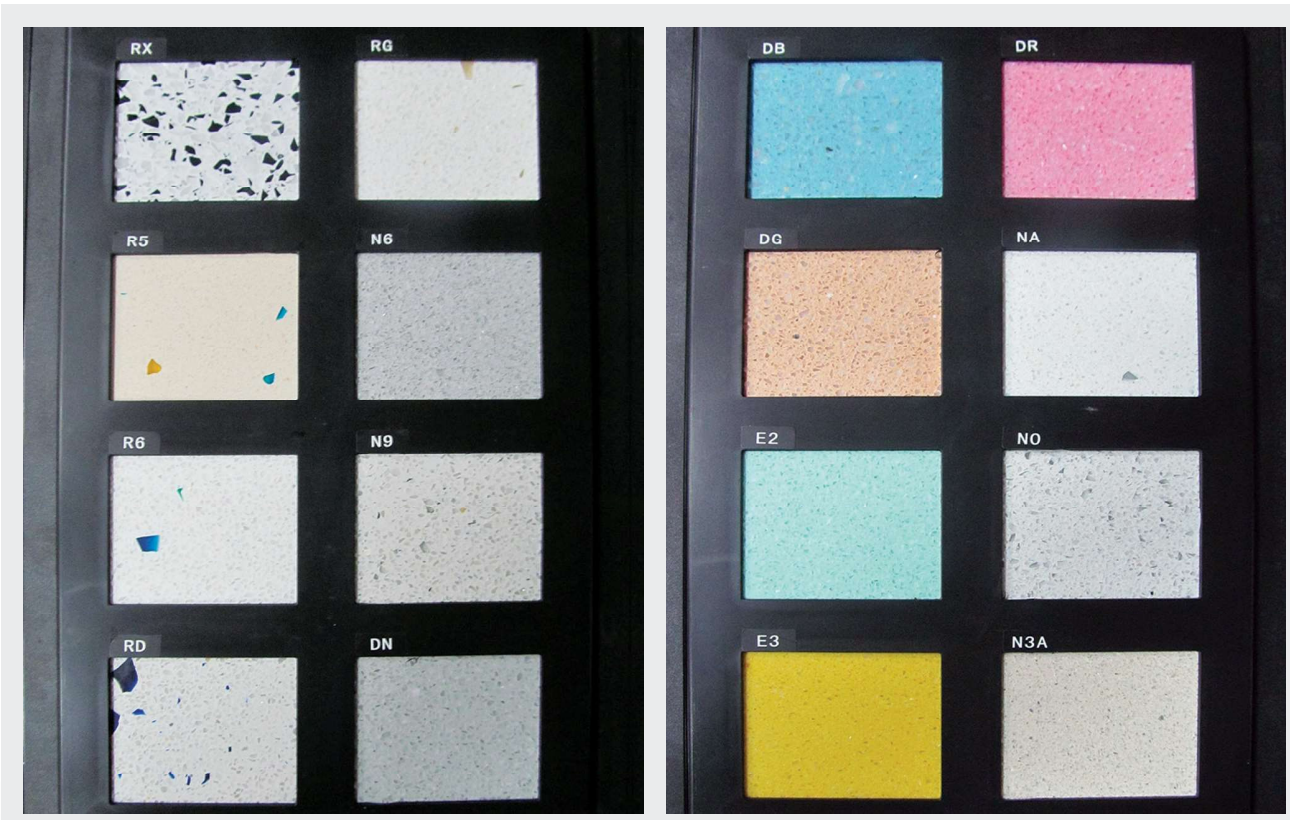
1.1 Background

Agglomerated stone tiles are a composite material produced by binding stone chips with specially formulated resin. The two commonly used stones used in producing these products are marble and quartz.

This material is a good alternative for natural stone as there is less tonality issue, which thus eliminates the need for the time-consuming and labour-intensive process of dry laying for sorting of pattern and colour tone. There is also a wide range of colours to choose from because of the extensive range of coloured stone fillers available. The agglomerated stone tile is physically less porous and harder than many types of natural stone. Since it has a uniform internal structure, it does not have hidden cracks or flaws that may exist in natural stones.

The two commonly used stones in producing agglomerated stone tiles are marble and quartz.

Agglomerated marble tiles (carbonate-based), also known as reconstituted or compressed marble, are relatively soft and maintenance is much easier as re-polishing can revitalize its appearance. In addition, agglomerated marble tiles offer a better range of appearance.



Agglomerated stone tiles has wider range of colour than natural stone tiles using coloured filler.

Agglomerated quartz tiles (siliceous) are much harder, and they usually measure at 7 of the Measurement of Hardness (MOHs) scale as compared to most marbles, which measure at about 3. This makes it much more resistant to scratches, but makes re-polishing and levelling more difficult on site.

Table 1.0 MOHs Hardness Scale

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

1.2 Composition

Typical agglomerated stone tiles consist of 93% stone chips and 7% resin by weight. Stone chips are the main filler and other materials like colour pigment, coloured glasses, sea shells, metals or mirrors may be added to create the desired visual effect. In general, the larger the sizes of stone chips used, the resin used will be reduced.

Different types of resins are used by different manufacturers, with Epoxy and polyester resins being the most commonly used. Some manufacturers may use cement instead. (Note: Cement based agglomerated stone tiles are not covered in this guide as it is less commonly used here.)

Do note that some polyester resins are not completely UV stable and therefore agglomerated stone tile may not be suitable for outdoor applications. Continuous exposure to UV can cause discoloration of the stone and breakdown of the resin binder.

The mix ratio varies depending on the manufacturer. A higher percentage of resin will increase the coefficient of thermal expansion and reduce abrasion resistance of the agglomerated stone tiles. In general, agglomerated stone tiles have a higher thermal expansion coefficient than natural stone due to the resin content.

As such, the quality of the agglomerated stone tiles depends very much on the stability of the resin binder used.

1.3 Characteristics

Agglomerated stone tiles have the same performance characteristics of natural stone as predominantly 93-95% of the fillers are natural stone. Agglomerated quartz tiles have harder wearing properties (higher MOH) than those made with marble as shown in Table 2.0. However, once agglomerated quartz tiles are installed, they cannot be ground and polished if there is any lippage or unevenness in the flooring.

Table 2.0 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

Agglomerated quartz tiles are also more resistant to acidic chemicals than agglomerated marble tiles due to the presence of mineral deposits – iron in particular, in the marble, when it comes in contact with acid and water. Application of a compatible impregnator on the surface of agglomerated marble tiles should be considered.

1.3.1 Moisture sensitivity

Agglomerated stone tiles bound by resin binders may show varying degrees of moisture sensitivity and this characteristic is exhibited by curling, which is caused by differential expansion. Do note that the expansion and curling process is not completely reversible once the moisture source is eliminated.

As such, resin based agglomerated stone tiles are not recommended for use in external areas, swimming pools, or any other water retaining structures e.g. spa baths or fountains.

1.3.2 Thermal movement

Generally, agglomerated stone tiles have a higher coefficient of thermal expansion than porcelain or natural stone due to the resin binder. This is reflected in the BS 5385-5:2009 Wall and Floor tiling clause 4.4, which recommends a higher frequency of movement joints for agglomerated stones.

1.3.3 Abrasion resistance

The abrasion resistance for all agglomerated stone products reflect their natural stone components. Agglomerated marble tiles have a lower abrasion resistance than agglomerated quartz tiles but may still be suitable for use in areas with high traffic.

