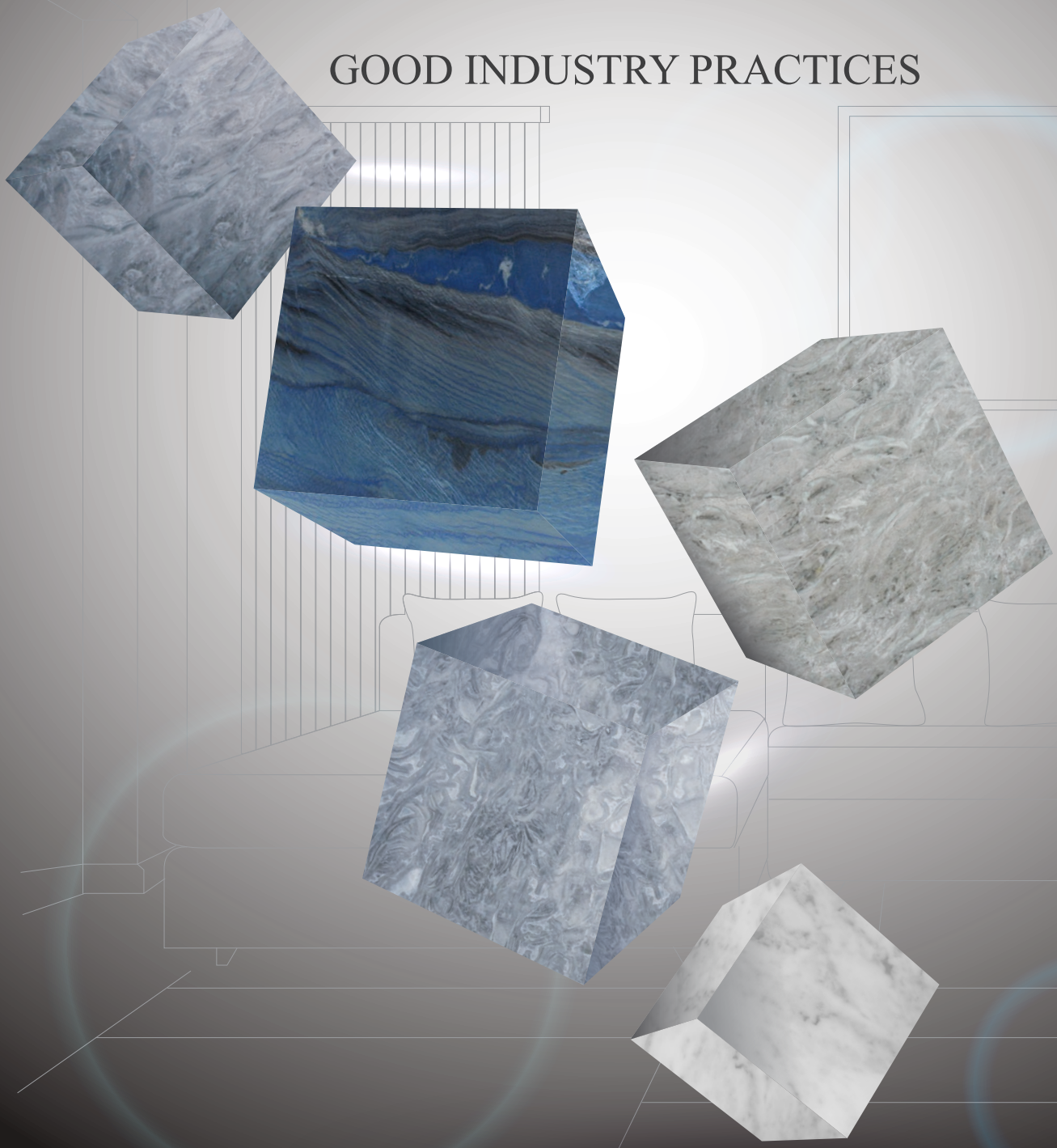
CONQUAS Enhancement Series

NATURAL STONE FINISHES

GOOD INDUSTRY PRACTICES



Building and Construction Authority

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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 higher consistency in 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 Guides are part of the CONQUAS Enhancement Series which share some of the good practices adopted by practitioners and contractors on how good workmanship quality can be achieved on site. BCA has updated this guide to keep pace with new practices, construction methods, materials and products adopted by the industry. The "Good Industry Practices – Marble & Granite Finishes" has now been renamed to "Good Industry Practices – Natural Stone Finishes" guide.

This updated guide will be more inclusive as it aims to provide clear and practical illustrations on the quality checks of natural stones during manufacturing and installation. Common issues associated with natural stone finishes, their causes and possible solutions to address them are also highlighted.

This guide is not meant to be a definitive dictation on how natural stones must be designed and installed. It only serves to illustrate some of the good practices designers and contractors have adopted while designing and installing natural stones. We gratefully acknowledge the contributions of practitioners in the production of this guide and trust that the industry will find this publication useful. We welcome any contributions from readers to further improve any subsequent editions of this guide.

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ACKNOWLEDGEMENT

This edition of 'Good Industry Practices – Natural Stone Finishes' was developed with inputs from architects, developers, builders, specialist contractors and members of various industry associations and organisations.

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

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1.0 INTRODUCTION

A natural stone finish is a system comprising no less than substrate, adhesive, stone, grout and movement joints. All components are equally important and intimately related to one another. Adequate compatibility must exist among the components as they could only function collectively. The system could only be as strong as the weakest component, if not worse.

Therefore, material selection, system design, method identification, installation execution and maintenance must take into consideration the performance characteristics of each individual component, and the in-situ environmental conditions that prevail during the installation process as well as the long term usage. These considerations are similar for new technologies and materials in Design for Manufacturing and Assembly such as Prefabricated Prefinished Volumetric Construction (PPVC) and Prefabricated Bathroom Unit (PBU). It is recommended to refer to the respective guides for natural stone installation in these technologies.

Due to the volume constraint, this guide will focus on interior installation and finishes of natural stones.

2.0 DESIGN

To achieve good stone finishes, it is critical to take into account the material selection besides proper installation and quality control. It is important to understand the characteristics of the selected materials as well as their compatibility with one another to achieve optimal performance.

2.1. STONES SELECTION

Natural stones are cut into blocks at the quarry and then transported to a processing plant where they are cut into slabs. Modern tools such as the wire diamond cutter has improved the precision and quality of cutting blocks of stone into slabs. The slabs undergo further processing such as polishing, drying, being further cut into different sizes and dry laying in factory before getting packed for delivery.

Natural stones are formed under varying conditions, hence no two pieces bear the same composition and appearance. Besides geological types, stone names have been greatly compounded from commercial trades and quarry origins, making them very difficult to comprehend. To aid selection, the only characteristics that are relevant to the performance of the stone finishes are discussed here.

2.1.1. Types of Stone

Stones are classified into 3 categories:

- ***Sedimentary stone:*** Formed from sediments in rivers or glaciers broken off from organic or inorganic elements, accumulated and consolidated to form rock beds. Limestone and sandstone are examples of sedimentary stone.
- ***Metamorphic stone:*** Originated due to transformation of existing rocks under very high heat, pressure and fluid. Marble and slate are examples of metamorphic stone.
- ***Igneous stone:*** Formed from volcanic material such as magma which cooled and solidified. Granite and basalt are examples of igneous stone.

2.1.2. Characteristics of Stone

The characteristics of stone are dependent on the way they were geologically formed, as such, each type of stone is unique. Variations of grain and vein formed differ from stone to stone. Some stones show very little variations in colour but may show variations in pattern and grain density while others may show wide variations in colour, vein formations and porosity.