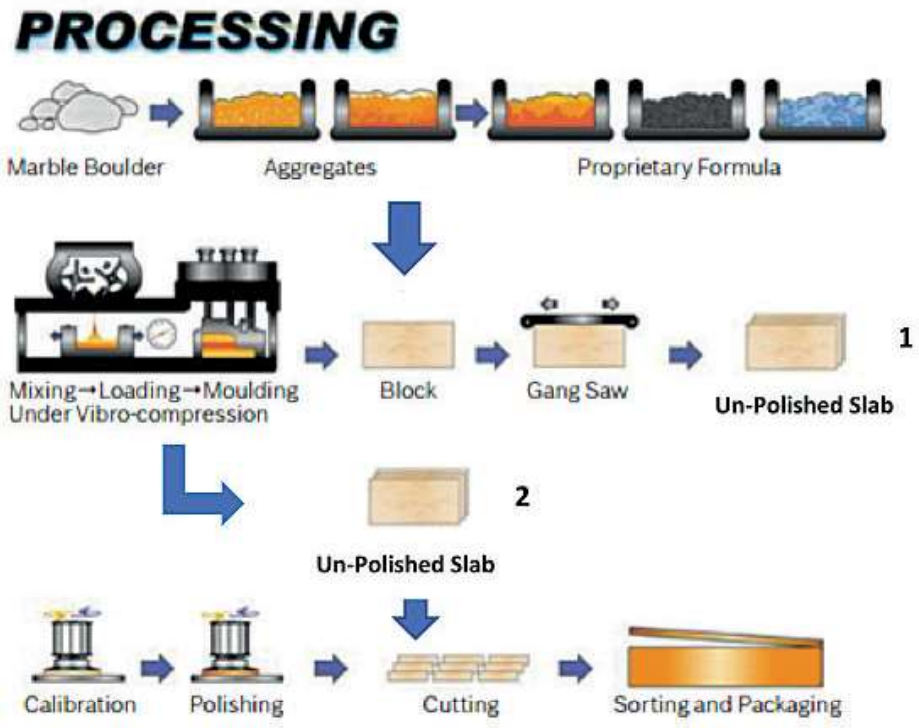
It is always important to consult the manufacturer for detailed information and technical support on the suitability and applicability of the product for its intended use.

Polished finishes are more likely to show scratch marks if the abrasion resistance is low. As such, it is recommended to have additional polishing with epoxy coating after installation, particularly when there is the need for spot levelling to address lippages or levelling by grinding. The grinded/levelled surface may have a matt/patchy appearance due to the different levels of polishing and may look wavy from an angle.

1.4 Manufacturing Process

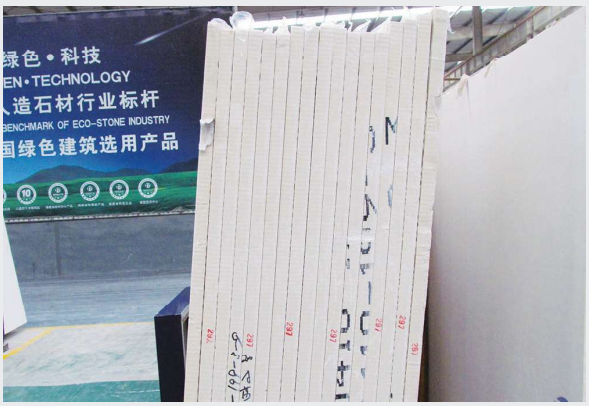
In general, agglomerated stone tiles are produced by mixing approximately 93% stone chips and 7% polyester or epoxy resin by weight and pressed into sheets/slabs (or blocks) using a vibro-compression vacuum process.

Table 3.0 A Schematic Outline of Production Cycle of Agglomerated Marble tiles



1. A Schematic Outline of Production Cycle of Agglomerated Marble tiles
2. A Schematic Outline of Production Cycle of Agglomerated Quartz tiles

Stone chips are crushed to size or supplied in bags before manufacturing.



Agglomerated marble is usually casted in blocks while the harder agglomerated quartz usually in slabs due to the difficulty in cutting.

The process of manufacturing agglomerated stone tiles are generally as follows:

1. Process stone chip
    a. Crushed to size

    b. Purchase from supplier

2. Mix stone chips with mineral filler, resin, additives, colouring agents and then heat the mix
    a. Polyester or epoxy resin are commonly used as binder

    b. Generally, micronized silica (silex) or micronized feldspar fillers are used with siliceous aggregates (quartz) and calcium carbonate fillers for calcareous aggregates (marble)

    c. The additives, added in small quantities to the mixes to obtain specific results, are catalysts, which accelerates the hardening of the resin. Bifunctional silanes may be added to siliceous aggregate mixes to improve mechanical strength

    d. Metal oxide pigments are commonly used as colouring agent to achieve the required colour effects

3. Casting in mould to form slabs or blocks (Note: Agglomerated Quartz is usually cast in slabs due to the difficulty in cutting)

4. Compact with high pressure and start vibrocompression vacuum process
    a. The vacuum compacting process prevents macro-porosity in the compacted mix and micro-porosity in the bonding resins minimising water absorption to 0.02% in weight

5. Cure slabs or blocks
    a. By heating or naturally. Hydrogen peroxide may be added to enhance curing.

6. For blocks, cut into slabs
    a. Using gang saw or wire diamond cutter (preferred as quality of cut is better)

    b. Thickness around 10 mm to 20 mm (maximum thickness for tile according to BS EN 15285:2008)

7. Calibrate and polish slabs
    a. Preferably in automatic calibrating-polishing machine

8. Cut slabs into tiles
    a. Preferably using a laser-guided cutting machine with tolerance of maximum +/-0.05mm

Cutting of agglomerated marble blocks into slabs using gang-saw.

Laser-guided saw for higher accuracy in cutting agglomerated stone

Automatic calibrating and polishing machine preferred.

1.5 Transportation and storage of product

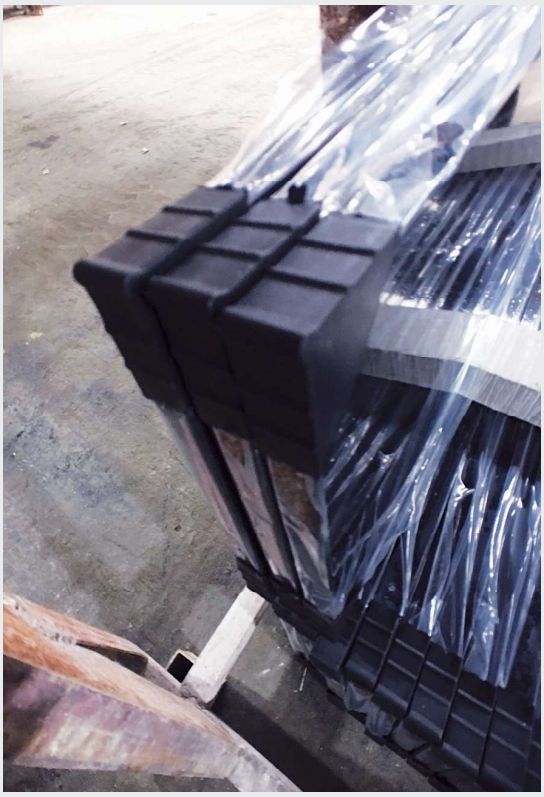
Agglomerated stone tiles are supplied in either boxes or crates (for larger tiles). It should not be stored externally unless they are completely protected from direct sunlight, water and rain.

Materials should remain in their purchased packaging for as long as possible. They should be stored flat and not leaned against walls.

The tiles should be acclimatised before installation.

Packaging of Agglomerated stone tiles should be watertight.

Option to protect surface with plastic sheet especially for supplying in uncut slabs.



Option to protect skirting edges with plastic caps to prevent chipping during transportation.

2.0 DESIGN CONSIDERATIONS

2.1 Tile selection

It is important to consider the physical characteristics of resin based agglomerated stone tiles and the service conditions of the tiled location.

Agglomerated stone tiles are normally available in thicknesses between 10mm-12mm. Thicker agglomerated stone tiles are also = available for heavy duty conditions.

The surface finish should be considered with regard to slip resistance, traffic conditions, spillage and maintenance.