2.1.3. Types of Surface Finishes

Surface finishing is another factor that influences stone selection. Different surface finishes provide different characteristics such as slip resistance, chemical resistance, maintenance, etc. Consequently, the surface appearance of processed stone differs markedly from that of unprocessed surface. The different types of surface finishes and its applications are as follows:

- ***Polished:*** A shiny glossy surface is achieved by using diamond abrasives grit followed by polishing powder. The surface is very smooth and has a mirror-like effect. Polished stone is not porous and has higher resistance to humidity and chemicals. Typically used for internal floorings.
- ***Honed:*** Diamond abrasives are used for honed finishes as well. The surface is smooth, non-reflective and is more porous, unlike a polished finish. Typically used at both internal and external areas with less exposure to chemical or moisture.
- ***Sandblasted:*** A matte textured surface with no gloss as a result of a pressurised flow of sand and water. Typically used for exterior walls.
- ***Abrasive:*** A flat, non-reflective surface with no gloss. Typically used for areas exposed to weather such as entries, foyers, etc.
- ***Exfoliated (Flamed):*** A rough and very porous surface that is produced by applying a high temperature flame to the surface of the stone causing crystals to pop. Typically used for external areas where slip resistance is prioritised.
- ***Others:*** Includes antique, bush hammered, natural cut, etc.

2.1.4. Wet Areas

Wet areas are areas within a building that are exposed to water splashing or direct wetting. Wet areas are commonly installed with discharge outlets and provided with water inlet supply. Installation of stones in wet areas require good design and planning. Due to their natural properties such as porosity and vulnerability to moisture ingress, it is important to seek the supplier's recommendation when selecting stones in wet areas. Marble, Limestone, Quartzite and Slate are some of the suitable choices of natural stones in wet areas.

Fall in wet areas should be laid towards the discharge outlet in accordance to specification and drawings. Insufficient gradient, uneven laying of stones and lippages in wet area may lead to ponding and possibly staining of the stones.

For natural stones that are exposed to weather or outdoor conditions, it is important to follow the recommendation of the designers, manufacturers or suppliers on the suitability of stones, types of adhesive, types of stone sealer, and types of grout (if any) etc. to achieve the optimum performance of these materials.

2.1.5. Slip Resistance

Most natural stones would have good slip resistance under clean and dry condition regardless of their surface finishes. However, when wet and/or contaminated, the slip resistance may deteriorate or drop, especially so if stone is of a polished finish. For safety, the slip resistance class of the selected stone can be established in accordance to SS 485:2011 for testing of dry floor friction.

Mineral or resin polymer floor coating may be applied to improve slip resistance of an existing floor. Resin polymer floor coating dries to a matt sheen and requires 3 days of curing. Mineral floor coating is virtually translucent and the usage is immediate when it dries but has a lower Slip Resistance Value as compared to resin polymer.

2.1.6. Selection Criteria

Prior to starting stonework, it is important to ensure that the selected stones are able to meet the project specifications. Table 2.1.6 provides guidance on the selection criteria.

Table 2.1.6. Stone selection criteria

Stone selection criteria	Requirements
1. Stone condition	- Variations in colour, shade, texture and vein patterns are unavoidable. - Inherent variations, geographical location and climate of the country of origin should be taken into consideration when selecting stones.
2. Traffic and load conditions	- Appropriate types of stone should be used for light and heavy traffic areas depending on the load conditions. Harder stones are preferred for heavy traffic condition such as loading and unloading areas. - For heavy traffic condition, based surface of stones should be flat to ensure sufficient adhesion and stability.
3. Abrasion resistance	- For flooring application, harder stones should be used. - Minimum abrasion resistance for stone floors used in: a) Public areas such as lift lobby, stairway and entrance, shopping mall and MRT station shall be 10 ~ 12 in accordance to ASTM C241. b) Residential areas with light foot traffic shall be 8 in accordance to ASTM C241. - To prevent uneven wear, the abrasion resistance shall not differ by more than 5 in accordance to ASTM C241 if different stones are used together.
4. Chemical stability	- There shall be no chemically unstable minerals, especially in white stones, that may impair the durability of the stones or cause objectionable staining. - If in doubt, petrographic examination is recommended to be carried out to identify potentially unstable minerals such as mica, pyrite etc. before installation.
5. Slip resistance	- For safety reason, the slip resistance classification needs to be established based on usage of the location. Reference can be made to SS 485:2011.
6. Thickness	- Stones must be sufficiently thick to resist load due to traffic and impact. The thickness of: a) Stone tiles are up to 12mm thick and no greater than 610mm along any dimensions in accordance to EN 12057. b) Stone slabs are greater than 12mm up to 80mm thick and of any dimensions in accordance to EN 12058. - If different thickness of floor and wall stones are used, inconsistent tonality could occur even if it is of the same colour tone. If it is necessary to have the same matching colour for both floor and wall, stones of the same thickness should be used. - Table 2.1.7 describes the dimensional stability of stones.
7. Durability	- Stones exposed to high levels of moisture such as in bathrooms, outdoors and floorings shall be evaluated for durability in terms of salt crystallisation damage and efflorescence. - Capillary porosity, saturation coefficient and salt crystallisation tests shall be carried out to ascertain whether the stone is durable. - Even if the stone selected has proven durability, excessive wetting could still cause deterioration.
8. Stone supplied	- The supplier should specify the country where the stones are cut, processed and polished. - Stones should be polished in the factory. Stones with chamfered edges are recommended as they tend to minimise the problems of lippage. - However, with chamfered edges, there may still be some degree of jagged edges and slight accumulation of dirt at the joint between stones.

2.1.7. Dimensional Stability

Modern production technology has made it possible to cut natural stones into slices as thin as 8mm to 10mm. These stone veneers can be installed as a pre-finished surfacing material just as easily as ceramic tiles.

However, these thin materials are sensitive to moisture; in essence, water contained in the adhesive may react with these stones and cause them to warp. The supplier should furnish the performance data and provide warranty for these products.

Stone veneers are classified into 3 groups. Table 2.1.7 classifies the stones base on their dimensional stability.

Table 2.1.7. Classifications of stone based on dimensional stability

Group	1	2	3
Warping (under specific condition for 6 hours)	Less than 0.3mm	Between 0.3mm to 0.6mm	More than 0.6mm
Suitable adhesive	Normal setting adhesive	Fast-setting and high gripping adhesive	Reaction-resin adhesive that contain no water

2.1.8. Confirmation of Stones Selection

Where consistent colour tones and patterns are required, it is recommended that the following procedures be carried out to confirm the quality of stones selected:

A. Mock-up at site
B. Pre-lay at factory
C. Dry lay at site

As these procedures are labour intensive with time and cost implications, they should be specified prior to the finalisation of negotiations of price and completion dates.

A. Mock-up at Site

A sample floor or wall selection of a suitable size should be installed, grouted and cleaned using specified materials in a pre-selected location on site, as agreed by all concerned. The mock-up sample should be representative of the approved design and the eventual finished work. It shall be retained as a reference standard throughout the execution of the stonework.

Representatives from all concerned parties (project developer, architect, designer, supplier, contractor and sub-contractor) should be present at the time of installation of the mock-up. They should notify their approval of the completed mock-up in writing prior to commencement of the actual stonework.

The sub-contractor involved should know the exact standard of quality which they are expected to deliver. The contractor should also ensure the client's quality requirements especially on the project's acceptable tolerances are fully understood.

B. Pre-lay at Factory

It is recommended to verify the method and machinery used in the factory to process the stones. Visiting the factory would be the most immediate and efficient way to witness the natural stones' characteristics, patterns of the veins and varying colour tones. Pre-laying should be done in an area with appropriate and adequate lighting. The owner or owner's representative should be given the opportunity to suggest re-adjustments but should also bear in-mind that colour variations and natural veins are intrinsic to natural stones. The stones selected should be marked and packed in appropriate containers. The containers should also be marked to identify the intended location that the stone materials were selected for.

Figure 2.1.8.b. Pre-lay at factory

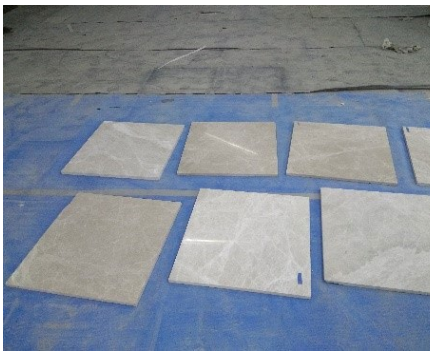
Note: Natural stones having consistent character and colour tone such as granite, may not require a pre-lay procedure.

C. Dry Lay at Site

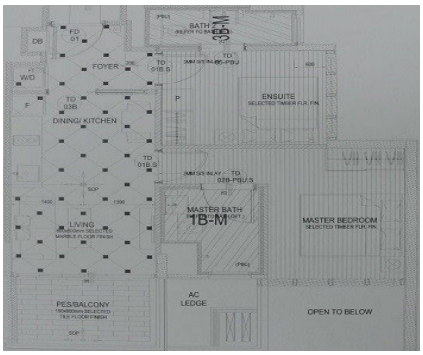
Procedure of dry lay at site is similar to pre-lay at factory. The stones selected should be marked in accordance to the intended setting out design, packed in appropriate containers and delivered to the location where they are to be fixed. At the fixing location, stones should be stacked on an appropriate material to prevent any rising dampness that might affect the stones. The stones should be laid in accordance to the dry layout marking.

Dry lay in units is the best simulation of installation as the stones are exposed to the actual conditions (such as natural light from windows and balconies) as seen by unit owners. Dry lay at site also offers an additional verification of the factory pre-lay materials. However, the fragility of some natural stones and the possibility of damage due to multiple handling (during dry lay), site condition and space constraints, it is recommended to consult the suppliers on the appropriate option to choose.

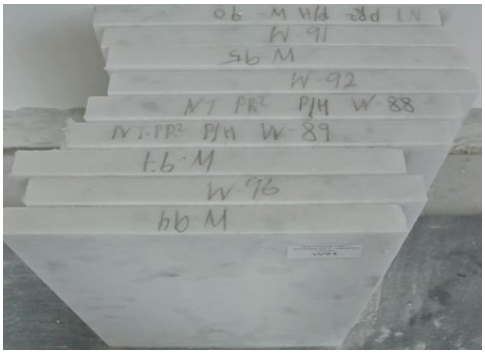
Dry lay at site



Tonality sorted out



Stone to lay in accordance to approved drawing



Stones marked in accordance to dry lay sequence

Stones stacked after dry lay

Figure 2.8.1.c. Dry lay at site

2.2. ADHESIVE

Adhesive or also known as thin-bed mortar, is used to provide cohesion between substrate and stone prior to grouting. To ensure good quality finishes and problem-free installation, it is important to select a compatible adhesive. If in doubt or unsure of the performance of the adhesive, it is a good practice to consult the manufacturer.

2.2.1. Types of Adhesive

Based on EN 12004/12002 and ISO 13007-1, there are primarily 3 types of adhesive:

- Cementitious (Type C): Mixture of hydraulic binding agents, aggregates and additives which is mixed with water or liquid latex admix before use.
- Dispersion (Type D): Mixture of binding agent in the form of polymer dispersion, additives and other mineral fillers which is ready for use.
- Reaction-resin (Type R): Mixture of synthetic resins, mineral fillers and additives in which hardening occurs by chemical reaction.

2.2.2. Classifications of Adhesive

The above types of adhesive can be further divided into the following classes and characteristics:

- Normal adhesive (Class 1)
- Improved adhesive (Class 2)
- Fast-setting with early tensile strength adhesive (F)
- No vertical slip (T)
- Adhesive with extended open time (E)
- Deformable characteristic (S1)
- Highly deformable characteristic (S2)

For cementitious adhesives used in stonework, they are available in single component or two component products.

- 1-component adhesive: Requires only water to be added to a powdered polymer.
- 2-component adhesive: Requires liquid latex additive to be added rather than water.

Both 1-component and 2-component cementitious adhesives are available in normal-setting and fast-setting. For natural stones that are prone to moisture ingress, when using normal-setting cementitious adhesives, 2-component adhesive is preferred over 1-component. Nevertheless, fast-setting adhesive will be most ideal for such stones. Table 2.2.2 shows examples of classifications of adhesive.

Table 2.2.2. Classifications of adhesive

Type of adhesive	Adhesive classes and characteristics	Classified as
a) Adhesive 'X'	Cementitious (C), normal (1)	C1
b) Adhesive 'Y'	Cementitious (C), improved (2), slip resistant (T), with extended open time (E)	C2TE

2.2.3. Adhesive Selection

In selecting an adhesive for stonework, factors such as location of the work (e.g. external or internal of the building), types of substrate (e.g. concrete wall/floor, drywall, etc.) and condition of area (e.g. dry or wet area) should be considered. Although there are established criteria for selecting adhesive for different types of stone, substrate and location, it is a good practice to consult the manufacturer for technical support on the product selected. Table 2.2.3 provides a quick guide on the selection of adhesive.

Table 2.2.3. Selection of adhesive

Type of stone	Location	Substrate	Recommended type of adhesive based on EN 12004/12002 & ISO 13007-1
Natural Stones (less-absorbent)	Internal / External (Wall & Floor)	Concrete / Cement Render / Screed	C2TE
Natural Stones (porous, moisture sensitive and staining)	Internal (Wall & Floor)	Concrete / Cement Render / Screed	C2 F/S1 2-component
Natural Stones with size 600mm x 600mm or more	Internal (Wall & Floor)	Concrete / Cement Render / Screed	C2 FTE/S1
		Deformable substrates e.g. drywall	C2 FTE/S2

2.3. GROUT

Grout is used to fill up the space between stones. Selecting the right type of grout is as important as selecting the right stone and adhesive. Grout should be of suitable fineness and consistency. These would allow the grout to fill the designed joint width successfully.

Adequate grout joint is important as it accommodates for slight sizing difference from one stone to another and prevent them from cracking or ‘popping-up’ due to incompatibility. It also helps to minimise the appearance of inconsistencies in the stones. The grout joint width may vary depending on the type of stone used. The grout joint width should be in accordance to the supplier’s recommendation or BS 5383-3 in the interest of achieving optimum grout performance.

2.3.1. Classifications of Grout

There are 2 types and classifications of grout in accordance to EN 13888 and ISO 13007-3:

- Cement-based grout (CG) : available in Sanded Grout or Non-sanded Grout
  - ❖ Normal Performance (CG1)
  - ❖ Improved Performance (CG2)

- Epoxy-based grout (RG)

Grout is visible and can be water-resistant. However, in most Portland cement based grouts, water or other liquids can still be absorbed into the joints due to its capillary pores. Table 2.3.1 describes different types of grout and applications.

Table 2.3.1. Different types of grout and applications

Type of grout	Descriptions	Applications
Cement grout (CG) – Sanded	Consists of fine graded aggregates, Portland cement, synthetic resins and coloured pigments added with water retentive additive. The water retentive additive allows the grout to stay moist until the cement cured.	- Used for larger grout joints (3mm or larger) - Excellent alternative for natural stones and heavier tiles
Cement grout (CG) – Non-sanded	Consists of very fine filler, synthetic resins, coloured pigment and water retentive additive. The water retentive additive allows the grout to stay moist until the cement cured.	- Used for smaller grout joints (3mm or smaller) - Easier to apply on dry or vertical surfaces
Epoxy grout (RG)	Consists epoxy resin, silica fillers, pigments and a hardener. Epoxy grout is waterless mix formed by mixing a base material (part A) and a hardener (part B).	- Ideal for porous and moisture sensitive stones - Have very low water absorption, higher compressive strength, are resistant to staining and easy to maintain

2.3.2. Grout Performance Criteria

Table 2.3.2.a. Guide on grout performance for CG based on EN 13888 and ISO 13007-3

Fundamental characteristics	Requirement
1. Abrasion resistance	≤ 2000 mm^3
2. Flexural strength	≥ 2.5 N/mm^2
3. Compressive strength	≥ 15 N/mm^2
4. Shrinkage	≤ 3 mm/m
5. Water absorption after 30 minutes	≤ 5 g
6. Water absorption after 240 minutes	≤ 10 g
Additional characteristics	**Requirement**
7. High abrasion resistance	≤ 1000 mm^3
8. Water absorption after 30 minutes	≤ 2 g
9. Water absorption after 240 minutes	≤ 5 g

Table 2.3.2.b. Guide on grout performance for RG based on EN 13888 and ISO 13007-3

Grout performance	Requirements
1. Abrasion resistance	≤ 250 mm^3
2. Flexural strength	≥ 30 N/mm^2
3. Compressive strength	≥ 45 N/mm^2
4. Shrinkage	≤ 1.5 mm/m
5. Water absorption after 240 minutes	≤ 0.1 g

2.4. IMPREGNATORS

The environment where natural stones are installed usually determines the likelihood of staining or discolouring the stones' surface. To prevent stones from surface stains or discolouration, application of a compatible impregnator should be considered. The compatibility may vary from stone to stone, depending on the stone's characteristics.