The common reference standard for agglomerated stone floor tiles is BS EN 15285:2008 Agglomerated Stone – Modular tiles for flooring and stairs (Internal and External). The essential characteristics to take note for specifications and product information are:

Maximum dimensional tolerances– BS EN 14617-16:2013

Determination of dimensional stability - BS EN 14617-12:2012

Water absorption (%) – BS EN 14617-1:2013

Bending strength (MPa) – BS EN 14617-2:2008

Abrasion resistance (mm3) – BS EN 14617-4:2012

Chemical resistance (in % gloss loss) – BS EN 14617-10:2012

Slip resistance – SS 485:2011 or BS EN 14231:2003

Impact resistance – BS EN 14617-9:2005

Thermal shock resistance – BS EN 14617-6:2012

Coefficient of linear thermal expansion – BS EN 14617-11:2005

The important characteristics to consider are:

1. Coefficient of linear thermal expansion
    - The resin may expand excessively under heat
    - Do consider having a flexible tile adhesive

2. Dimensional stability on prolong exposure to presence of water
    - Staining issues range from water trapped in substrate (insufficient curing or condensation), water through untreated edges thru pointing or wet mopping and spilled liquid on the surface
    - Use only reaction resin or fast-setting cementitious adhesive
    - Always ensure substrate is properly cured
    - Do consider application of an impregnator to prevent stain from being trapped inside the tile

3. Discolouring
    - May discolour under prolong exposure to UV from the sun but its strength and its chemical and physical characteristics will not be affected
    - Some may come with gel coat that contains UV stabilisers to ensure colour stability and gloss
    - When in contact with moisture, some agglomerated marble tiles may turn yellowish due to its iron content

4. Abrasion resistance (mm3)
    - For high traffic areas, agglomerated quartz will be more suitable than agglomerated marble

5. Chemical resistance (in % gloss loss)
    - Agglomerated quartz is more chemical resistant than agglomerated marble

Surface staining of compressed marble due to penetration of water or chemical

2.2 Finishes

Common choices of finishes are polished or honed. Polished finishes are generally used where a reflective surface is required and slip resistance is less important. A honed finished tile is chosen for its matt appearance where reflective surface is not required and where improved slip resistance is important. A sand blasted finish is used when higher slip resistance is required e.g. intermittent wet locations.

The surface texture will affect the cleaning regime required. When considering choice of finishes, it is important to understand that there is a compromise between slip resistance and ease of cleaning and/or maintenance.

As the finishes on the edges are typically either square or micro bevelled, extra effort is required to prevent the edges from chipping off during handling, especially when the tiles are positioned vertically.

For residential projects, consider putting in the specification for a light polishing and sealing after installation and before handing over. Due to grinding of edges to remove lippages and patchy spot polishing after grinding, the floor may look wavy or dull (matt) at an angle. The tile joints maybe visible too, especially after filling with cementitious grout for straight edge joints.

A light polishing and sealing before handing over is recommended to achieve the perfect flush look.

2.3 Slip Resistance

Slip resistance should be one of the most important design considerations for safety reasons.

Agglomerated stone tiles, like natural stone, have good slip resistance in clean and dry conditions regardless of the type of finished surface. However, the performance when wet or contaminated, would depend on the roughness of the finished surface and the type of contaminant present.

For use in public areas, the SS 485:2011 specification for slip resistance classification of pedestrian surface materials should apply. Below is the pedestrian flooring selection guide (including ramp) for various public areas:

Table 4.1 Pedestrian Flooring Selection Guide – Minimum pendulum or ramp recommendations for specific locations

Location	Pendulum	Ramp
External colonnades, walkways and pedestrian crossings	W	R10
External ramps	V	R11
Entry foyers hotel, office, public buildings - wet	X	R10
Entry foyers hotel, office, public buildings - dry	Z	R9
Shopping centre excluding food court	Z	R9
Internal ramps, slopes (greater than 2 degrees) - dry	X	R10
Lift lobbies other than entry foyers	Z	R9
Other shops with external entrances - entry area	X	R10
Food outlets including fast food outlets, buffet food servery areas	X	R10
Hospitals and aged care facilities - dry areas	Z	R9
Hospitals and aged care facilities - ensuites	X	A or R10
Shop and supermarket aisles except fresh food areas	Z	R9
Shop and supermarket fresh food areas	X	R10
Communal changing rooms	X	A
Swimming pool surrounds and communal shower rooms	W	B
Swimming pool ramps and stairs leading into water	V	C
Toilet facilities in offices, hotels, shopping centres	X	R10
Undercover concourse areas of sports stadium	X	R10
Accessible internal stair nosings (dry) -handrails present	X	R10
Accessible internal stair nosings (wet) -handrails present	W	B or R11
External stair nosings	W	R11

In accordance to SS 485:2011, dry floor friction test is for internal floors. The standard indicates that floors should have a dry floor friction classification of F unless normal usage dictates that the floor should have a low dry coefficient of friction, e.g. dance floors.

Table 4.2 Classification of pedestrian surface materials according to the dry floor friction test

Classification *(Notional contribution to risk)* (SS485:2011)	Test Result Mean Value (COF)
F (Moderate to very Low)	≥ 0.4
G (High to very High)	< 0.4

For safety reasons, it is highly recommended that the slip resistance class of the selected agglomerated stone tile is established, rather than taking the slip resistance class provided by the manufacturer at face value. For public areas with high traffic, wet areas like the main entrance should have a safe slip resistance class under wet conditions. Hence for large public areas, the choices of stone finishes can vary depending on the designation (zoning) of wet and dry areas or service conditions.

Pendulum test equipment

Ramp Test

To reduce water ingress, particularly for high traffic areas (commercial buildings), high quality mat well (recessed type preferred) could be provided at the entrance to trap water, especially during the rainy season. In addition, introduction of secondary matting and external canopies can help to further reduce water ingress.

Mat well for trapping water and grits

To improve slip resistance of existing floor tile, a mineral or resin polymer non-slip coating will help. The slip resistance of resin polymer non-slip coating in wet conditions is better but not as aesthetically pleasing as it will leave a matt sheen when it dries. Mineral non-slip coating is almost translucent and will not affect the aesthetics of the tile, but it has a lower Slip Resistance Value (SRV).

2.4 Thermal Sensitivity

Agglomerate stone tiles are more prone to thermal expansion and contraction especially in areas with prolong exposure to direct sunlight such as conservatories, atria, open balconies or where this is underfloor heating/cooling. It is recommended to always consult the manufacturer for suitability for such applications.

BS 5385-5: 2011 recommends greater frequency of movement joints in bays not greater than 25m^2 in size with an edge length that is not greater than 6m, to accommodate the high thermal expansion of the resin agglomerated stone tile.

Where underfloor heating/cooling system is used, the pipes or cables should be suitably located to ensure that the system is contained within the pattern of movement joints. Where large format tiles (i.e. with a single side 600mm or greater) are being used, adopting wider joint widths and smaller bay sizes should be considered. It is important to ensure that there is no contact between the heating/cooling cable, mesh and the back of the agglomerated stone tile. This can be achieved using a self-levelling compound or a thin layer of tile adhesive that is allowed to cure and dry before the agglomerated stone tiles are fixed.

2.5 Wet Areas

Due to the higher coefficients of moisture expansion for resin-based agglomerated stone tiles, assurances should be sought from the supplier or manufacturer that it is fit for use in wet areas like toilets and whether any precautionary measures should be taken during and post installation.

The design for shower area should ensure that water is quickly and effectively channelled away from the tiled floor area to the drainage outlet in order to keep water contact to a minimum. Consideration may be given to the use of epoxy resin grouts (commonly known as marble glue) to help provide impervious joints. A proprietary tanking system should be applied to the substrate.

2.6 Pool & Fountains

Due to the high degree of moisture expansion, the use of resin-based agglomerated stone tiles in a total immersion situation such as swimming pools, fountains etc. is not recommended.