The main purpose of an impregnator is to block contaminants from seeping into the stones and staining them. Impregnator seals the stones from the inside by penetrating into the stones and chemically interacting through the pores. This process then forms a resistant barrier on the pores surface thus protecting the surfaces from staining and preventing liquids from penetrating through the pores.

Impregnator can be applied on 5 sides (top and 4 sides) or 6 sides of the stone. Moisture ingress from the substrate and occurrence of stains may be a concern for 5-sided applications. In cases where 6-sided applications are requested, precautionary measures should be taken. Applying impregnator on the bottom side of stones may interfere with the bonding performance of adhesive. A 'pull-off' test should be carried out to verify the bonding strength of the stone with the adhesive, or seek recommendations from the adhesive manufacturers.

Impregnators can be either solvent-based or water-based. Solvent-based impregnators penetrate quickly, reaching deep into stones. However, they are not environmentally friendly due to the volatile organic compounds (VOC) contents and they produce a strong smell. On the other hand, water-based impregnators are more environmentally friendly and have little or no smell.

Nevertheless, it is always recommended to seek manufacturer's advice on the selection of impregnators that are compatible to the types of stone used and areas of installation (indoor and outdoor).

2.5. MOVEMENT JOINTS

Movement joints are provided to accommodate movement in large continuous finished areas, or between adjacent building components (e.g. brick wall and concrete column) and dissimilar substrates. It is the responsibility of the designers to identify the various possible movements. These can be:

- in-situ joints which are formed during construction or sawn cut afterwards, filled with filler board and backer rod, and sealed with a suitable sealant or
- prefabricated movement joints which are installed prior to the laying of stones

The backer-rod material in the joint should be compatible with the sealant used. It should be flexible, compressible without forcing sealant.

All movement joints need to be filled with a sealant. The sealant should be capable of accommodating the anticipated amount of movement without loss of adhesion to the sides of the joints and be able to withstand the normal service conditions affecting the installation, e.g. resistance to water and, where applicable, ultraviolet light. If in doubt or unsure of the performance of the sealant, it is a good practice to consult the manufacturers.

Due to tendency of staining, oil-based organic sealant should not be used in natural stone finishing works. The same goes to asphalt-coated materials sometimes used as joint backers.

Locations and details of the movement joints should be specified and shown in drawings in consultation with the supplier/manufacturer. For more details, refer to SS 68, Code of Practice for ceramic wall and floor tiling. Table 2.5 shows the locations of movement joints and their appropriate joint widths.

Table 2.5. Location of movement joints and their appropriate joint widths

Location of joints	Minimum joint width
1. Structural movement joints should be carried through screed/render, adhesives and stone layer. If the joints in the base structure are not straight and parallel, or if their layout does not coincide with that of the stone tiles, guidance should be sought from the designer.	- Not less than the existing structural joint widths
2. Where stone work abuts restraining surfaces, such as columns, beams, perimeter walls, curbs, pipes and ceiling.	- 5mm for interior - 12mm for exterior
3. At junctions where the substrate changes alignments, such as concave wall corners, or where the substrate changes materials, such as between conventional clay bricks and aerated precision blocks.	
4. To divide continuous stone finish on large floors and walls into bays of 50m^2 for interior and 25m^2 for exterior, with the bay lengths not more than twice as long as the corresponding widths.	- 3mm ~ 5mm for interior - 10mm ~ 12mm for exterior

2.6. ADJOINING LOCATIONS / TRADES

Design at adjoining locations or trades i.e. bedrooms and toilets, timber and natural stone floorings is a challenge. Planning for a smooth interface joint involves the understanding of use of the area, sequence of works, matching the finished level of the adjoining flooring or wall and selecting the appropriate interface material. Inadequate consideration may have an adverse impact on the quality of the finishing. Some designers may select joint grout to seal such joint whereas others may introduce metallic strip, capping or sealant as an alternative to achieve a neat joint and to prevent staining of the stone from adjacent material. Figure 2.6 shows examples of adjoining locations and trades.

Joint with metallic strip

Joint with laminate or timber capping

Threshold to reduce water ingress

Window frame flush with wall finish surface

Joint at door frame covered with sealant

Timber skirting – less joints and no wet work

Joint at floor trap covered with grout

Figure 2.6. Adjoining locations and trades

2.7. ANCHORAGE SYSTEM

When anchoring stones with mechanical anchors, the types of anchorage system are dependent on the following factors:

- shape, weight and dimensions of the stone
- height and location to be anchored
- substrate conditions including that of the structure to which the stone is anchored and on the design and material out of which the anchors are manufactured to any case, corrosions due to oxidisation or bimetallic reaction shall be taken into consideration for all anchors dowels, pins and supporting angles

As a guide, at least 4 anchors shall be used to install a stone piece of up to 1m^2 of facial area, and 2 more shall be added for every additional 0.75m^2 on the same piece. For more specific details and designs, refer to BS 8298 Code of Practice for design and installation of natural stone cladding and lining.

2.8. WATERPROOFING

With regard to natural stone finishes, waterproofing refers to the normal protection of the stones from damages due to both rising dampness and direct contact with water, such as in a shower compartment.

2.8.1. Rising Dampness

Continuous rising dampness due to capillary action should be prevented by a proper vapour barrier in the form of polyethylene sheet below floor slab and/or of any damp-proof-course in wall.

2.8.2. Direct Contact with Water

A stone finish, even when its joints are filled with impervious grout, cannot stop water from passing through. In wet areas, a waterproofing membranes should always be installed to prevent water penetrating to the neighbouring areas and below. The water trapped between the waterproof membrane and the stone layer can only evaporate by passing through the stone layer. Depending on the stone type, the evaporation may sometimes lead to efflorescence and watermark on the stone face. To prevent watermarking and staining, a water-repelling impregnator may be applied to the visible face of porous stones.

For more details on waterproofing in wet areas, refer to Good Industry Practices Guide – Waterproofing for Internal Wet Area, CONQUAS® Enhancement Series.

2.8.3. Mixing-Water Transmissions

Mixing water used in construction may take time to evaporate especially in cast-in-situ concrete members. Stone installation should commence at least 28 days after curing of these members to prevent unnecessary moisture transmission through the stone finishes.

Part of the mixing water in cementitious adhesives will unavoidably evaporate through the stone finishes. This is a potential cause of failure for thin and moisture sensitive stones. In relation to this, resin-based or fast-setting cement-based adhesives should be used.

Some specifications call for sealing the back face of stones in order to prevent watermark and efflorescence. However, caution should be taken as the sealer might prevent the adhesives from adhering to the stones. It is a good practice to seek the recommendations of the sealer manufacturer to ensure that the performance of the stone finish is not compromised.

3.0 DELIVERY, HANDLING AND STORAGE

Natural stones are supplied in an appropriate containers such as in boxes or crates. It is important that they are delivered and handled with care and properly stored to protect from exposure to conditions that may affect or damage the stones. It is important to abide to the relevant safety requirements to prevent any accident.

3.1. STONES

Approved stones delivered should be of the same type, category and source and free from any damages. Stones should be packed in well-padded containers that will 'absorb' any impact due to unavoidable movements. This is to prevent damage or chipping to the stones during loading, unloading and transporting. Upon delivery of the stones, it is advisable to inspect the stones before sending them for storage. This is to avoid any dispute between suppliers and contractors.

Stones delivered should not be stored in locations that are exposed to direct sunlight, water and rain unless they are completely protected from damage or contamination. Temporary storage areas should be kept dry and clean from debris at all times.

3.2. ADHESIVES, BEDDINGS AND GROUTING MATERIALS

Adhesives, beddings and grouting materials delivered should be retained in their original packaging with the seals and labels kept intact until the time of use. The materials should be protected from damage or contamination by moisture, excessive heat, foreign matters or other causes. The packages must not be placed directly on the ground to avoid contamination or staining from foreign materials that may be around.

Dry and ventilated storage facilities should be provided on site to maintain the temperature range within appropriate levels recommended by the material manufacturers.

Transporting materials to site

Offloading materials from truck

Sending materials for storage

Storage of materials

Figure 3. Delivery, handling and storage of materials

4.0 PREPARATORY WORKS

Before commencing stonework, the site supervisors should carry out the following preparatory works to ensure proper stone installation:

- Surface preparation
- Screeding / rendering if necessary
- Stone preparation

4.1. SURFACE PREPARATION

The surface of the substrate should be level/plumb and true to design specifications, or to a tolerance of 3mm measured by a 2m straight edge. If the required surface evenness is not achieved, screed (for floor) or render (for wall) should be considered. The substrate should be level, cured to specification, clean and not hollow. It should be free from any loose or deleterious substance such as dust, debris, oil and grease that may reduce or inhibit adhesion of the next layer of material. Any strong acid or alkali on the surface should be neutralised prior to the work of the next layer of material.

In cases where moisture sensitive stones are used, the moisture content of the substrate should be checked by using a portable moisture meter. Where moisture content consistently exceeds the permissible requirement, use of portable moisture meter (measures to a depth of 25mm) may not be sufficient due to its limited depth coverage. More invasive methods such as RH probes or calcium-carbide test may be used. In view of the high relative humidity (RH) in the air locally (almost 95%), the workable moisture content range should be around 2% or < 75% in RH of the substrate. Table 4.1 provides more details on surface preparation for different types of substrate.

Table 4.1. Surface preparation for different types of substrate

Types of substrate	Surface preparations	Remarks
1. Masonry surfaces e.g. brick walls	- Check level and render to level.	In wet areas, apply waterproofing membrane before rendering.
2. Reinforced concrete surfaces	- Concrete to cure for 28 days. - Apply screed to level if necessary.	
3. High-precision concrete block surfaces	- If level satisfies, suitable primer may be applied. Otherwise, apply render to level.	If in doubt, to seek manufacturer's recommendations before rendering.
4. Proprietary partition walls e.g. dry walls	- Manufacturers of these boards should certify their suitability of use. The boards should be installed in strict accordance with the manufacturer's instructions, especially with spacing and grade requirements of the supporting metal studs to ensure the rigidity of the substrate. Boards and steel frames should be strong enough to take the load of the stones and the associated adhesive. - The boards may be coated with a suitable primer to adjust moisture absorption before stone installation. The board manufacturer's instructions should be strictly followed. - The surface boards should be free from contaminations such as dust, laitance, grease, wax, loose or flaking areas etc. - For more details, refer to Good Industry Practices Guide – Drywall Internal Partition, CONQUAS® Enhancement Series.	

Removing concrete protrusion

Cleaning surface with water

Cleaning surface with broom

Checking level of surface

Checking of hollowness

Checking moisture content

Figure 4.1. Surface preparation

4.2. SCREEDING / RENDERING

4.2.1. Screeding

For floor, where screeding is required, pre-packed mortar can be considered due to the consistent quality on the mortar mix.

Screed should be allowed to be air cured for a duration recommended by the manufacturers before stonework. After curing, moisture content should be checked. Permissible moisture level will depend on the bedding used. Any hollowness or cracks must be rectified to ensure soundness of the screed. Levelness also needs to be checked. It should not exceed a tolerance of more than 3mm gap over 2m prior to stonework. This tolerance is not accumulative over the entire span of the floor. Self-levelling screed may be required to correct the level. For a screed thicker than 50mm, a layer of non-oxidising metal-mesh should be considered to be placed in the middle as reinforcement and to prevent screed cracks.

Provide level-pegs before screeding

Screeding with timber float

Figure 4.2.1. Floor screeding

4.2.2. Rendering

Cement-sand based render is also commonly used. The render thickness should be limited to 30mm, otherwise, strips of non-oxidising ribbed metal latching should be anchored onto the substrate prior to rendering. Similar to floor screed, render should be allowed to be cured for a duration recommended by the manufacturers before stonework. Checks as mentioned for the floor, similarly, need to be carried out for the wall as well.

4.3. STONES PREPARATION

For absorbent or porous stones, the front surface and edges may be pre-treated by applying impregnator. Before deciding on the use of impregnator, an appropriate test should be carried out to check on the compatibility of the impregnator with the stones. Always ensure that the correct impregnator is used. Treated stones should be allowed enough time to be cured before installation. Instructions from the impregnator's manufacturers should be strictly adhered to ensure safe application.

Dust and residue on the back surface of the stones should be removed. Coating the back surface with a sealer should be avoided as it may prevent the adhesive from adhering to the stones

Watermark and efflorescence problems can be prevented by specifying adequate adhesive and/or by providing vapour barrier and damp proof course. In any case, a trial test should always be conducted with new combination of materials to verify their suitability and compatibility.

In the case where moisture-sensitive stones are used, the moisture content of the substrate should be checked to ensure that it is within the tolerable range of both the stones and the adhesive. Both the stones and adhesive manufacturer's requirements should be met.

4.3.1. Cutting of Stones

A diamond blade cutter is the best option for cutting stones. It cuts cleanly and is suitable for all types of stone. The proposed method is to do wet cutting. The water lubricates the blade and also helps to cool down the blade from overheating. Stones should be wiped dry after cutting. Any residue from the stone should be removed immediately especially from the back and side. Appropriate proper protective equipment (PPE) should be worn when cutting stones.

5.0 INSTALLATION

Close supervision should be provided on both in-process and finishes work. In order to achieve high overall quality of buildings, it is important that quality control be driven by the site management to ensure that a project can meet its workmanship requirements.

Site supervisor should be adequately trained and display competency in his works. Quality control starts with good planning and it is a good practice to prepare an Inspection and Test Plan, ITP (refer Appendix A) which summaries the project's inspection, acceptance criteria and the frequency of inspection.

Appendix B shows the inspection checklist for stone installation. Site supervisor should carry out the listed in-process inspection to ensure those steps are being properly done.

5.1. ADHESIVE PREPARATION

To prevent poor performance and failure, adhesive should be mixed with consistent proportions in accordance to the manufacturer's recommendations and instructions. In order to achieve homogenous paste free of lumps, only mechanical mixer, clean container and potable water are to be used for mixing of adhesive. The mixing quantity of the adhesive should be limited such that the mixed paste could be used up within pot life of the particular product. Tampering to the adhesive that is about to set by adding water or liquid latex admix will compromise with the adhesive's performance and may give rise to adhesion failure. Figure 5.1.a and Figure 5.1.b illustrate adhesive preparation for 1-component adhesive and 2-component adhesive respectively.

Amount of water in accordance to manufacturer's specs

Pouring measured water into clean container

Adding powdered polymer into container

Mixing with an electric mixer

Adhesive mix ready for use

Figure 5.1.a. 1-component adhesive preparation

Additive (component 1) in accordance to manufacturer's specs

Pouring component 1 into a clean container

Adding powdered polymer (component 2) into the container

Mixing with electric mixer at low speed

Adhesive mix ready for use

Figure 5.1.b. 2-component adhesive preparation

5.2. LAYING STONES

A scratch coat of adhesive should be applied onto the substrate with the flat side of the trowel, followed by spreading the adhesive on top of the scratch coat using a notched trowel. It is recommended to trowel the adhesive in one direction such that the grooves are parallel and much lesser air will be later trapped under the stone. When spreading the adhesive, the area cover should be limited to $1m^2$ or within arm's length to prevent adhesive from setting before the stone is laid. It is also a good practice to apply a coat of adhesive on the back surface of the stone.