2.7 Floor Substrate

Agglomerated stone tiles should be fixed on to a dry, flat, cohesively strong, stable and rigid substrate that is free from surface contaminations such as dust, laitance, grease, wax, loose or flaking areas etc.

Levelness of substrate should be not more than 3mm over 2m in length or to SR1 as specified in BS 8204. Final finishing with a self-levelling compound is recommended especially for screedless floor slab. For power floated concrete, sealer or shot blasting is required to improve bonding.

Any cementitious floor screed (ditto for render) or concrete slab (screedless flooring system) to receive resin agglomerated stone tiles should be completely cured (approximately 2 weeks) for 50mm thick Cement & Sand (C&S) screed and tested. A quick check using a portable hygrometer (e.g. Tramex, Portimeter, etc) is recommended. The permissible moisture level will depend on the type of adhesive used, i.e. to follow the adhesive supplier's recommendation.

Self-levelling cements to achieve or correct level of substrate

Due to the limitation on the depth coverage of the portable moisture meter (normally around 25mm), when in doubt, do consider other more invasive methods by inserting the RH probes into the middle of the slab, e.g. ASTM F2170 – 11 method. In view of the high RH (relative humanity) in the air locally (almost 95%), the workable moisture content range should be around 2% by weight or < 75% in relative humidity. Technically it is called the "equilibrium relative humidity (ERH) of the screed" to minimise/eliminate the movement of moisture between substrate and the agglomerated stone.

In any case, consultation with the agglomerated stone manufacturer should also be undertaken to ascertain the maximum moisture levels permitted prior to the installation of their material.

Checking of moisture level of substrate with portable moisture meter.

2.8 Wall substrate

Wall substrates, particularly drywall with plasterboard, should be strong enough to take the weight of the agglomerated stone tiles and the associated adhesive bed. The average weight restriction on plasterboard as a wall substrate is around 32 kg/m2.

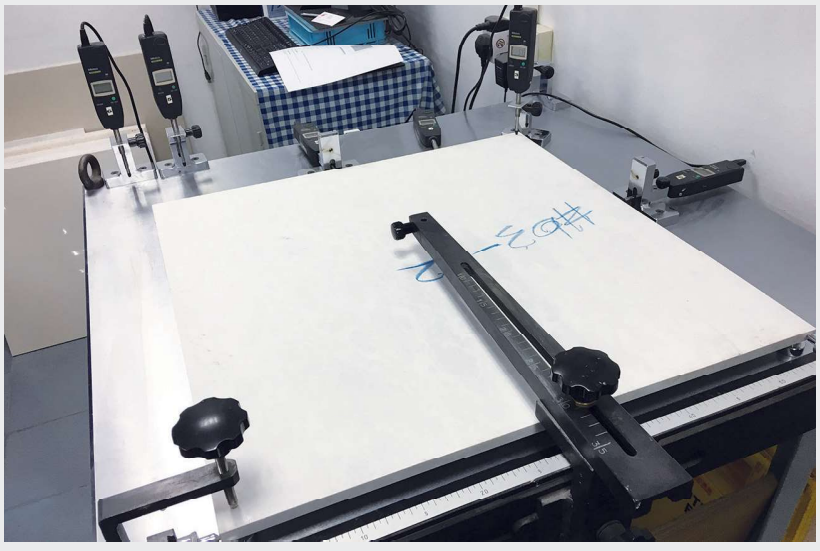
The general weight of agglomerated stone tiles for common thickness are as follows:

- 25 Kg/m^2 for 10 mm thick
- 30 Kg/$m^2$for 12 mm thick
- 50 Kg/m^2 for 20 mm thick

A 1 mm thickness of tile adhesive will add a further 1.5Kg/m^2

2.9 Adhesive Selection

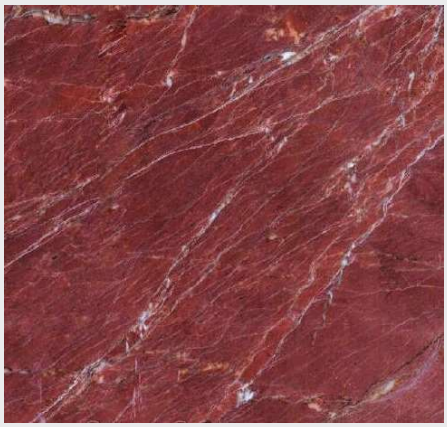
As some of the agglomerated stone tiles are susceptible to moisture deformation (warping / curling), care is required to ensure compatibility with the adhesive used, i.e. to limit water from adhesive to the agglomerated stone.



Dimensional stability test due to moisture

Reaction resin adhesives and rapid setting cementitious adhesives work well with agglomerated stone tiles (as recommended in BS 5385-3:2009).

For agglomerated stone tiles (e.g. Rosso Levante or Verde Tirreno) that are more water sensitive which affects the dimensional stability, use only water-free reaction resin adhesive and ensure that the substrate is properly cured.



Rosso Levante

Verde Tirreno

Note: If the agglomerated stone tile binder is epoxy, it is advisable to use an epoxy based adhesive.

For light coloured agglomerated stone tiles, it is recommended to select white adhesives to avoid colour distortion particularly where the tiles are translucent or partially translucent.

In general, the low water absorption necessitates the use of adhesives that develop high adhesion strength and a strong bond.

The other aspect to consider is the thermal expansion of agglomerated stone tile caused by temperature change such as underfloor heating/cooling systems, direct sunlight or from general changes in the ambient conditions. Hence, adhesive selected will need to be deformable to accommodate such movement.

Based on BS EN 12004, adhesive for agglomerated stone tiles should be:

- Reaction resin adhesive type R1 or R2 for moisture sensitive (1 or 2 denotes the strength)
- Rapid setting cementitious adhesive type C2F S1 and C2F S2 (S1 or S2 denotes deformable class)

Note: Cement-based adhesive with S2 (highly deformable) classification should be used where the loading and traffic conditions are not heavy.

Table 5.1 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

Table 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

It is advised that further guidance should be sought from the tile and adhesive manufacturer for the right type of adhesive to be used. It is recommended to always do a mock up as early as possible to ensure compatibility. Though optional, pull out and shear tests to verify the design can be conducted.

2.10 Grout

In considering the moisture sensitivity and thermal stability, resin based agglomerated stone tiles should be grouted with improved cement-based grouts classified CG2 to BS EN 13888 (e.g. CG2A, CG2W or CG2WA) or alternatively with water-free resin grouts. Cement-based grouts are cured faster due to rapid setting but may still contain water as compared to water-free resin-based grout which is better in deformity but takes longer to cure. Water during maintenance may slip through the grout joint and stain the agglomerated stone from the sides.

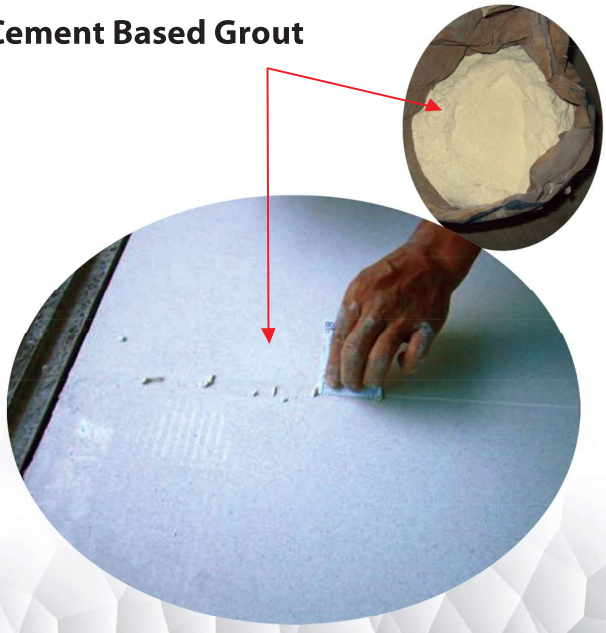
Another aspect to consider is whether the agglomerated stone tiles require sealing as it may affect the adhesion of the grout if it is accidently applied to the sides of the stone.