The stone should be placed onto the combed adhesive in accordance with the setting out lines. Once the stone is placed in position, tapped uniformly to achieve good surface contact. Appropriate tile spacer should be used to ensure consistent joint width. A spirit level should be used to ensure that the stones are even and level. Alternatively, suitable tile levelling system as shown in Figure 5.2 could be used to level stones. It is usually designed for 2-in-1 function as a tile spacer as well.

Residues of adhesive should be removed immediately before it hardens while work is in progress. The finished surface should be protected and the adhesive should be given enough time to set before joint grouting work.

For screed-less substrate, stones can be directly laid onto the substrate. However, the substrate should be reasonably level to receive the stones. Alternatively, levelling mortar may be applied to correct the level. In view of the thickness of the adhesive, it is recommended to seek advice from the manufacturers on the right size of notched trowel to be used.

Spreading adhesive with flat side of trowel

Trowelling adhesive with notched-trowel

Adhesive fully trowelled

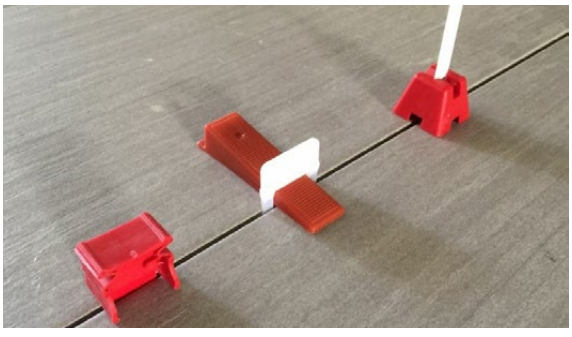
Wipe clean all sides

Applying adhesive on back surface of stone

Tapping on stone for uniformity

Tile spacer for consistent joint

Checking level



Different types of tile levelling system

Figure 5.2. Laying stones

5.3. GROUTING

Grouting can be carried out once the installation of stones are able to receive light foot traffic. The mixing method and procedure for preparing pre-packed cementitious grout paste should be in accordance to the manufacturer's recommendation. Dry or semi-dry mix should not be used to fill the grout joints.

Open grout joints collect dust or deleterious substances and reduce the quality of the grouting. Hence, it is recommended to fill the grout joints as soon as possible. To achieve consistency of pointing colour, it is advisable to grout to one location e.g. bedroom, kitchen, etc. in one operation using the same mix ratio. Grout joints should be filled completely with grout paste by using a soft trowel.

The grout should be given enough time to set and the surplus thereafter cleaned off with adequate tools and cleaning agents. For most grouting products, a damp hard cellulose sponge and clean water should suffice. Once cleaning process is done, the grout should be protected long enough for proper setting and hardening before foot traffic is allowed.

Grout preparation similar to adhesive preparation

Filling grout joints with
firm rubber trowel

Cleaning surplus with sponge
after grout had set

Figure 5.3. Grouting

5.4. MOVEMENT JOINT INSTALLATION

The depth of the movement joint should be controlled, as specified by the sealant manufacturers, by proper filling material and compressible backer-rod with closed pores. To prevent shrinkage cracks to propagate into the stone layer, movement joint to divide continuous stone finish on large floors and walls should also be extended into the underlying screed or render works.

The joints should be sealed by sealant of adequate durability and movement accommodation factor (MAF). In any cases, the instructions from the sealant manufacturers should be followed strictly.

5.5. FINAL PROCESS AFTER INSTALLATION

Final polishing and sealing newly installed or rectified stones are strongly recommended to enhance the shine and provide stain protection before handing over. It is also recommended to consider checking with a gloss meter especially at an angle to ensure consistency in the polishing / reflection.

5.6. INSPECTION OF COMPLETED WORKS

The finished works should be inspected to ensure they meet the client's requirements and standards. Table 5.6 shows the inspection checklist for the final inspection of natural stonework.

Table 5.6. Checklist for final inspection of natural stonework

CONQUAS® assessment checklist

1. Finishing

Standards

- No paint stain or marks
- Consistent colour tone

- Floor divider provided where required or as specified in approved drawings

2. Alignment and Evenness

Standards

- Evenness of surface not more than 3mm per 1.2m
- Lippage between stones not more than 0.5mm

- Fall in wet areas in right direction towards water discharge point or outlet

- Consistent joints and aligned
- Consistent skirting size and joint align with floor if of same material

- Stones meet at right angle and not more than 4mm over 300mm
- Straight edge (stones to stones) and aligned

3. Crack & Damages

Standards

- No visible cracks / defects

4. Hollowness

Standards

- No hollow sound when tapped with CONQUAS rod

5. Jointing

Standards

- Consistent colour and neat pointing

- Consistent joint size and aligned

- No visible gap between wall and skirting

6.0 PROTECTION

The site control of environmental conditions should be maintained after completion of the stonework, until the longest curing time of the materials has lapsed.

Completed stonework should be protected from any traffic, direct sunlight exposure and rain. The completed work should be allowed to cure in well-ventilated and dry conditions, at a duration recommended by the stone suppliers and adhesive manufacturers. Covering the completed work too soon may cause stains or watermarks to appear. Protection can be done by covering the completed area with appropriate protective materials that are suitable to the area of usage. For a more robust protection, it is recommended to provide an up-turn around the perimeter as shown in Figure 6.

Avoid any high impact vibrations and hammering on adjacent and/or backside of walls throughout the duration of curing of materials. It is also important for contractors to communicate between various trades to prevent damages and unnecessary reworks. Establishing a trade working timeframe would be helpful towards achieving an ideal curing process and preventing work conflict between trades.

The protective material should only be removed just prior to handing over to property owners.

Completed stonework protected with protective material

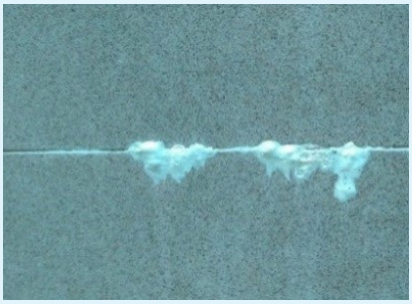
Protection with an up-turn

Completed works protected by restricting access

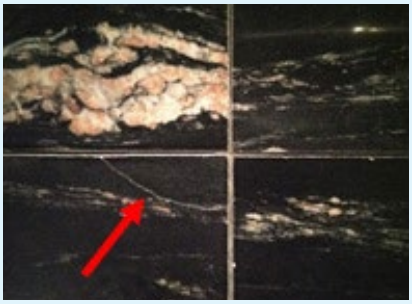
Figure 6. Protection

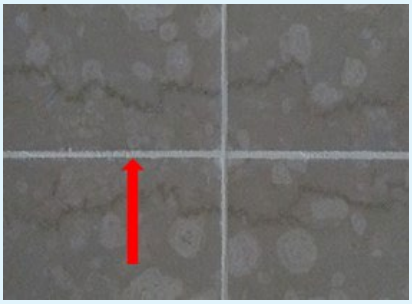
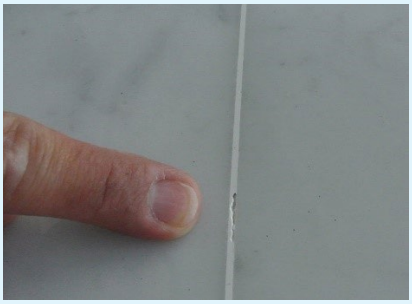
7.0 COMMON FEEDBACK

To achieve good stonework, designers and site supervisors should understand the common feedback related to stone installation and how to avoid them. Workers should be skilled and they should take pride in their craftsmanship. The following are some of the common feedback from owners.