For straight-edged agglomerated stone tiles, resin-based grout will provide a "seamless" finish (i.e. which make the whole tiled area look monolithic), especially when another round of polishing and coating (optional) is done after grouting. The silhouette of any straight object, e.g. window, sliding door etc., will appear straight rather than wavy at an angle.

BS EN 13888 Table 7 – Classification and designation

Symbol Type	Class	Description
CG	1	Normal cementitious grout
CG	2W	Improved cementitious grout with additional characteristic of reduced water absorption
CG	2A	Improved cementitious grout with additional characteristic of high abrasion resistance
CG	2WA	Improved cementitious grout with additional characteristics of reduced water absorption and high abrasion resistance.
RG		Reaction resin grout

Cement Based Grout



Epoxy Based Grout

It is important to consult the supplier of the agglomerated stone tiles to establish if the tiles should be sealed before the grouting process begins. To ensure good adhesion of the grout mortar in the joints, care should be taken to ensure that the sealer is confined to the surface of the tiles and that the sides of the tiles remain untreated.

To ensure full/maximum penetration/filling of the joint, un-sand/non-sand cement-based grout should be specified for tile joints of 3 mm and below. The un-sanded grout is better suited to fill smaller gaps, flows better and has the ability to stay consistent. Sanded grout will not achieve the required depth of penetration in smaller joints and its consistency will change when spread. The sand component will become heavy while the cement component becomes light. This makes for very weak grout which may loosen and come off with scrubbing or pressure cleaning.

Polyester resins are rigid once cured and do not expand nor contract to different temperature variations and in extreme case, may be prone to delamination. Epoxy resin however will soften and lose its structural strength once exposed to temperatures above 65°C.

Resin-based RG grouts costs more and is more tedious to apply (as it sets quickly) and rectify as compared to cement-based grouts. While resin-based RG grout is stain-proof, it hazes or residues on tile surfaces with a glossy sheen and looks plastic. To avoid this, it is important that the installer cleans the tiles properly before and after grouting as it will be very difficult to clean once cure.

2.11 Impregnator

For agglomerated stone tiles that will be installed in an environment prone to staining, the application of a good-quality impregnator should be considered on the top surface. The main objective of an impregnator is to block contaminants from entering the substrate of the stone while at the same time allowing it to expel interior moisture. They are therefore 'breathable' or vapour permeable.

Often confused with sealer which seals agglomerated stone tiles at the surface, the impregnator seals the agglomerated stone from the inside. Sealers are much cheaper than impregnators but require frequent stripping and re-application especially at high traffic areas. Unsightly scuff marks will appear and will slightly darken the shine and colour of the agglomerated stone.

Impregnators can either be solvent-based or water-based. The solvent or water acts as the carrier which brings the resins into the stone. As the carrier evaporates, the resins are left in the stone to seal. Generally, solvent-based impregnators are better and lasts longer as they penetrate deeper into the agglomerated stone. However, they may not be environmentally friendly due to the volatile organic compounds (VOCs) contents.

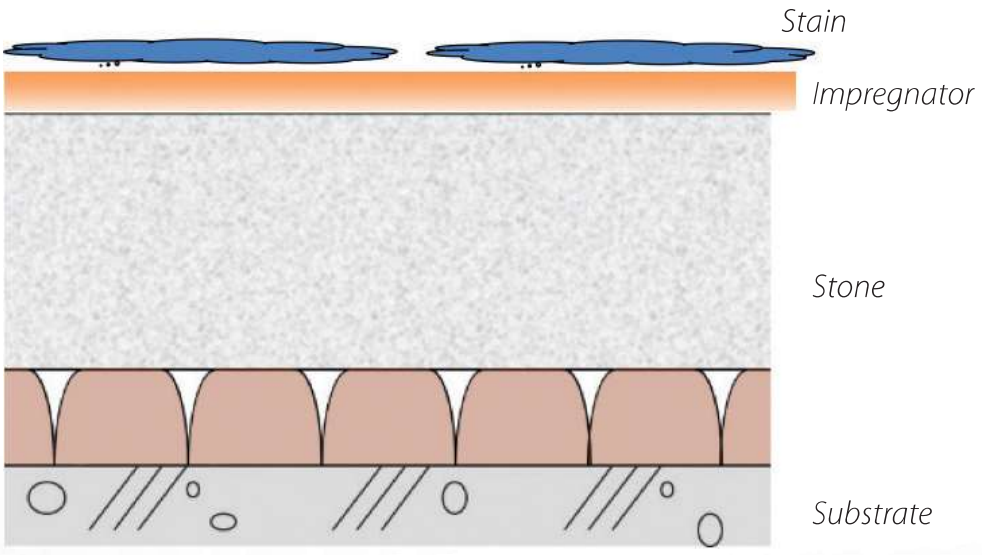
Another aspect to consider is whether the impregnator is an olio phobic or hydrophobic product. An olio phobic impregnator will repel oil and water-based liquids whereas a hydrophobic impregnator will only repel water-based liquids. Many hydrophobic sealers are labelled 'oil resistant'. However this only means that they will slow down the absorption of oil while still allowing it to eventually enter the stone. Olio phobic impregnator is suitable for use in the kitchen area and bathrooms. The kitchen area is where a range of different liquids are likely to stain and damage the agglomerated stone while bathrooms are where there can be a high concentration of body fats.

The most popular resins are silicone, silane, siloxane, ester epoxy and fluorocarbon alphatic (a.k.a. fluorochemicals). Fluorocarbon alphatic resin is recognised as the best and longest lasting performer. It is also easier to produce in a formulation that can be carried by water, which eliminates the use of volatile and hazardous mineral solvent.

Sealers on the other hand will provide protection on the surface and can better resist stains but are susceptible to change in appearance (create shine and darker tone of colour) and will require frequent stripping and reapplication.

Nevertheless, it is always recommended to consult the manufacturer whether the selected agglomerated stone requires an impregnator, especially if the water absorbency is lower than 0.02% by weight. Green Marbles (Serpentinite) require sealing when installed in an environment where staining is likely to happen.

A simple test can be done by placing a drop of water on the agglomerated stone tile. Let it dwell for about 5 minutes and then wipe it dry. If a darkened patch appears where the water droplet was (it will disappear once the water evaporates), it would mean that some of the water was absorbed. Hence, an impregnator should be considered if the agglomerated stone is to be installed in an environment prone to liquid staining.



2.12 Movement Joints

Resin based agglomerate stone tiles are more sensitive to thermal expansion and contraction as well as dampness from underlying screeds, thus requiring more movement joints to be installed as compared to stone or ceramic floor tiles. BS 5385-5:2011 (Code of Practice on design and installation of terrazzo, natural stone and agglomerated stone tile and slab flooring) advises that, in normal conditions, movement joints should be installed at bay sizes not exceeding 36m^2 as resin based flooring units can have a coefficient of thermal expansion more than three times that of cement terrazzo and natural stone.

Movement joints for the flooring described in BS 8204-1 are as follows:

1. flexible joints aligned to structural movement joints
2. flexible movement joints to accommodate smaller movements than structural joints
3. contraction joints which are non-compressible to relieve tension

BS 5385-5:2011 also advise that structural movement joints should be provided where flooring abuts restraining surfaces (e.g. perimeter walls, columns, kerbs, steps and plant fixed to the base) that are more than two metres apart. Movement joints should be contiguous with the perimeter movement joints and placed where the flooring runs across door thresholds.

For agglomerated stone tiles bedded on substrate with higher differential movement characteristics (e.g. metal panel, aerated concrete, etc.), minor spalling at grouted joints or fracture and major dislocation of the agglomerated stone tiles may occur. Installing stress relieving movement joints is recommended as it prevents damage from restrained dimensional change.