Common feedback	Possible causes	Recommendations
1. Finishing		
1.1. Efflorescence 	a) Salts within stone and/or adhesive and render/screed mortar b) Moisture getting into adhesive and mortar beds from under the floor or through joints	- Avoid excessive wetting - Use proper waterproofing
1.2. Inconsistent tonality  	a) Choice of materials with excessive colour variations b) Lack of pre-laying to ensure colour variation is acceptable c) Prolonged dampness due to water ingress	- Select suitable stone - Carry out pre-lay - Use proper waterproofing
1.3 Paint stain / marks 	a) Protection not provided during paint work b) Spillage of paint c) Insufficient protection coverage	- Provide proper protection - Provide proper protection - Provide sufficient protection coverage

Common feedback	Possible causes	Recommendations
2. Hollowness		
2.1. Hollow stone 	a) Stone set on substrate over a large open area b) Air entrapped in either between adhesive or substrate c) Voids within the stone	- Acoustical effect rather than bonding problems - Stone to be properly laid - Select suitable stone
3. Alignment and Evenness		
3.1. Stones out of alignment 	a) Inconsistent dimensions of stone b) Poor workmanship	- Select suitable stone - Use skilled worker
3.2. Uneven surface 	a) Warped stone b) Varied stone thickness c) Uneven substrate d) Incorrect adhesive thickness	- Proper dimensional stability - Correct stone thickness - Proper surface preparation - Use proper tools / skilled worker
3.3. Uneven level between 2 stones (lippage) 	a) Varied stone thickness b) Incorrect adhesive thickness c) Uneven substrate d) Poor workmanship e) Large stone with narrow grout joint	- Correct stone thickness - Use proper tools / skilled worker - Proper surface preparation - Use skilled workers - Widen grout joint

Common feedback	Possible causes	Recommendations
4. Crack & Damages		
4.1. Scratched stone 		
4.2. Cracked stone  	a) Inadequate expansion joints b) Damaged by other trade or direct impact c) Inherent characteristics of stone e.g. stylolite	- Allow movement joints - Proper protection - Inherent
4.3. Chipped stone  		

Common feedback	Possible causes	Recommendations
5. Jointing		
5.1. Jagged pointing / edge  	a) Insufficient curing time b) Poor workmanship c) Poor cutting and handling	- Follow manufacturer's recommendation - Use skilled workers - Use proper tools and skilled workers
5.2. Poor grout joint 		

7.1 REPAIRING WORKS

Builders are encouraged to "Do things right the first time" as it can help eliminate double work. However, minor damages such as chips, cracks and scratches on natural stones are unavoidable. Replacing localised damaged stones may result in other issues with the completed stonework. Factors like tonality difference, damage to adjacent stones, loss of time, etc. can occur. Therefore, repair to the installed or laid stone with the correct and approved method can be an alternative to replacement of stones for minor damages.

8.0 MAINTENANCE

Natural stone flooring offers a luxurious boost of elegance and beauty. To keep the floor at its best, proper care and maintenance are essential to prevent stains, cracks and scratches. Sweeping and mopping on a regular basis will help to remove dust, dirt and grit that may harm the stone surface. Placing mats or rugs at the entrance can also help to minimise dirt and grit but caution should be taken on the use of rubber or jute-backed mats/rugs as they themselves may stain the stone surface.

For wet mopping, clean water and neutral (pH7) cleaner should be used. At the end of the process, wipe the surface thoroughly with water to remove all traces of the cleaner solution and buff to dry as water may leave etch spots if left to dry by itself.

Refrain from sliding or dragging heavy furniture such as tables and chairs as they can cause scratches to the stones. Use of protectors on the bottoms of furniture or other heavy objects helps to minimise scratches. Avoid using vacuum cleaners as it can also cause damage to the stones.

Spills such as oily food, coffee, vinegar, ink, etc. should be removed quickly to prevent any staining of the stone surface. It is recommended to use an absorbent material to blot the spill instead of wiping. By doing so, the spill will not be spread. Follow up by flushing the area with water, rinse it for several times as needed and buff to dry to prevent water marks on the stone surface.

Surface stains can be removed with an appropriate cleaning product. When in doubt, it is recommended to seek advice from the stone suppliers or specialists.

APPENDIX A

Inspection and Test Plan
Project :
Scope of work :

S/No	Activity	Responsibility	Inspection method	Requirement reference	Acceptance criteria	Initial stage	Records
1.	**SUBMISSION**						
1.a	Shop drawings	MC / D / O	Review	-	Approved	Initially	Approved submissions
1.b	Stone samples	MC / D / O	Review	Section 2.1	Approved	Initially	Approved submissions
1.c	Adhesive samples	MC / D / O	Review	Section 2.2	Approved	Initially	Approved submissions
1.d	Test reports	MC / D / O	Review	-	Approved	Initially	Approved submissions
1.e	Technical data	MC / D / O	Review	-	Approved	Initially	Approved submissions
2.	**INCOMING MATERIALS INSPECTION**						
2.a	Stones	MC / D / O	Visual / measure	Section 3.1	As per approved samples & shop drawings	Each delivery	Delivery dockets
2.b	Adhesives	MC / D / O	Review	Section 3.2	Conform to specifications and approved sample submission	Each delivery	Delivery dockets
2.c	Grouts	MC / D / O	Review	Section 3.2	Conform to specifications and approved material submission	Each delivery	Delivery dockets

Prepared by : _____	Verified by : _____	Approved by : _____
Date : _____	Date : _____	Date : _____

Legend: **MC – Main Contractor** **D – Designer** **O – Owner**

APPENDIX A

Inspection and Test Plan ***(continued)***
Project :
Scope of work :

S/No	Activity	Responsibility	Inspection method	Requirement reference	Acceptance criteria	Initial stage	Records
3.	**STONE PREPARATION**						
3.a	Mock-up unit	MC / D / O	Visual / measure	Section 2.1.8.A	Approved from all representatives	Before installation	
3.b	Dry lay at site	MC / D / O	Review	Section 2.1.8.C	Approved from D & O	Before installation	
4.	**IN PROCESS INSPECTION**						
4.a	Checking substrate	MC / D / O	Visual / measure	Section 4.1	Surface flat, solid, clean and free of foreign materials	Before laying screed	Checklist @ Appendix B
4.b	Screeding / Rendering	MC / D / O	Visual / measure	Section 4.2	Screed / render level and no formation of cavities	Before laying stone tiles	Checklist @ Appendix B
4.c	Preparing adhesive	MC / D / O	Visual / measure	Section 5.1	Manufacturer's instruction	100% work done	Checklist @ Appendix B
4.d	Laying stones	MC / D / O	Visual	Section 5.2	Fit stones neatly and true level	100% work done	Checklist @ Appendix B
4.e	Checking stone surfaces	MC / D / O	Visual / measure	Section 5.6	Within 3mm tolerance per 2m or with proper gradient	100% work done	Checklist @ Appendix B
4.f	Check stone joints	MC / D / O	Visual / measure	Section 5.6	Maintain uniform joint widths	100% work done	Checklist @ Appendix B
4.g	Holding point prior to grouting	MC / D / O	-	-	-	-	-

Prepared by : _____	Verified by : _____	Approved by : _____
Date : _____	Date : _____	Date : _____

Legend: **MC – Main Contractor** **D – Designer** **O – Owner**

APPENDIX A

Inspection and Test Plan ***(continued)***
Project :
Scope of work :

S/No	Activity	Responsibility	Inspection method	Requirement reference	Acceptance criteria	Initial stage	Records
5.	**GROUTING**						
5.a	Grout mix	MC / D / O	Visual	Section 5.3	Manufacturer's instruction	100% work done	Checklist @ Appendix B
5.b	Completely fill joints	MC / D / O	Visual	Section 5.3	Smooth and flush on surfaces	100% work done	Checklist @ Appendix B
5.c	Removing surplus grout	MC / D / O	Visual	Section 5.3	Surface is clean	100% work done	Checklist @ Appendix B
6.	**FINAL INSPECTION**						
6.a	Cleaning	MC / D / O	Visual / measure		Surface is clean	At completion	
6.b	Protection	MC / D / O	Visual / measure	Section 6	Finish work is protected	At completion	
6.c	Work acceptance	MC / D / O	Visual / measure		As per specifications	At completion	Inspection records
7.	**WORK HAND-OVER**						
7.a	Rectification works	MC / D / O	Visual	-	-	At hand over	-
7.b	Inspection by owner	MC / D / O	-	-	-	At hand over	-

Prepared by : _____	Verified by : _____	Approved by : _____
Date : _____	Date : _____	Date : _____