It is also important to note that where resin based agglomerated stone tile flooring is subjected to high temperatures (i.e. from strong sunshine), an assessment of the likely temperature range and corresponding linear changes should be made.

A typical installation of agglomerated stone tiles should include movement joints within the tiled area itself and on internal corners of walls, along with the floor-to-wall connection. They should also be used at the perimeter of applications of over two metres, or where there is excessive thermal and vibration movement. A movement joint must be inserted where the floor goes over a structural beam or where there's a supporting wall below.

All movement joints must be properly formed, according to the degree of exposure, with a suitable flexible material. The extension capability and recovery performance of the chosen joint former or sealant would determine the actual joint width. In this guidebook, the recommendations for spacing and sizes of movement joints are based on the context of a typical indoor environment in Singapore.

It is important that the designed minimum gap is not obstructed. Checks should be carried out before joints are sealed. Perimeter joints can usually be hidden beneath the skirting.

If there is presence of day-work joints, they should be bonded during screed installation as recommended in BS 8204-1 (BS 8204-1:2003 + Amendment 1:2009 Screeds, bases and in situ floorings). As for movement joints, they should be post-cut in the screed during setting out of the floor tiling.

Reinforcement in screeds should cross all day-work joints to ensure that no unpredicted movement can affect the performance of the agglomerated stone tile flooring particularly where the agglomerated stone tiles are installed using adhesive.

Where underfloor heating/cooling system is used, the pipes or cables should be strategically located to ensure that the system is contained within the pattern of movement joints.

Pre-formed movement joints come in various widths. The amount of movement that can be absorbed depends on the size of the joint and the compressible material used. Thus, it is important to consider the thermal movement and traffic density of the target area when selecting the width and material (e.g. brass, aluminium, stainless steel and PVC) of the movement joint. If not, the installation is likely to fail.

Pre-formed plastic expansion joint

When selecting the suitable width, it is useful to note that pre-formed surface joints usually accommodate movement up to 20% of the movement zone width. Thus, a 10mm-width joint will extend and compress by approximately 2mm. As for the suitable type of material, aluminium is generally ideal for commercial use, whereas brass and stainless steel are used for heavy commercial and industrial projects such as warehouses, production facilities and airports (i.e. where the tiled surface is cleaned by a scrubbing machine or where there are rolling loads such as pallet trucks and metal-rimmed trolleys). Stainless steel is also ideal where chemicals are used, such as laboratories and food processing plants. PVC can be used for residential and medium duty commercial applications including offices and swimming pools, and areas subjected to light mechanical loading such as showrooms and car dealerships.

Aluminium or Steel strip can be used as divider

3.0 INSTALLATION

3.1 Ordering

The consistency in colour and chip match of agglomerated stone tiles is superior to marble or granite. However, as the base product is natural, each slab's colour may vary across production batches. It is, therefore, advisable to place orders in a single batch (depends on the limit to volume per batch) if possible, so that the manufacturer can blend raw materials in a single batch to minimize risk of tonality variation. It is also important to ensure that one does not install a mix of agglomerated stones from different batches.

Do note that for white agglomerated quartz tiles, small black specks may appear as it is not always possible to remove all the tiny black chips.

3.2 Quality Control at Factory

When ordering agglomerated stone from unknown sources, do consider making a trip down to the factory to have a look at the manufacturing processes and facilities used in the production. In addition, it may be necessary to verify with the manufacturer's research laboratory on the research and type of tests done.

Things to look out for in the factory visit:

1. Source of stone
2. Storage condition of raw material (preferably sheltered)
3. Method of controlling the mix proportion
4. Method of production – vibro-compression
5. Method of curing – sheltered and period of curing
6. Method of cutting block to slab – gangsaw or diamond wire
7. Method of calibrating – preferably automated
8. Method of polishing – preferably automated
9. Method of cutting tiles from slab – laser guided
10. Method of quality control and sorting – i.e. Quality control by human or automated using imaging technology
11. Method of packing – preferably sealed
12. Establishment of the test laboratory

To ensure the production is in order, it is recommended to consider deployment of a qualified personnel at the factory to witness the entire production process all the way to packing and sealing the shipping containers.

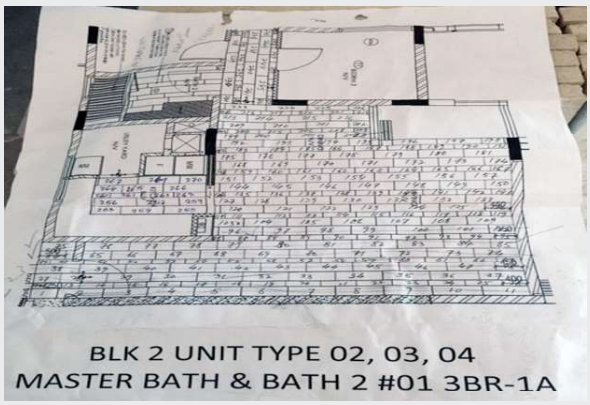


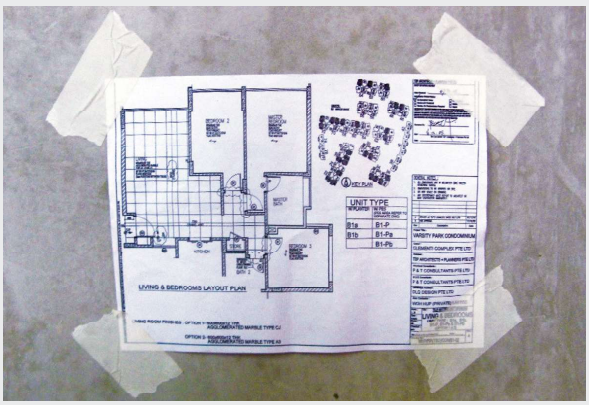
3.3 Site Storage

Agglomerated stone tiles should be stored indoor and prevented from getting wet. Extra care should be taken to ensure that the edges on the surface of the agglomerated stone are not damaged or chipped during handling.

3.4 Tile Layout Plan, Shop Drawing & Method Statement

Prior to installation, approval should be sought for the proposed tile layout plan (especially for alignment with fittings), shop drawing (especially on details of movement joints) and method statement for the installation process.





Approved tile layout plan displayed on site wall for easy reference.

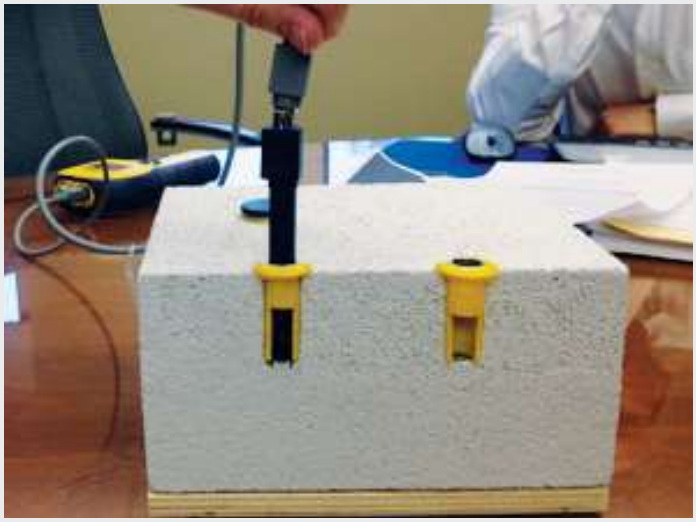
3.5 Quality Control before tiling

Prior to commencing the installation of tiles:

1. Clean substrate to ensure it is in good condition for installation and remove curing compounds, sealers, soil, mortar, dirt, dust, etc. that might affect the bonding
2. Seal all cracks with epoxy resin or approved method by the consultant
3. Check moisture level of substrate
4. Clean the agglomerated stone tile to remove dust that affect bonding

As resin based agglomerated stone tiles are sensitive to water, checking the moisture content of substrate is important before tiling. Normally, a quick check using a portable moisture meter (e,g, Tramex, Portimeter, etc) would suffice. The permissible moisture level will depend on the type of adhesive used and it is advisable to follow the adhesive supplier's recommendation. The number of spots to be check is optional but do consider checking those spots near windows as the moisture level may be affected by rain.

Portable moisture meter for quick check of moisture level of substrate surface



ASTM F2170 – 11 method involves inserting RH probes into the middle of the slab for more accurate reading of moisture in slab/wall

3.6 Application of Sealer

Agglomerated stone tiles may require sealing depending on the manufacturer's recommendations. Always ensure that the correct impregnator is used as most water based sealers will be repelled by the resin binder in the tile. The use of a solvent based product will be required in most cases. It is recommended to test on an un-laid tile before treating the whole area as some solvent products may cause damage to the surface structure and discolour the tiles.

Pre-sealing some resin tiles will make removal of the excessive grout residue easier. It will also protect against possible bleed, tram-lining or picture framing i.e. the shadowing that an unsealed tile can show if the face and edges are not sealed. This effect can be caused by moisture, sometimes contaminated with grout colourant, which can be absorbed into the edges of some resin tiles. Such staining can be very difficult to remove from these tiles. It is recommended to seek advice from the manufacturer or supplier.

3.7 Floor Tiling

The common bedding prepared for installation of floor tiles involves casting a 20 mm to 30 mm thick cement-sand floor screed over a concrete floor slab. The screed should be cured for a minimum of 14 days before laying of tiles, failing which, cracks or debonding of tiles may occur due to inadequate surface preparation. Do check and rectify any hollowness or cracks and ensure levelness of not more than 3 mm gap over 2 m prior to tiling. Self-levelling (non-shrink type) may be required to correct the level.

Do consider using pre-packed quick drying screed to reduce curing time and for better quality control on the mix.

Screeding with pre-packed quick drying screed over concrete slab

For screedless floor system, floor tiles can be directly glued to the concrete slab with a thin-bed (non-shrink type) adhesive of up to 10mm thick. In view of the thickness of the thin bed adhesive, it is recommended to check with adhesive supplier for the right size of notched trowel to be used. Do ensure that the concrete slab is properly cured (minimum 28 days) and cracks are rectified prior to tiling.

Ensure proper sequence and tools used for installing agglomerated stone tiles.

During installation, proper tile spacer (usually made of plastic) should be used to ensure consistent tile joints and also to provide expansion joints at all edges to wall.

Use plastic spacers to ensure consistency of width of tile joints.

3.8 Wall Tiling

The common background for agglomerated stone tiles is cement-sand render as it is dimensionally stable and of sufficient cohesive strength. The thickness should not be more than 20 mm thick and applied in minimum of 2 coats with mechanical keys to prevent sagging or sliding during application. Common methods for creating mechanical keys are by spatterdash and bonding coat methods. Additional anchored metal lathing should be considered if the render is too thick.

For cement-sand render bedding, do allow a minimum of 10 days for curing before tile installation. It should also be checked for hollowness, crack and a levelness of not more than 3 mm gap over 2 m.

For tiling agglomerated stone tiles over highly deformable substrates such as plywood or board partitions where the chances of downward movement on a vertical surface is generally high, the adhesive will need to be fast setting, deformable, slip resistant and extended time for large format agglomerated tiles (i.e. type C1 or C2 FTE/S2 as per BS EN 12004).

3.9 Tile Levelling System

To reduce or eliminate lippages when installing agglomerated stone tiles, especially large format type, a suitable tile levelling system should be considered. It is usually designed with a 2-in-1 function as a tile spacer as well. This will help reduce/eliminate the need to level the edges by grinding and ensure consistency of the joint width.

Use of tile levelling system to eliminate/reduce lippages

Do note that this does not mean checking on the tile sizes and flatness are not required. It will generally eliminate/reduce lippages if the tile sizes and flatness are within acceptable tolerance.

3.10 Grouting

Grouting can be done once the tile adhesive has set. Pre-packed cementitious grout should be mixed with the amount of water recommended by the manufacturer.

Reaction resin adhesives may require longer curing time.

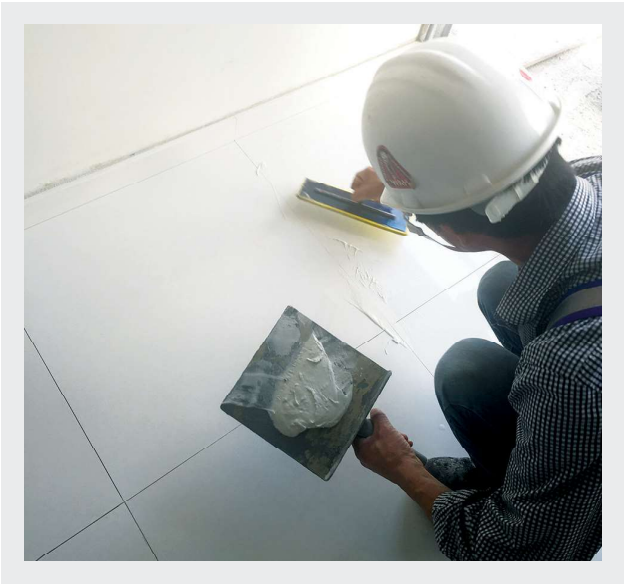
Grouting should not be unduly delayed as open joints might collect general building dust and deleterious substances. Avoid using excessive amount of water during the grouting process.

Cement based grout should be cleaned off within the recommended working time and with minimum amount of water. Reaction resin grout should be also cleaned off within the recommended working time and ensure that all traces are removed from the face of the tile.

It is essential that all the joints are completely filled with grout to ensure that the grout is long lasting. This can be accomplished by making several passes over the same area from different directions with the grout float. For thick agglomerated stone tile, it is recommended to consider using a modified tool to push in the grout.

For thin joint width like 1.5mm, reaction resin grout will be better able to fill up the joint and prevent water from entering the agglomerated stone at the edges.

Raking tool to compact grout in narrow joints.



Making several passes over joints at different directions to joints are completely filled.

For internal corner tile-to-tile joint and joint between fittings (e.g. bath tub, window etc.), do consider filling it up with colour-matching caulking rather than grouting for better prevention of water slipping through and accommodation of movement.

Please note that some impregnator or sealer manufacturers may specify a minimum time before commencement of the grouting process in order to leave sufficient curing time for impregnators/ sealers. It is recommended to follow the manufacturer's guidelines.

3.11 Cutting Tiles

Additional health safety precautionary measures should be taken at this stage. Prolonged inhalation of crystalline silica released during sizing, cutting, grinding and polishing of agglomerated quartz can lead to silicosis (scarring of the lungs). Agglomerated quartz tiles generally contain around 93% of crystalline silica, which is much higher as compared to 45% typically found in granite.

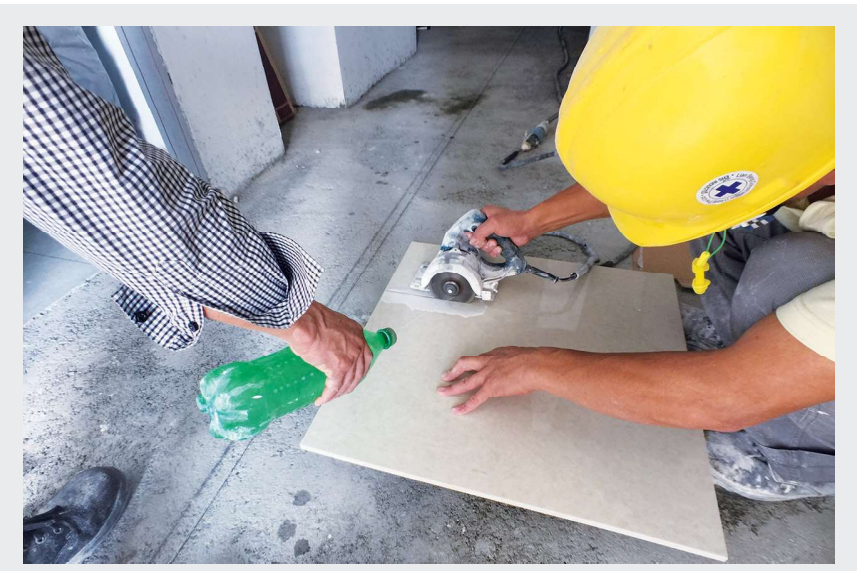
In addition to silicosis, scientific evidence suggests that occupational exposure to crystalline silica puts workers at increased risk of other serious health conditions like chronic obstructive lung disease, lung cancer, kidney and connective tissue disease, and tuberculosis.