Legend: **MC – Main Contractor** **D – Designer** **O – Owner**

APPENDIX B

CHECKLIST FOR IN-PROCESS INSPECTION OF NATURAL STONE WORKS
Project:
Location:

Checklist	Acceptance criteria/ Requirement reference	Date of inspection	Remarks
Surface preparation			
1. Check age of concrete substrate	- Concrete cure for 28 days		
2. Check substrate surface	- Surface flat, solid, clean and free of foreign materials		
Preparation and laying of screed			
3. Wet concrete surface prior to laying screed	- Surface is in a saturated-surface-dry condition		
4. Lay screed	- Section 4.2		
5. Check screed surface	- Screed is level and no formation of cavities		
6. Moist cured screed	- Screed cured for a duration recommended by manufacturers		
Preparation of adhesives			
7. Check adhesive mix	- Follow manufacturer's instruction		
Laying stone			
8. Laying adhesive	- Section 5.1		
9. Laying stone	- Section 5.2		
10. Check stone surface and joints	- Use spirit level or tile levelling system to ensure stones are within 3mm per 1.2m and joint widths are uniform		
11. After stone are firm, clean off excessive adhesive	- Surface is clean		
12. Protect freshly stonework against stepping	- Section 6		
Grouting			
13. Check grout mix	- Follow manufacturer's instruction		
14. Completely fill joints	- Joints are smooth and flush on surfaces		
15. Removing surplus grout	- Section 5.3		
Protection			
16. Protect completed stonework	- No traffic is permitted for a duration recommended by stones and adhesives suppliers		

REFERENCES

ASTM F2170 - 11 Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs using in situ Probes

BS 5385-1:2009 Wall and floor tiling. Design and installation of ceramic, natural stone and mosaic wall tiling in normal internal conditions. Code of practice

BS 5385-2:2015 Wall and floor tiling. Design and installation of external ceramic, natural stone and mosaic wall tiling in normal conditions. Code of practice

BS 5385-3:2014 Wall and floor tiling. Design and installation of internal and external ceramic and mosaic floor tiling in normal conditions. Code of practice

BS 5385-4:2009 Wall and floor tiling. Design and installation of ceramic and mosaic tiling in special conditions. Code of practice

BS 5385-5:2011 Wall and floor tiling. Design and installation of terrazzo, natural stone and agglomerated stone tile and slab flooring. Code of practice

BS 8203:2001+A1:2009 Code of practice for installation of resilient floor coverings

BS 8204-1:2003+A1:2009 Part 1: Concrete bases and cementitious levelling screeds to receive floorings. Code of practice

BS 8298 Code of Practice for design and installation of natural stone cladding and lining

EN 12004:2007 Adhesives for tiles – Definitions and specifications

EN 13501-1:2007+A1:2009 Fire classification of construction products and building elements. Classification using test data from reaction to fire tests

EN 13888:2009 Grouts for tiles – Definitions and specifications

EN 12057 Natural stone products - Modular tiles - Requirements

EN 12058 Natural stone products - Slabs for floors and stairs – Requirements

EN 1925 Natural stone test methods - Determination of water absorption coefficient by capillarity

EN 1926 Natural stone test methods - Determination of uniaxial Compressive Strength

EN 1936 Natural stone test method - Determination of real density and apparent density, and of total and open porosity

EN 12407 Natural stone test methods - Petrographic examination

EN 12372 Natural stone test methods - Determination of flexural strength under concentrated load

EN 13161 Natural stone test methods - Determination of flexural strength under constant moment

EN 13755 Natural stone test methods - Determination of water absorption at atmospheric pressure

EN 14066 Natural stone test methods - Determination of resistance to ageing by thermal shock

EN 14157 Natural stone test methods - Determination of the abrasion resistance

EN 14231 Natural stone test methods - Determination of the slip resistance by means of the pendulum tester or SS 485:2011

ISO 13007-1:2014 Ceramic tiles - Grouts and adhesives - Part 1: Terms, definitions and specifications for adhesives

ISO 13007-3:2014 Ceramic tiles - Grouts and adhesives - Part 3: Terms, definitions and specifications for grouts

ISO 10545-3:1997 Ceramic tiles – Determination of water absorption, apparent porosity, apparent relative density and bulk density

ISO 10545-13:2016 Ceramic tiles – Determination of chemical resistance

ISO 10545-14:2015 Ceramic tiles – Determination of resistance to stain

SS 68 Code of Practice for ceramic wall and floor tiling

SS 483:2000 Specification for ceramic tiles – definitions, classification, characteristics and marking

SS 485:2011 Specification for slip resistance classification of pedestrian surface materials

Note

CONSTRUCTION QUALITY ASSESSMENT SYSTEM (CONQUAS®)

The Construction Quality Assessment System (CONQUAS®) is an assessment service offered by BCA to assess the quality of workmanship of new building projects.

CONQUAS® is an assessment standard for all new Public Sector projects under the Bonus Scheme for Construction Quality (BSCQ). This scheme gives direct incentive to construction companies for achieving good quality work. For Private Sector projects, CONQUAS® is also used by the developers as the quality yardstick for their projects.

The CONQUAS® assessment scope covers structural, architectural and M&E works. Structural works are assessed throughout the construction period during the superstructure stage while architectural and M&E works are assessed during and after the completion of the project.

Applications must, therefore, be submitted before the commencement of superstructure works. Projects that are eligible for CONQUAS® are:

1. All new public building projects. It is also applicable for public projects with combination of new building works and demolition, upgrading, addition & alteration, renovation and conservation works if the contract value for the new building works is at least S$5 million.
2. Private projects with CONQUAS® requirement under URA/SLA/HDB/JTC land sales agreement and;
3. All other new private building projects.

Fees are charged base on the Gross Floor Area (GFA) of the projects and payable upon acceptance of application.

CONQUAS® is a registered trademark in Singapore, United Kingdom, Australia, South Africa, PRC, Hong Kong SAR, Malaysia, India and Thailand.

BCA QUALITY MARK

BCA QUALITY MARK FOR GOOD WORKMANSHIP SCHEME

The BCA Quality Mark for Good Workmanship scheme was launched on 1 July 2002 to help developers meet the rising expectation of Singaporeans for better quality homes. Aimed to encourage developers to consistently deliver quality homes, over 89,000 residential units from various major developers have been committed to the scheme since its launch.

Under the Scheme, BCA will assess the workmanship quality of the internal architectural finishes of every unit of newly completed residential projects. The assessment will cover all locations within the units (bedrooms, bathrooms, kitchen, living & dining rooms, balconies, utility yard, where applicable). In addition, the assessment will include water ponding test for all internal wet areas like bathrooms/toilets and RC flat roofs, in-process inspection on key trades and optional BCA Watertightness Test on windows.

The Quality Mark for Good Workmanship will be issued to individual apartment unit that achieves the stipulated quality workmanship standard (a minimum CONQUAS® score for internal finishes) set by BCA. The Quality Mark certifies the condition of the apartment unit at the time of inspection. Any unit that fails to achieve the standard will not be issued the Quality Mark.

ELIGIBILITY FOR THE QUALITY MARK SCHEME

The voluntary scheme is open to developers and builders that meet the following criteria:

a. Participated in CONQUAS® for earlier projects. Those projects will have to meet a minimum CONQUAS® score stipulated by BCA;
b. Completed full unit assessment for at least one project (not required if the builder has prior Quality Mark experience); and
c. Projects that undergo such unit assessment will also need to be subjected to CONQUAS® scoring.

For further enquiries and application details, please contact the following officers from Quality and Certification Department:

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BSCQ
Ken Ho — Tel: 6730 4496 — Email: ken_ho@bca.gov.sg

QUALITY MARK
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CONQUAS® / BSCQ / QUALITY MARK
Enquiry — Tel : 6730 4400

For more information you can visit our website at http://www.bca.gov.sg.
Click on IQUAS>CONQUAS or Bonus Scheme for Construction Quality or Quality Mark

For more information on the CONQUAS and Quality Mark performances of developers and contractors, please visit our **Quality Housing Portal** at https://www.bca.gov.sg/Professionals/iquasscorechart/

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