The proposed control measure is to do wet cutting, grinding and shaping i.e. wet Suppression. Ventilation and filtration systems (LEV Suppression) should be used to collect silica-containing dust at its source.

The operator must wear appropriate PPE, e.g. N95 Respirator. Tiles should be wiped dry after cutting. Care should also be taken to immediately remove any residue from the tile before fixing, especially from the back and side. It is not possible to cut these tiles using a standard scribe and snap cutter.

N95 Respirator to be worn in cutting agglomerated quartz tiles

Resin based agglomerated stone tiles should be drilled with a drill with a water feed and dried immediately afterwards.



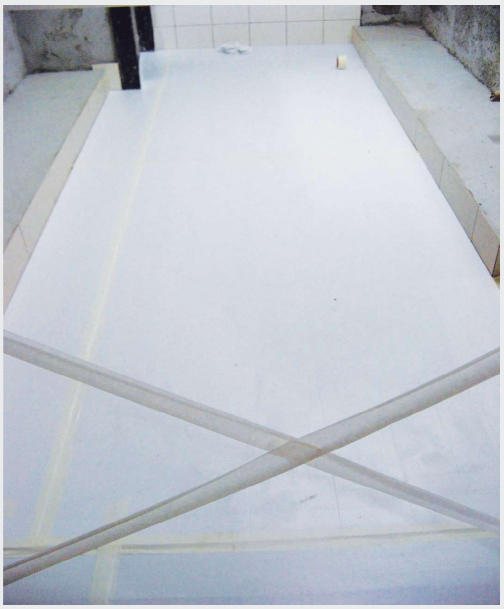
Cutting of agglomerated stone tile with diamond blade cutter and feed with water to control dust

3.12 Protection

After tiling, the tiled area should be kept off limits to any traffic and cured in a well-ventilated dry condition at a duration as recommended by the adhesive supplier. Windows should be closed to prevent the tiled area from exposure to rain. As a guide, normal set will require 28 days to be fully cured as compared to fast set which normally cures after 48 hours,

Traffic over tiled surface should be kept to a minimum. This can be achieved by proper planning of the sequence of processes and locking up the tiled area. Only authorised access should be allowed with proper record and handing over.

For light traffic, plastic corrugated sheets are recommended as the cushion will minimise damages arising from falling objects and point loads (e.g. ladder). The plastic corrugated sheets will not be damaged by water and can be recycled. In addition, always ensure that the joints are tightly sealed with good waterproofed tape to hold the sheets in place as well as prevent water and dirt from entering through the joints.



To barricade tiled area to prevent traffic

Ensure all joints of protection are sealed with waterproofing tape to prevent water and dirt to enter

For heavy traffic area, plywood should be considered with all joints sealed. Do note that the plywood may stain the flooring. As such, do consider lining the back of plywood with white laminate or another layer of plastic sheet to prevent staining.

3.13 Workmanship Tolerances

The general applicable good workmanship standards according to BCA CONQUAS standards for floor and wall tiling are as follows:

a. Not more 3 mm gap over a 1.2 m straight edge for levelness of surface
b. Not more than 4 mm over 300 mm for squareness of corners
c. Not more than 3 mm over 1 m for verticality of surface
d. Falls provided for wet area and in the right direction
e. No hollowness detected when tapped with a hard object
f. No visible damages like chips and cracks
g. Consistent tile joint width
h. No stains on tile and joint
i. No tonality issue or as approved by the consultant

Tile layout should be in accordance to approved tile layout plan. Where skirting is of the same material, the skirting joint is expected to align with the tile joint unless otherwise specified.

Any repaired area should not be visible, patchy or rough.

3.14 Repair

Minor scratches on agglomerated stone tiles can be repaired by buffing, while deep scratches can be repaired by grinding.

Lippages can be repaired by grinding and polishing. Special lippage disc is required for heavy grinding of serious lippages that are over 1.5mm. Otherwise, at least 4-5 stages of diamond disc grinding are required starting from 50 and/or 120 grit, 220 grit, 400 grit and 800 grit. 1,800 grit grinding may be required if the surface still appears dull. A gross meter may be required to check the degree and consistency of gloss especially at an angle.

Chipped and cracked agglomerated stone can be patched with a proper stone repair kit. The material used for filling should be as strong as the agglomerated stone.

Do consider using proprietary stone repair kit for better repair work and finishing

Hollowed area can be filled by injecting grout of the approved type. Normally 2 drilled holes are required to pump in the filler and for venting out to ensure complete filling.

If the repaired areas are still visible or hollow, replacement of the tile will be the only option. However, a slight variance in the tonality have to be expected especially if the replacement agglomerated stone comes from different batches.

3.15 Final touch

To achieve a seamless look, a final polishing and sealing is recommended after installation. Wavy reflection, distorted silhouette of straight edges especially at an angle may not be acceptable to some owners even though there are no lippages and the evenness of the agglomerated stone floor is within the tolerance of not more than 3 mm gap over 1.2 m length. It is also recommended to consider checking with a gloss meter especially at an angle to ensure consistency in the polishing/ reflection.

To consider a light polish and seal to improve condition of tiled surface before handing over.

3.16 Cleaning after installation

After the grouting is completely dry, the floor may need a gentle wash to remove any grout residue, grease or grime marks that may have occurred during the installation processes.

Do avoid using acid based cleaner as it will react with agglomerated marble tiles as well as alkaline based cleaner as it will stain agglomerated quartz tiles. It is recommended to use a pH neutral cleaner in conjunction with a white non-scratch pad. Always follow the product manufacturer's instruction. As a precaution, it is also recommended to first try it out on a test area to determine suitability of the product. If the problem persists, do contact the manufacturer or supplier for other appropriate product and application advice.

3.17 Maintenance

Dust mopping or vacuuming as often as possible for homes and more in commercial buildings to prevent/minimise damages to the surface and the sealer caused by traffic. Placing a floor mat at the entrance to the building will trap grits and dust thereby help to reduce damages.

Although agglomerated quartz tiles have better chemical resistance properties compared to agglomerated marble tiles, spilled food (oil) and liquid e.g. fruit juice, vinegar, wine, coffee, coke, etc., should be removed quickly to prevent staining of the agglomerated stone tiles. It is recommended to blot the spill instead of wiping the area to restrict the spreading of the spill. Follow up by flushing the area with plain water and mild soap, rinsing several times as needed. Buff dry the area thoroughly to prevent any water residue marks on the agglomerated stone.

Steam mops should not be used for cleaning resin based agglomerated stone tiles as prolong exposure to heat may cause localised damage on the resin and the sealer.

Use a good stone cleaner or stone soap for wet mopping. Stone cleaners should be pH7 (neutral). Always towel or buff dry after mopping as water may leave etch spots if left to dry.

For commercial applications, regular periodic buffing may be required to remove stubborn stains and revitalise the surface. Do not use cleaners with wax.

Household and commercial cleaning products must be used with caution as they may contain bleaching agents or ingredients that may burn or discolour resin finishes. It is always recommended to contact the manufacturer or supplier for advice and product information.

Regular buffing to maintain original floor finishes

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